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Original Article

Dynamic stretching does not affect peroneal and tibial muscle reaction properties

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ABSTRACT

Objectives: This study aims to investigate acute and chronic effects of dynamic stretching on peroneal and tibialis anterior reaction properties.

Patients and methods: Between September 2015 and June 2017, a total of 21 male athletes (mean age 22.6 years; range, 20 to 30 years) were included in this study. All participants were randomly divided into two groups as dynamic stretching group (n=11) and control group (n=10). The participants in the dynamic stretching group performed stretching exercises for the ankle evertor and dorsiflexor muscles five days a week for six weeks. Peroneal and tibial muscle reaction properties were evaluated at baseline (two times for acute effect) and at the end of the intervention. Electromyographic activity parameters including reaction time, reaction duration, and reaction magnitude of the muscles were measured using an ankle supination tilting platform. There were four different supination conditions: *(i)* ankle neutral, 15° inversion (0015), *(ii)* ankle neutral, 30° inversion (0030), *(iii)* ankle 20° plantarflexion, 15° inversion (2015), and *(iv)* ankle 20° plantarflexion, 30° inversion (2030).

Results: There were no significant differences in acute and chronic effects of dynamic stretching exercises for peroneal and tibial muscle reaction time, reaction duration, and muscle activity in four positions on the ankle inversion simulation platform (p>0.05).

Conclusion: Our study results suggest that dynamic stretching exercises have no positive or negative effects on muscle reaction properties and on the possible risk of ankle sprain during sudden ankle inversion. Dynamic stretching exercises may still be preferred for sports where strength and force effects are important.

Keywords: Ankle sprain, dynamic stretching, electromyography, muscle latency.

It has been recognized for many years that stretching exercise should be performed both to reduce the likelihood of injury and to contribute to sports performance.[1,2] Several studies have shown that dynamic stretching has no negative or even positive effects on the muscle strength,[3,4] sprint performance,[5] vertical jump performance,[5] and other sport-specific skills.[6] Based on these results, some authors have suggested that static stretching included in the pre-exercise warm-up program may impede performance and should, therefore, not be performed or replaced with dynamic stretching.[4,7]

In studies on the prevention of injuries of stretching exercises, the results of static stretching are mostly in the foreground. Current scientific publications on stretching exercises to reduce sports injury risk have employed static stretching to many muscles in common and discussed general sports injury events in bone, ligament, and muscle tissues.[8-10] Meanwhile, studies examining the effects of other types of stretching exercises, such as dynamic stretching, in terms of prevention of injuries are limited in the literature. To clarify the role of pre-activity stretching in the prevention of injuries, a recent review article has stated that the risk of seeing sports injuries is multifactorial and is sport-specific.[11] Therefore, it has been emphasized that the results should be analyzed in relation to injury types (such as muscle strain or ligament sprain) and that more focus should be placed on the primary risk factors for this injury when the effects of stretching on injury risk are evaluated.[11]

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Peroneal and tibialis anterior muscle reaction time is an important parameter in assessing the risk of ankle sprains.[12] Several studies have shown that the risk of ankle sprain may be high, when the reaction time is delayed, and that the shortening of the reaction time of these muscles can improve the protective reflex mechanism and reduce the risk of ankle inversion sprains.[13,14] According to the results of a recent meta-analysis, Hoch & McKeon[15] found that the peroneal reaction time was delayed in patients with ankle sprains and that this deficit was more prominent in patients with chronic ankle instability. It is known that some exercise types can shorten this period according to the data in the literature.[16-21] Among them, the study showing reductions in peroneal and tibialis anterior muscle reaction time following eccentric strengthening exercise is very interesting with respect to the topic that we also aimed to investigate in our study.[18] In eccentric contraction, there is a lengthening (or stretching)-type contraction in the muscles, which is similar to dynamic muscle stretching in terms of its effects on muscle morphology. Therefore, dynamic stretching can also influence muscle reaction time. However, this effect of dynamic stretching seems to not have been investigated in the literature.

In the present study, we aimed to investigate the effects of *(i)* pre-activity (acute) dynamic stretching and *(ii)* regular dynamic stretching as a long-term intervention (chronic) of the peroneal and tibialis anterior muscles on the peroneal and tibialis anterior muscle reaction time during a sudden ankle inversion simulation.

PATIENTS AND METHODS

Between September 2015 and June 2017, a total of 21 male athletes (mean age 22.6 years; range, 20 to 30 years) were included in this study. All participants were randomly assigned to either the dynamic stretching group (n=11) or the control group (n=10) using sealed, opaque envelopes. The allocation sequence and preparation of the concealed envelopes were completed by one study researcher. Participants and procedures flow through the study is described in Figure 1. All 21 subjects enrolled in this study were regular participants in recreational sports, such as running, soccer, or basketball, which they played one to two times a week for durations of 30 to 60 min. *Exclusion criteria were as follows:* existing or previous ankle sprain; low back or lower extremity dysfunction; any ankle surgery or fracture or any occurrence of giving-way; having pain, swelling, or functional limitations in the ankles; or participation in any therapeutic exercise for the ankles within the preceding 12 months. All of the participants had no mechanical ankle instability prior to participating in the study according to

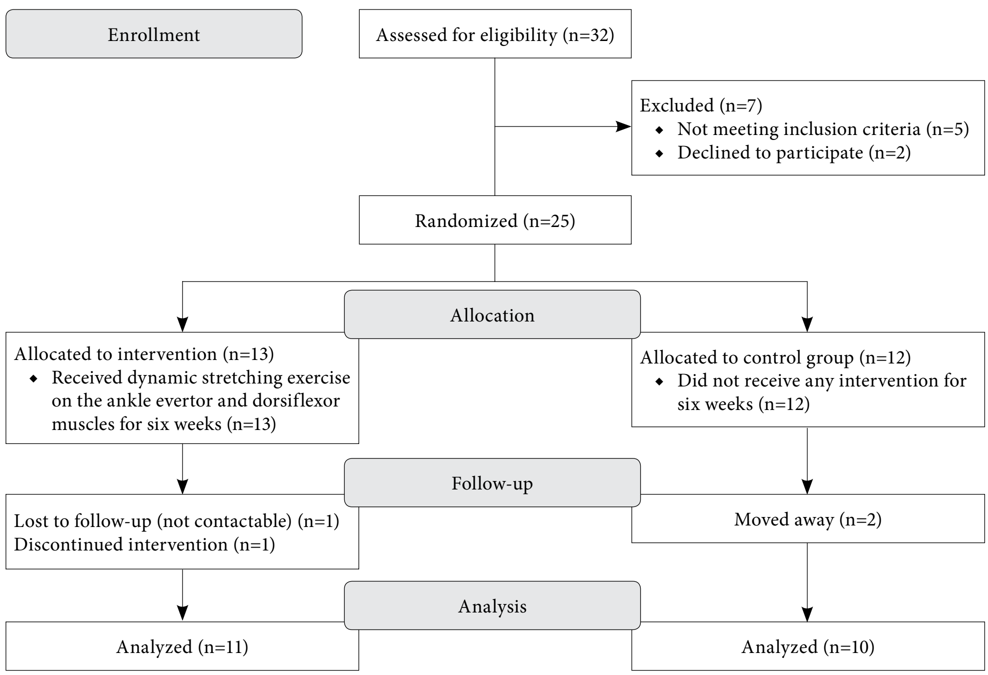

Figure 1. Flow diagram of participants.

anterior drawer and talar tilt tests performed by the same clinician. All measurements were performed in the dominant leg. To be consistent with previous studies, the leg that the participant uses to naturally kick a ball was defined as the dominant leg.[22]

The platform was also randomly activated on the non-dominant leg during muscle reaction time measurements using a sudden ankle supination platform to prevent learning effects and concentrating on one ankle of the participants. However, only an analysis of the dominant ankle was performed. There were nine right- and two left-dominant participants in the dynamic stretching group, and nine right- and one-left dominant participants in the control group.

A written informed consent was obtained from each participant. The study protocol was approved by the Institutional Ethical Board for Protection of Human Subjects of Medical School of Uludag University (No. 2015-7/13). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Experimental design and procedures

Before initiating the experiments, the participants were invited to the laboratory to receive information about the test procedure. Furthermore, to be familiar with the testing, sudden ankle inversion simulations on the ankle supination tilting platform were performed. Additionally, the dynamic stretching exercises planned to be performed on the ankle evertor and dorsiflexor muscles were demonstrated.

All testing protocols were performed on the same day. The participants who were included in the dynamic stretching exercise group performed the stretching exercises on the ankle evertor and dorsiflexor muscles five days a week for six weeks. To determine the acute and chronic effects of dynamic stretching, the measurements were repeated immediately after the first stretching session and six weeks later. Blinding to treatment allocation of the participants was not possible due to the nature of the intervention groups. However, the principal investigator was blinded to the intervention group allocation (dynamic stretching or control group) and was responsible for baseline and follow-up assessments.

Dynamic stretching exercise

Unassisted dynamic stretching exercises were designed for the ankle evertor (ankle in neutral and maximal plantarflexed positions) and dorsiflexor muscles in the dominant leg. Dynamic stretching was constituted by the contraction of the antagonist muscles of the target muscle group to be stretched in a rhythmic manner. Rhythmic active contractions in the ankle invertor muscles were performed, when dynamic stretching of the peroneal muscles was desired. The participants were told which muscles should be contracted before stretching exercises. The stretching exercises were performed for four sets, each with a 30-sec duration. The ankle was positioned to the resting position and held for 15 sec between the sets and when the muscles to be stretched were changed. The participants implemented these dynamic stretching exercises five days a week for six weeks in the laboratory under supervision.

Ankle evertor muscles (peroneus longus and brevis)

(i) The participant was instructed to sit on a chair while stretching the muscles in an ankle-neutral position. The foot on the side not to be stretched continued to touch the floor. The other foot, which was to be stretched, was lifted and placed on this knee. The participant, then, actively swung the ankle inward to the end of the range of motion where he felt tension (inversion) and returned back to the starting position, so that the ankle was still kept in neutral position.

Figure 2. Dynamic stretching exercises performed in ankle evertor muscles. **(a)** Ankle in neutral and **(b)** plantarflexion position.

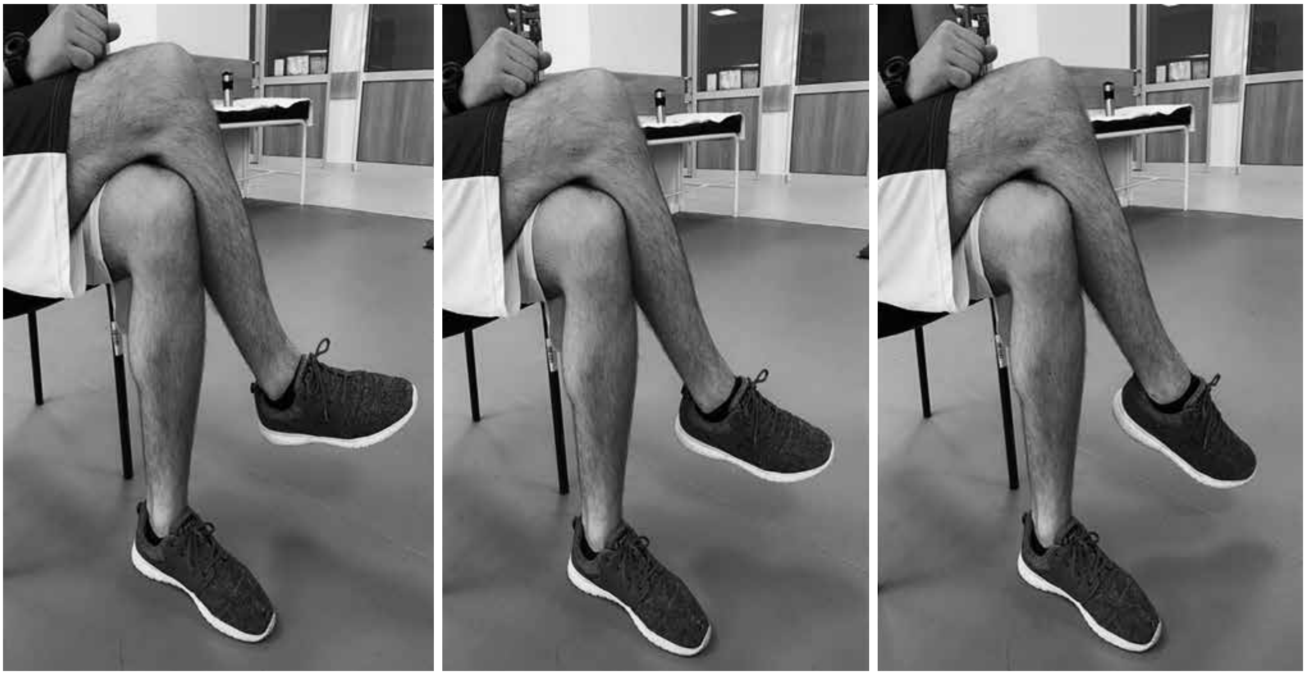

Figure 3. Dynamic stretching exercises performed in ankle dorsiflexor muscles.

This motion was repeated 30 times with a frequency range of one sec (Figure 2a). The participant was instructed to sit on a chair again, while stretching the muscles in an ankle plantarflexion position. The foot on the side not to be stretched continued to touch the floor. The other foot, which was to be stretched, was lifted and placed on this knee. Thereafter, the participant brought and pushed their ankle as far forward as possible (maximal plantarflexion). While in this position, the participant actively swung the ankle inward to the point where the ankle reached to the end of range motion and where tension was felt (inversion) and brought it back to the starting position. This motion was repeated 30 times with a frequency range of one sec (Figure 2b). The stretching duration for the peroneal muscles with both stretching methods was 240 sec in total.

Ankle dorsiflexor muscles (tibialis anterior)

The participant was instructed to sit on a chair. The foot on the side not to be stretched continued to touch the floor. The other foot, which was to be stretched, was lifted and placed on this knee. Thereafter, when the ankle was in neutral position (0°), the participant, by contracting the calf muscles (gastrosoleus), actively push the ankle forward (plantarflexion) to the end of range of motion and to the point where tension was felt in the tibialis anterior muscle, and again back to the starting position (Figure 3). This motion was repeated

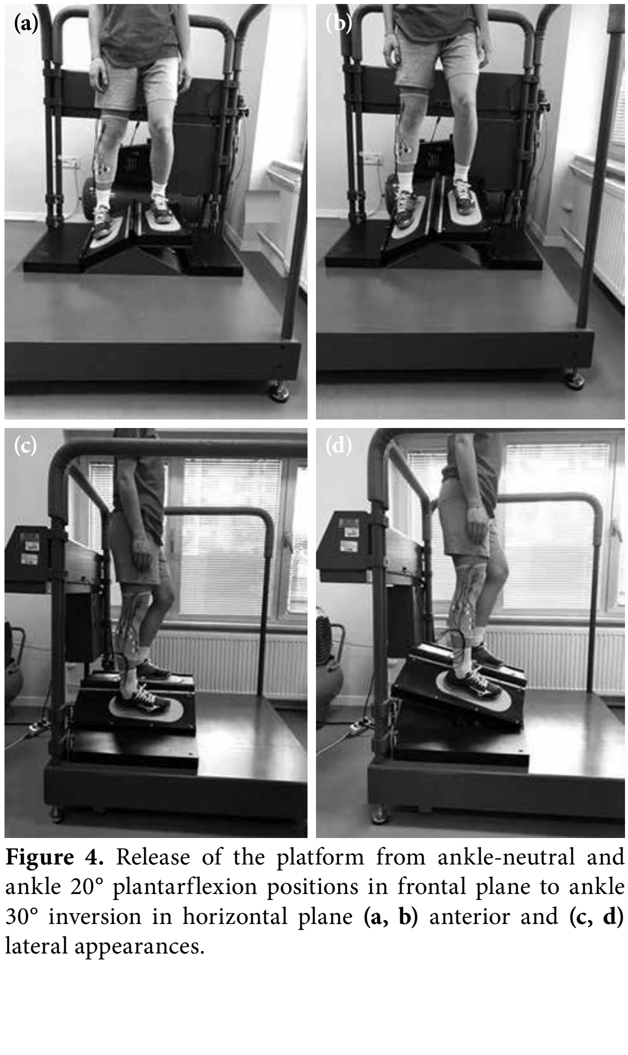

Figure 4. Release of the platform from ankle-neutral and ankle 20° plantarflexion positions in frontal plane to ankle 30° inversion in horizontal plane **(a, b)** anterior and **(c, d)** lateral appearances.

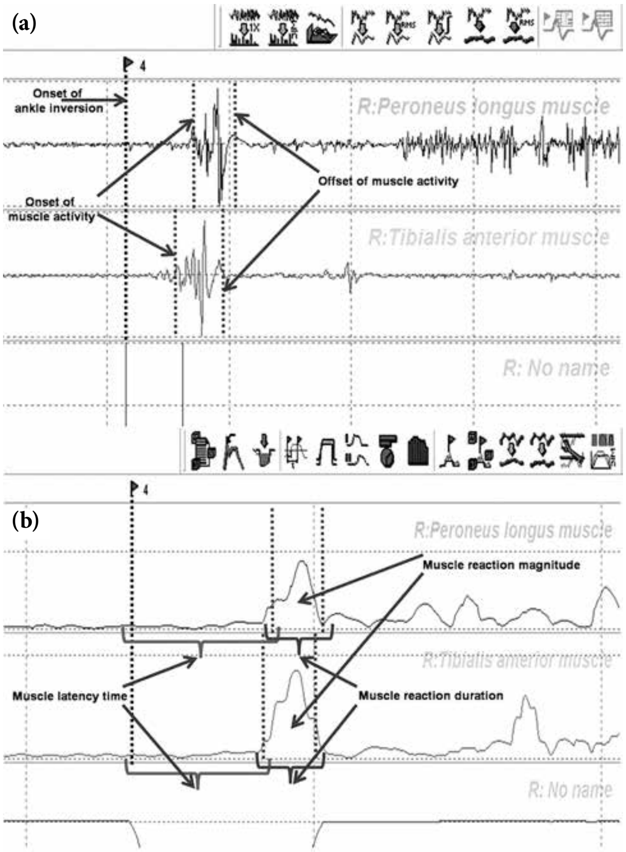

Figure 5. (a) The cut-off levels of the electromyography activity and **(b)** measured electromyography activity parameters during ankle supination. Electromyography, electromyography.

30 times with a frequency range of one sec. The total duration of the dynamic stretching for this muscle group was 120 sec.

Electromyography activity measurements

The electromyography (EMG) activity parameters (muscle latency time, muscle reaction duration, and muscle reaction magnitude) recorded from the peroneus longus and tibialis anterior muscles via a portable eight-channel Muscle Tester™ device (ME6000, Mega Electronics, Kuopio, Finland) were measured using an ankle supination tilting platform. Bipolar pre-gelled Ag/AgCl surface electrodes (Covidien-Kendall™ electrodes with a 0.8 cm silver-silver chloride disks; Covidien Plc., Mansfield, MA, USA) were used to record the EMG from these muscles. There were four different supination conditions: *(i)* ankle in neutral position and 15° inversion (0015), *(ii)* ankle in neutral position and 30° inversion (0030) (Figure 4a and b), *(iii)* ankle in 20° plantar flexion position and 15° inversion (2015), and *(iv)* ankle in 20° plantar flexion position and 30° inversion (2030) (Figure 4c and d). A detailed description of the same custom-built trap door mechanism, positioning of the participant, skin preparation, electrode placement over the muscles of the peroneus longus and tibialis anterior, signal amplification, storage in the microcomputer, sampling of the analog EMG signal, testing procedure, and normalization of the EMG amplitude was published previously by Sekir et al.[3] and Keles et al.[18] After testing, the raw EMG amplitude values (mV) from the data transmitted to a personal computer were calculated automatically using ME6000 software (MegaWin v3.1, Mega Electronics Ltd., Kuopio, Finland). The stored raw EMG data were expressed using the software in absolute root mean square amplitude values (mVs). The criterion for the onset of EMG activity of the muscles during sudden ankle inversion was an increase in the signal to greater than twice the noise level (Figure 5a). Similarly, offset of the EMG activity was determined, when the EMG signal was returned to the noise level (Figure 5a). The time interval between the moment of ankle inversion to the first EMG response was defined as the muscle latency time (Figure 5b). The time interval between the first EMG response and the offset of the EMG activity was defined as the muscle reaction duration (Figure 5b). Finally, the magnitude of the muscle reaction was obtained from the EMG activity amplitude between the onset and offset times (Figure 5b). This value was normalized against the maximal voluntary contraction (MVC) trial that yielded the highest peak torque value during isometric ankle dorsiflexion and eversion contractions. The mean muscular magnitude for the peroneus longus and tibialis anterior muscles was expressed in the percentage (%MVC) of the amplitude values.

Statistical analysis

Statistical analysis was performed using the SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean and standard deviation (SD). In all tests, a two-tailed p value of <0.05 was considered statistically significant. A power analysis was performed based on the reported values of other studies. According to the sample size estimation test for two means in a repeated measures design analysis, group sample sizes of n1= n2= 10 would have 80% power to detect a mean difference of 10±11% between variables with a significance level (alpha) of 0.05 ($N=(r+1).(Z_{\alpha/2}+Z_{1-\beta})^2.\sigma^2)/(r.d^2)=N=(1+1).(1.96+0.84)^2.11^2)/(1.10^2)\cong 19$).[23,24] Normality of data distribution and equality of the variances were verified by the Shapiro-Wilk and Levene's tests, respectively.

Table 1. Muscle reaction time data in the four different ankle inversion simulation positions of the groups at the beginning and at the end of six weeks of stretching exercises (mean±SD)

	Control group			Dynamic stretching group			P value (group x time)	
	Before	After	6 week	Before	After	6 week	Acute	Chronic
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*p*	*p*
Peroneal (msec)								
N15	92.1±15.7	90.9±17.9	92.8±14.5	93.5±12.2	88.4±22.5	91.6±11.5	0.526	0.561
N30	96.0±15.9	94.3±20.8	95.3±16.6	88.9±8.4	84.8±17.2	87.4±13.2	0.675	0.841
PF15	92.5±11.3	91.2±13.3	92.1±9.6	89.8±10.4	87.1±17.4	92.8±11.5	0.780	0.467
PF30	93.7±13.6	92.6±11.3	90.9±12.3	87.9±8.3	84.6±16.1	89.4±15.0	0.733	0.453
Tibial (msec)								
N15	96.7±17.2	94.4±16.9	94.0±15.4	98.6±12.3	93.2±17.2	96.0±9.2	0.615	0.991
N30	101.1±13.5	97.3±22.9	99.2±18.7	95.4±9.2	96.8±10.1	91.4±12.1	0.237	0.551
PF15	94.9±12.6	91.6±14.4	92.1±9.6	91.1±7.5	92.6±15.4	95.7±19.6	0.337	0.390
PF30	97.2±13.2	95.3±11.3	94.2±11.2	89.2±13.3	92.6±12.7	91.6±14.6	0.272	0.319

SD: Standard deviation; N15: Ankle neutral, 15° inversion; N30: Ankle neutral, 30° inversion; PF15: Ankle 20° plantarflexion, 15° inversion; PF30: Ankle 20° plantar flexion, 30° inversion; 6 week: Following 6 weeks of stretching exercise program; Acute: Interaction after the first stretching exercise; Chronic: Interaction between the baseline and the end of 6 weeks of stretching program; msec: Millisecond; p>0.05.

A 2 (stretch type) × 2 (time) mixed-design one-way analysis of variance (ANOVA) model was used for comparisons of changes in EMG activity parameters in dynamic stretching and the non-stretching control condition. This model was performed for analyzing both acute and chronic effects. When an appropriate and significant interaction was indicated, follow-up analyses included paired-sample t-test and independent sample t-test to examine the differences between times and groups, respectively. In addition, an independent sample t-test was used to determine whether there was a probability of a significant difference in the pre-test mean scores and anthropometric data between the two groups.

RESULTS

In the dynamic stretching group, the mean age was 22.6±3.9 years, the mean height was 178.6±8.8 cm and the mean body weight was 76.1±11.2 kg. In the control group, the mean age was 22.4±3.0 years, the mean height was 179.7±5.5 cm, and the mean body weight was 80.1±12.3 kg. There was no statistically significant difference in the anthropometric data between the groups (p>0.05).

Tables 1, 2, and 3 show the reaction time, reaction duration, and reaction magnitude values for the peroneus longus and tibialis anterior muscles before and immediately after the first stretching session

Table 2. Muscle reaction duration data in the four different ankle inversion simulation positions of the groups at the beginning and at the end of 6 weeks of stretching exercises (mean±SD)

	Control group			Dynamic stretching group			P value (group x time)	
	Before	After	6 week	Before	After	6 week	Acute	Chronic
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*p*	*p*
Peroneal (msec)								
N15	39.5±16.6	38.7±17.5	45.7±16.2	45.9±19.9	48.2±28.2	47.2±17.2	0.323	0.126
N30	37.3±12.6	36.1±12.2	41.6±21.2	46.5±16.1	41.8±29.7	42.2±11.2	0.452	0.307
PF15	33.9±14.1	37.2±16.7	34.7±14.2	36.0±18.2	32.7±17.7	27.8±10.1	0.479	0.127
PF30	36.1±14.3	40.8±13.0	35.6±13.5	33.9±12.5	38.2±28.4	38.0±9.8	0.967	0.487
Tibial (msec)								
N15	39.7±16.4	41.2±17.7	43.7±16.4	48.8±21.0	44.6±25.9	48.7±14.4	0.159	0.342
N30	35.3±14.6	35.5±14.5	40.5±21.5	42.1±18.4	33.1±16.3	35.9±12.2	0.234	0.124
PF15	40.6±15.8	38.8±13.7	33.5±13.8	38.9±17.7	33.2±17.3	34.7±19.5	0.695	0.772
PF30	42.9±18.7	41.6±19.8	38.7±10.7	41.1±15.5	38.1±18.9	36.1±9.9	0.862	0.914

SD: Standard deviation; N15: Ankle neutral, 15° inversion; N30: Ankle neutral, 30° inversion; PF15: Ankle 20° plantarflexion, 15° inversion; PF30: Ankle 20° plantar flexion, 30° inversion; 6 Week: Following 6 weeks of stretching exercise program; Acute: Interaction after the first stretching exercise; Chronic: Interaction between the baseline and the end of 6 weeks of stretching program; msec: Millisecond; p>0.05.

Table 3. Normalized muscle reaction magnitude data in the four different ankle inversion simulation positions of the groups at the beginning and at the end of 6 weeks of stretching exercises (mean±SD)

	Control			Dynamic stretching group			P value (group x time)	
	Before	After	6 week	Before	After	6 week	Acute	Chronic
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*p*	*p*
Peroneal (%MVC)								
N15	43.3±27.3	42.3±27.7	41.4±22.3	50.2±22.1	39.6±24.0	45.8±16.1	0.211	0.570
N30	38.2±23.0	35.6±23.6	41.9±19.6	43.2±18.3	37.5±26.9	44.1±17.0	0.715	0.392
PF15	39.6±22.7	33.3±25.5	38.9±28.2	35.6±12.9	29.7±15.8	32.4±13.2	0.356	0.599
PF30	38.1±23.6	36.0±19.4	43.2±26.1	37.6±10.4	35.1±15.9	46.8±16.3	0.950	0.853
Tibial (%MVC)								
N15	16.5±15.0	14.7±13.3	19.2±17.6	11.3±4.7	10.9±6.4	16.7±13.0	0.596	0.742
N30	14.4±12.9	11.8±10.5	13.9±14.0	12.1±8.5	8.3±5.2	10.1±7.4	0.728	0.339
PF15	14.2±7.5	17.8±15.5	15.2±10.4	17.4±11.7	15.3±10.6	12.6±6.3	0.243	0.377
PF30	16.8±13.8	18.1±17.4	23.2±24.9	14.8±5.9	13.4±9.5	14.6±11.2	0.707	0.458

SD: Standard deviation; N15: Ankle neutral, 15° inversion; N30: Ankle neutral, 30° inversion; PF15: Ankle 20° plantarflexion, 15° inversion; PF30: Ankle 20° plantar flexion, 30° inversion; 6 Week: Following 6 weeks of stretching exercise program; Acute: Interaction after the first stretching exercise; Chronic: Interaction between the baseline and the end of 6 weeks of stretching program; %MVC: Percent maximum voluntary contraction; p>0.05.

(acute effect) and at the end of six weeks of stretching exercises (chronic effect) in the two groups. The baseline values in muscle reaction time, reaction duration, and reaction magnitude of the peroneus longus and tibialis anterior muscles were not different between the dynamic stretching group and control group ($p>0.05$). There was no significant Group × Time interaction for reaction time, reaction duration, and reaction magnitude in terms of acute and chronic effects between the groups according to the 2×2 ANOVA model ($p>0.05$).

DISCUSSION

The main result of the present study indicated that dynamic stretching exercise performed as a single bout (acute effect) or as habitual regularly (chronic) did not have a statistically significant effect on reaction properties of the peroneal and tibialis anterior muscles (risk factors for ankle sprain).

McHugh and Cosgrave[11] stated that the effects of pre-activity stretching exercises on the prevention of injuries should be analyzed in relation to injury types (muscle strains, ligament sprains) and that more focus should be placed on a particular primary risk factor for that injury. Peroneal reaction time during the sudden ankle inversion moment is known to be an important risk factor for ankle inversion sprain injuries.[13] Examination of the effect of dynamic stretching exercise targeting the peroneal and tibialis anterior muscles on the reaction properties of these muscles during ankle inversion simulation would be important to determine the direct impacts of dynamic stretching exercise. There are several studies in the literature, other than dynamic stretching exercises, with conflicting results showing the effects of different exercise programs on peroneal reaction time. These exercise programs have been conducted in healthy[16,17,19,20] and functionally unstable ankles.[16,21] Some of them reported improvements in muscle reaction time,[19,21] while others did not.[16,17,20] Previous studies which were conducted in healthy individuals and showed no effect on the peroneal or tibialis anterior reaction time have generally utilized balance board exercises,[20] resistance exercises with elastic tubes,[16] and plyometric exercises.[17] On the other hand, studies using a neuromuscular training model[19] and eccentric strengthening exercise[18] in the ankle muscles showed significant improvements in reaction time. In the study by Keles et al.,[18] the peroneal and tibialis anterior reaction times were shortened by 15 to 20% and 17 to 22%, respectively, after a six weeks of isokinetic eccentric-concentric training.

In the literature, there is a limited number of studies examining the effect of stretching exercises on peroneal or tibialis anterior reaction time during ankle inversion simulation. The closest contraction type to the stretching exercises which we applied in the present study is the eccentric contraction. During eccentric contraction, a stretching or, in other words, a lengthening occurs in the muscles. In this regard, eccentric contraction is similar to the muscle stretching in terms of its effect on muscle structure. Keles et al.[18] speculatively reported that an improvement in muscle spindle activity was seen following eccentric exercises, which would be a cause for shortening the peroneal and tibialis anterior reaction time. Muscle spindles are stretch receptors and receive stimulation from static and dynamic gamma motor neurons.[24] Gamma motor neurons innervate the intrafusal fibers within muscle spindles and regulate the sensitivity of these intrafusal fibers.[25] Several studies have shown that muscle activity increases in response to afferent fiber or mechanoreceptor stimulation and gamma motor neuron activation in the joints.[26,27] Dietz et al.[28] reported that a stretch of the muscle spindle would trigger motor nerve impulses to the muscles and eventually increased the concentric power of muscle fiber contraction. Therefore, tension in the muscles due to stretching exercises may produce an effect on the dynamic gamma motor neuron activity and consequently increase the sensitivity of the muscle spindles in the peroneal or tibialis anterior muscles during sudden ankle inversion. As a basic hypothesis of the present study, we consider that dynamic stretching exercise may have an effect on the muscle reaction times similar to eccentric exercises. However, we found no statistically significant changes in the peroneal and tibialis anterior reaction times with either acute or chronic dynamic stretching exercises.

In the present study, dynamic stretching exercises with a total duration of 240 sec did not have a positive or negative effect on the muscle reaction properties during the ankle inversion simulation in terms of both acute and chronic effects. In the studies showing no effect of static stretching on injury risk, stretching interventions involved 10 to 80 sec to one muscle group.[10,29] We believe that the amount of dynamic stretching in our study is sufficient to produce any possible effects on muscle reaction properties. Dynamic stretching for the ankle evertor muscles was performed in ankle neutral and maximal plantarflexion position, each for four sets of 30 sec. Thus, the total amount of dynamic stretching for the ankle evertors was 240 sec. In addition, the ankle dorsiflexor muscles were stretched only in one position for a total duration of 120 sec. When the effects of stretching on performance are taken into consideration, a narrative review article, which encompassed several studies, reported a clear dose-response effect, with >90 sec of dynamic stretching being more likely to result in a significant facilitation in performance and shorter durations did not affect performance.[30] Therefore, it is possible to state that the stretching duration performed in the current study would be enough to bring out eventual changes also in muscle reaction properties. At this point, it is possible to express that the applied dynamic stretching exercises do not increase the sensitivity of the muscle spindles sufficiently and, therefore, do not produce a stimulation in the gamma motor neuron response.

It is evident that studies evaluating the effects of exercise applications on muscle reaction duration or reaction magnitude in healthy individuals or in those having ankle instability are lacking in the literature. In this context, we can conclude that the present study is the first to investigate the effects of dynamic stretching exercises on parameters such as muscle reaction duration and reaction magnitude, which are the other muscle reaction characteristics that occur during ankle inversion simulation, in healthy individuals. It has been observed that the applied dynamic stretching exercises, either acutely or chronically, do not affect the muscle reaction duration or reaction magnitude in these individuals.

Nonetheless, there are some limitations to this study. First, it was unable to evaluate changes in the range of motion to dynamic stretch before and after the intervention. There is a possibility for an increase in the ankle range of motion later on with stretching and the lack of measurement of the range of motion might be a cause for measuring non-significant effects in the present study. Therefore, further studies should take this into account. The other remarkable limitation of the present study is the standardization of the testing procedure. In our study, the participants did not use headphones to eliminate noises which could lead to anticipation of the stimulus.

In conclusion, although dynamic stretching exercises did not shorten reaction time and increase reaction duration or reaction magnitude, they can be still used before sport activities, as they also did not delay muscle reaction time or decrease reaction magnitude in a way which might result in an increased injury risk. Furthermore, given the fact that dynamic stretching exercise positively affects force production, but also would not increase ankle inversion sprain risk, it can be also stated that dynamic stretching can be preferred confidently in sports where force production is in the forefront. Nevertheless, further studies are needed which evaluate the effects of dynamic stretching, both acutely and chronically, on muscle reaction properties and muscle morphology. In this way, the effect of dynamic stretching exercises on the risk of ankle sprain would be determined in more detail. Furthermore, in terms of contributing to the existing literature, it would be more appropriate to conduct further studies where stretching durations (both static and dynamic stretching) are longer (at least 240 sec) than the previous study and evaluate the effects on muscle reaction properties and muscle morphology.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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