EFFECTS OF STRETCHING ON SERIES ELASTIC MUSCLE STIFFNESS AND PASSIVE RANGE OF MOTION

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INTRODUCTION

Sports people participating in activities involving running and jumping are vulnerable to ankle, gastrocnemious and achilles tendon injuries. It has been reported that in some sports twenty percent of all injuries are to the ankle (Hume, 1993). Lack of extensibility in the soft tissues has been suggested as a mechanism for these types of injuries (Taylor et al., 1990). Extensibility is associated with the resistance to tissue as it lengthens (stiffness), and also the maximum range of which the tissue can lengthen. During functional activities where the joint is not moving towards its maximum ROM, the stiffness characteristics of the muscles and tendons are likely to have a greater role in resisting motion as compared to activities where end of range motion is required. In this latter scenario, the capsular structures are likely to have an increased contribution to restricting motion. It is thought that "warm up" activities which include aerobic and/or stretching exercises may serve to decrease the stiffness and also lead to increased ROM. It is possible that these types of exercises may affect joint soft tissues and musculo-tendinous tissue to a different degree. However, the respective contributions of aerobic exercise and stretching to improving joint range of motion (ROM) and musculo-tendinous stiffness are unclear. Such knowledge may improve the design of "warm up" activities that athletes undertake. Therefore, the purpose of this investigation was to determine the effect of stretching and jogging on the series elastic muscle stiffness of the Soleus/Achilles tendon complex and on the range of motion of the ankle joint.

METHODOLOGY

Twenty subjects with no musculo-skeletal conditions participated in this study. The subjects were required for four testing sessions. In the first session, maximum voluntary contraction (MVC) was assessed so that subsequent stiffness testing would be at 30% of their MVC. In the second session, subjects were randomly assigned to one of a stretching, jogging, or stretching /jogging combined protocols. During the third and fourth sessions, the subjects completed the remaining protocols. The stretching protocol involved five 30 second static stretches with 30 seconds rest between stretches, while the aerobic exercise protocol had the subjects jogging on a treadmill for 10 minutes at 60% of maximum-age-predicted heart rate.

A damped oscillation technique was used to measure the series elastic stiffness of the Soleus/Achilles tendon complex. When perturbed from an equilibrium position by a transient force, a single degree of freedom mass spring system such as that pictured in Figure 1A will oscillate at its resonant (natural) frequency. This frequency is a function of the stiffness of the spring and the magnitude of the mass. If a viscous damping component is added to this system the resulting oscillations will decay at an exponential rate governed by the amount of damping present (see Figure 1B). The Achilles tendon/muscle complex may be modeled as such a system and the stiffness then be calculated from a knowledge of the damping frequency of oscillation (as measured by an accelerometer), the mass, and the coefficient of damping. (For a detailed explanation of the coefficient of damping see McNair et al., 1992).

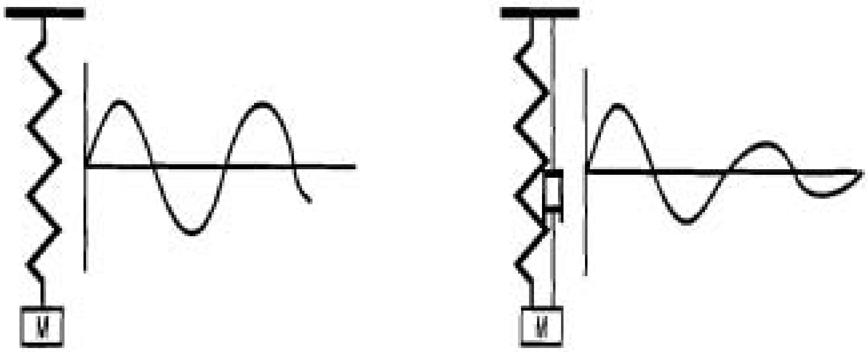

Figure 1 **A** **B**

Range of motion was assessed using weights and a pulley system to move the ankle joint through its range passively. Electromyography was used to monitor the activity of the plantar and dorsiflexors during these procedures. The statistical analysis of these data involved an analysis of variance with the alpha level set to 0.05.

RESULTS

The results for stiffness and ROM are presented in Table 1. For stiffness, just running was significantly ($p<0.05$) more effective than just stretching for decreasing series elastic muscle stiffness. In contrast, the results for range of motion showed that stretching, and the running/stretching combination was significantly ($p<0.05$) better than just running for increasing joint range of motion.

Table 1: Mean percent change in ROM and Stiffness.

	Run	Stretch	Run+Stretch
% change ROM	0	8	13
% change Stiffness	7	0	3

DISCUSSION

It has been suggested that "warm up" exercise can increase ROM about a joint and also decrease the stiffness of the soft tissues (Taylor et al., 1990). In doing so, the incidence of injury may be decreased. Increasing range of motion is particularly related to those sports where competitors must attain extreme ranges of motion (eg: gymnastics). The significance of the stiffness measures is related to resistance of the soft tissue to lengthening through the range of motion. For instance, a muscle which is relatively stiff may be more likely to be damaged in response to a sudden stretch than a more compliant muscle.

The change in stiffness was significantly better after just running than the change in stiffness observed after just stretching. Running has been shown to cause an increase in intramuscular tissue temperature of 4-5 deg above that of resting muscle (Saltin et al., 1968), and animal studies have shown that increasing the temperature of muscle and tendon increases extensibility (Warren et al., 1976). Therefore, it seems likely that the effect of decreased stiffness after just running is due to changes in temperature dependent viscoelastic properties of the muscle tendon complex.

An unexpected finding was the lack of statistical difference between running and the stretching/running regime, and also between stretching and the running/stretching regime, this is to say the combination lay between the other two regimes, and was not significantly different from either. It was expected that the combination programme would be at least as good as just running. In hindsight a methodological limitation may be responsible. When undertaking the combination regime subjects ran for 10 minutes, then stretched for 5, this means that, while they were stretching, there was up to 6 minutes from the end of running before they were measured. Fadilah and coworkers (1987) reported that, in in-vivo animal studies, a warming effect had dissipated after in about 5 minutes. In this regard, the heating effect in the muscles and tendons induced by running may have dissipated during the stretching part of the protocol, and the cooler muscle tendon complex did not change as much when comparing it to measurements taken straight after just running. In this regard, an interesting question is how long does the change in stiffness last after a running type warm up, and, if one warms-up and then stretches, have any changes gained during the running been lost?

The second variable measured in this experiment is ROM. The greatest improvements in ROM (13% compared to pre values) were seen when subjects undertook a running/stretching protocol, just stretching was next and just running had no effect on ROM values. Statistical analysis indicated a significant difference between the combination of running and stretching and just running and also just stretching improved ROM better than and just running.

Based on our data, if the activity may involve the joint being taken to its end of range the preparation phase for exercise should involve stretching that joint, just running may not be adequate. With regard to affecting stiffness, running has the greatest effect, although it is unknown what it is an optimal stiffness range.

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