The Influence of Pre-Activity Whole-Body Warm Up and Stretching on Musculo-Skeletal Stiffness

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Introduction

Musculo-skeletal stiffness is considered to be a risk factor for some sports related injuries. Warm up and stretching exercises are widely regarded as a sensible pre-activity precaution for preventing injury and enhancing performance in most sporting contexts (ACSM, 2000). Raising muscle temperature and pre-activity stretching exercises are thought to decrease musculo-skeletal stiffness and viscosity, which are promoted as injury protective mechanisms (Safran et al., 1989). This premiss is based on the concept that the observed increase in extensibility and strength of muscles and connective tissues will also increase their strain energy to failure thereby limiting damage to the tissues and risk of injury. Hence, the purpose of this study was to test the hypothesis that whole-body warm up and stretching exercises do in fact decrease the overall musculo-skeletal stiffness of the body. This was done by monitoring changes in musculoskeletal stiffness \textit{in vivo} based on the resonance and mass of the body following routine whole-body warm up and stretching exercises.

Methods

Body mass was obtained by direct measurement using clinical, electronic scales with a resolution of 0.1 kg. Whole-body resonant frequency was determined via the suspended beam method, which has a resolution of 0.1 Hz and a precision of \( \pm 0.35 \) Hz (Randall et al., 1997). The beam was made to vibrate in its fundamental mode by striking it at the centre of the beam with and without the test subject standing on it, details shown in Figure 1. Each resonance test can be readily made between interventions and takes about 10 s to complete so there will be negligible changes in body temperature during each assessment. Body resonance was determined from changes in the system frequencies and used, in conjunction with body mass, to estimate the effective stiffness (kN m\(^{-1}\)) of the test subject after each exercise condition.

Subjects were recruited from a university population (15 males), median age (26 and range 20 to 45 years). Measurements of whole-body stiffness were made for the pre-exercise condition then after a 10 minute warm up at 50% max heart rate reserve; a whole-body stretch routine and finally an intense exercise condition, consisting of a 15 minute treadmill run at 85% max heart rate reserve. Whole-body resonance, \( \omega_s \), was determined for the following four test conditions:

1. Pre-activity baseline condition,
2. After a routine warm up;
3. Immediately followed by a stretching routine,
4. After an intense endurance activity.

The warm up phase consisted of a 10 minute treadmill walk or jog at 50% max heart rate reserve. Two bouts of 30 s stretches were applied to each of the major muscle groups of the shoulder, trunk and legs. The endurance activity consisted of 15 minute treadmill run at 85% max heart rate reserve. Whole-body stiffness, \( k_s \), was estimated from the product of mass, \( m_s \), and resonant frequency squared, \( \omega_s^2 \), for each individual.
Figure 1. Beam configuration: A, accelerometer, subject’s body weight, $m_s$, modal mass of beam, $m_b$, $\alpha = m_s / m_b$, and equations for the subject’s body resonance, $\omega_s$, and effective subject stiffness, $k_s$, calculated using equations 1 and 2 respectively.

\[ \omega_s = \sqrt{\frac{\omega_b^2 \cdot (\omega_b^2 - \omega_s^2)}{\omega_b^2 - (1 - \alpha) \cdot \omega_s^2}} \]  
Eqn 1

\[ k_s = m_s \cdot \omega_s^2 \]  
Eqn 2

Results & Discussion

A one way repeated ANOVA model showed that both warm up (489 ± 160 kN m$^{-1}$) and intense exercise (458 ± 166 kN m$^{-1}$) significantly reduced musculo-skeletal stiffness (p < 0.05) compared to rest (523 ± 172 kN m$^{-1}$) while stretching (504 ± 177 kN m$^{-1}$) had no effect, shown graphically in Figure 2.

Figure 2. Effective stiffness by test condition for 15 subjects
This study confirms that warm up and intense exercise reduces whole-body stiffness while stretching appears to confer no additional benefit. Assuming that lowered musculoskeletal stiffness affords a protective mechanism against injury, pre-activity warm up is potentially a more effective prophylaxis than stretching. However, participation in an intense and prolonged bout of sporting activity or endurance phase, provides in itself, the greatest decrease in overall body stiffness and presumably protection from injury.

References