INFLUENCE OF STRETCHING, FLEXIBILITY, STRETCH-SHORTENING CYCLE AND LEG STIFFNESS ON RUNNING ECONOMY

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INTRODUCTION

The relationship between various anthropometrical and biomechanical factors and running economy (RE) has been of great interest to both researchers and runners for many years. Some studies have reported that less flexibility is associated with better RE [2,3,7,8], while other findings have been contradictory [4,5]. Leg stiffness and stretch shortening cycle contributions (SSC) during muscle activation have often been cited as a mechanism linking flexibility and RE, but little information is available relating leg stiffness [6], SSC and RE. The present study used two different measures of SSC contributions and measures of leg stiffness during running to investigate the influence of stretching, flexibility, leg stiffness and SSC on RE.

METHODS

Ten male runners with 10km run times between 29 and 45 minutes volunteered as subjects and participated in one treadmill accommodation session and two sets of two test sessions, with tests randomized in order and including one day in which a specified stretching routine was followed and one day without a stretching routing. Subjects first warmed up on a treadmill for 10 minutes. For test sessions involving stretching, subjects then performed a regulated stretching regimen. Immediately after the initial warm-up and stretching (when done), a number of passive lower extremity flexibility measurements were obtained.

After taking flexibility measurements, subjects then completed one of two different sessions where performance measures were obtained. During one session, lower extremity leg stiffness using a mass-spring model was derived from 2D video and force platform data obtained during running overground. This was followed by estimate of SSC during single leg knee extensions on an active Cybex dynamometer, where either static rest or an eccentric loading preceded concentric muscle activation. The second test session involved obtaining VO_2 as a measure of RE at three different speeds on the treadmill and then estimating SSC from typical counter-movement and no counter-movement vertical jumps on a force platform. One-tailed t-tests and correlation analyses were used to evaluate relationships that assumed better RE would be associated with less flexibility and greater SSC and leg stiffness.

RESULTS AND DISCUSSION

Only one of seven measures of lower extremity flexibility showed a significant change as a result of the structured stretching exercises, with the only increase in flexibility found for a sit and reach measure (avg=2.4cm, $p<0.01$). None of the performance measures showed significant differences between the stretch and no-stretch conditions (e.g., RE, 38.0 vs. 38.0, K_{vert} 36.1 vs. 34.6, SSC Jump, 11.7 vs. 12.1, respectively). As a result, data for the stretch and no-stretch conditions were averaged for subsequent analysis of relationships between the various performance measures.

Better RE (lower VO_2) was significantly associated with less flexibility for: a combined flexibility measure (sum of z-scores, r=0.63); hip flexion (r=0.61); ankle dorsiflexion with a straight knee (0.59); and hip horizontal abduction (r=0.70). Better RE was also associated with lower vertical leg stiffness (K_{vert}, r=0.58). This result is somewhat contrary to a study [1] that found better RE associated with greater triceps surae stiffness but a more compliant patellar tendon at low force levels, though measures of leg stiffness are not the same as muscle/tendon stiffness. While one might assume that a lower dorsiflexion ROM would be associated with a stiffer leg, the opposite was found here, with less straight knee dorsiflexion flexibility significantly correlated with lower stiffness (r=0.68 for K_{vert} and 0.80 for K_{leg}). Similar results were found with several other flexibility measures. None of the estimates of SSC were significantly related to RE, and greater SSC from the vertical jump tests was associated with lower leg stiffness (K_{leg}, r=-0.69).

Table 1. Average performance measures.

	Units	Mean	SD
VO_2	ml•kg^{-1}•min^{-1}	38.0	2.4
Sit & Reach	cm	0.70	10.2
Dorsiflexion (str)	deg	96.4	3.6
Hip Flexion	deg	86.2	12.0
Hip Horiz Abd.	deg	57.9	6.3
K_{vert}	kN/m	35.4	6.4
K_{leg}	kN/m	33.3	7.6
SSC Jump	%	11.9	9.5
SSC Cybex	%	20.2	18.6

CONCLUSIONS

Results support previous findings suggesting that better RE was associated with less flexibility but did not show a stretching routine to affect RE or other measures, and RE was associated with less vertical leg stiffness. SSC was not significantly related to RE, perhaps because SSC measures were obtained during activities other than running, and a valid method for estimating SSC during running has not yet been established.

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