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In males, more than 50 % of the variance in the 'general' speed test results was associated with jump test performance ($R^2=0.56$ for vertical jump; $R^2=0.55$ for long jump). However, when the specific speed test was considered, no more than 3% of the variance in results was attributed to variance in jump test performance ($R^2=0.00$ for vertical jump; $R=0.03$ for long jump). Only 12% of the variance in the specific speed test was associated with general speed test performance. In females, between 40 and 50% of the variance in general speed test results was associated with jump test results ($R^2=0.49$ for vertical jump; $R^2=0.41$ for long jump). For the specific speed test, again, no more than 3% of the variance in results was associated with jump test results ($R^2=0.01$ for vertical jump. $R^2=0.03$ for long jump). Around 52% of the variance in specific speed test results could be attributed to variance in general speed test performance.

The data demonstrate that in these elite performers, measures taken from commonly used jump test procedures are not associated with the results from a Badminton-specific movement speed test. It is likely that the technical aspects of Badminton movement could explain the lack of association between these measures. This point is reinforced by the fact that highly significant correlations are seen between both jump test results and the general speed test in males and females. If the validity of the specific speed test is accepted, then the validity of these jump tests for competitors in this sport should be questioned.

58. The Influence of Three Different Warm-Up Stretching Routines on Muscle Performance

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Prior to performing physical activity it is customary to undertake a warm up in the belief it reduces the risk of injury and increases performance. A typical warm-up includes cardiovascular exercise followed by mobility and stretching exercises. Existing research studies have examined the influence of different types of warm-up (active, passive) and different warm-up structure (intensity, duration and recovery) on performance (Bishop, 2003, *Sports Medicine*, 33, 483–498). In contrast there is little research comparing the acute effect of different stretching routines within an active warm-up. The aim of the current study was to examine the effect of three different stretching routines on muscle performance of the quadriceps and hamstrings.

Written informed consent from participants and ethical approval were obtained. Nine healthy males

volunteered to participate in a repeated measures study involving four experimental sessions conducted in a non-sequential order (mean \pm s, age 24.4 ± 5.0 years, mass 83.7 ± 9.4 kg, stature 164.2 ± 3.1 cm, body fat $16.3 \pm 7.1\%$). Each session included a 10-minute treadmill jog at 60% of age predicted maximum heart rate and then the respective standardised quadriceps and hamstring stretching regime that lasted for a further 6-minutes (static, dynamic, proprioceptive neuromuscular facilitation (PNF) or no stretching). Measures of heart rate, mean skin temperature (three sites, arm, thigh and chest) and hip range of motion in extension and flexion (Leighton flexometer) were taken before the warm-up, upon completion of the warm-up and post-isokinetic testing. Upon completion of the warm-up the participants performed six maximal knee flexion and extension isokinetic actions under three randomised angular velocities (1.05, 2.09 4.19 rad·s⁻¹, Contrex 1.0 dynamometer). Gravity corrected peak torque, mean torque, total work and mean power for quadriceps and hamstrings under the three angular velocities were recorded. All statistical analysis were conducted using SPSS vs 11.5 and significance was set at $P < 0.05$.

A repeated measures MANOVA examined the flexibility data. Results revealed there was a difference in both hip flexion ($F_{6,48}=4.927$, $P=0.001$) and hip extension ($F_{6,48}=3.481$, $P=0.006$) range of motion upon completion of the warm-up between stretching conditions. Follow-up pairwise t-tests with a Bonferroni adjusted significance level identified that PNF stretching led to greater range of movement compared to static stretching and no stretching for hip flexion and static stretching for hip extension. These results suggest that PNF stretching within the warm-up can lead to a greater acute increase in range of motion compared to other stretching conditions, which may have injury prevention implications.

A repeated measures MANOVA examined the isokinetic data. No differences between stretching conditions were identified for most of the dependent variables, suggesting the different stretching conditions had no significant influence on muscle performance. Condition effects were identified for mean torque of the knee extensors at 1.05 rad·s⁻¹ ($F_{3,21}=3.711$, $P=0.028$) and mean power of the knee flexors at 2.09 rad·s⁻¹ ($F_{3,21}=3.929$, $P=0.023$). Follow-up pairwise t-tests with a Bonferroni adjusted significance level indicated static stretching led to lower mean power of the knee flexors at 2.09 rad·s⁻¹ compared to the other three stretching conditions. There was no consistent trend between stretching techniques to indicate an optimal technique for enhancing muscle performance, although further research should investigate the potential reduction in mean power as a result of static stretching.

In conclusion stretching appears to have a small but significant effect on range of movement and muscle performance. PNF stretching as part of a warm-up routine produces greater range of motion, whereas static stretching could reduce torque output.

59. Reliability and Concurrent Validity of the Multi-Stage Shuttle Run Test in Adolescents Athletes

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The multi-stage shuttle run test (MSSRT) is widely used to assess maximal oxygen uptake and as an indicator of aerobic capacity in adolescents. Reliability coefficients for the MSSRT have been reported in the region of 0.87 to 0.93 and concurrent validity in the region of 0.51 to 0.69 in adolescents aged 12–15 years (Lui *et al.*, 1992: *Research Quarterly for Exercise and Sport*, **63**, 360–365). The application of existing research evidence to athletic adolescents may be limited since sensitive measures are needed due to the small variation in maximal oxygen uptake in response to interventions. The aim of the current study was to establish the test-retest reliability and concurrent validity of the MSSRT when used to estimate maximal oxygen uptake in athletes aged 12–13 years.

Parental written informed consent, verbal assent from participants and ethical approval were obtained. Twelve male adolescents who regularly trained in competitive club football with approximately 5–7 hours of training/competitive play per week participated (mean \pm s, age 12.5 ± 0.5 years, mass 41.4 ± 6.4 kg, stature 153.4 ± 5.1 cm). A repeated measures design involving three separate test sessions was used. The first session involved an incremental treadmill test using the modified Bruce protocol and online breath-by-breath metabolic analysis (Cardio II, Medgraphics, calibrated to manufacturers guidelines) to establish peak oxygen uptake. The second and third sessions took place one week apart and involved repeated trials of the MSSRT; on each occasion a standardised pre-recorded CD was used under the same environmental conditions. Maximal oxygen uptake was estimated using the age adjusted prediction equation (Leger *et al.*, 1988: *Journal of Sports Sciences*, **6**, 93–101). Pearson product moment correlation coefficients, paired t-tests and 95% limits of agreement were conducted using SPSS version 11.5. Significance was set at $P < 0.05$.

Estimated maximal oxygen uptake was $56.5 \pm 4.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $56.0 \pm 3.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for the MSSRT trials respectively. A relationship was

identified between the MSSRT test-retest ($r=0.86$, $P=0.001$); this suggests good reliability and was comparable to previous MSSRT reliability data in adolescents. Least products regression analysis corroborated this finding with an adjusted R^2 of 0.72 and $F=26.70$ ($P=0.001$). No systematic bias was identified between the MSSRT trials ($t=0.61$, degrees freedom=10, $P=0.560$). The 95% limits of agreement were $0.42 \pm 4.46 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; these limits identify random error between repeated trials. The random error between repeated measures suggests a typical adolescent in this study with a maximal oxygen uptake of $55 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ could record a result between 51.0 and $59.9 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ in a repeated trial. Given the typical small variation in maximal oxygen uptake in athletic adolescents in response to interventions this random error is likely to interfere with the ability to detect meaningful changes in aerobic capacity.

The peak oxygen uptake directly measured was recorded as $60.6 \pm 7.0 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, compared to the mean of the two MSSRT trials of $56.2 \pm 4.0 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. A relationship was identified between the directly measured maximal oxygen uptake and the estimated maximal oxygen uptake from the MSSRT ($r=0.67$, $P=0.017$). The correlation coefficient, similar to reported values, has previously led to the suggestion that the MSSRT provides a valid indication of maximal oxygen uptake. Least products regression also indicated poor reliability with an adjusted R^2 of 0.39 and $F=8.09$ ($R=0.17$). The paired t-test identified a difference between the two measures, indicating systematic bias ($t=2.93$, degrees freedom=11, $P=0.014$). The limits of agreement were recorded as $4.5 \pm 10.4 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, identifying the MSSRT systematically underestimated peak oxygen uptake by $4.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Moreover the limits of agreement indicated substantial random error between the two procedures.

In conclusion it appears that the MSSRT underestimates maximal oxygen uptake in adolescent athletes and is therefore not a valid estimate of maximum oxygen uptake in this population. Furthermore the test does not appear to have sufficient reliability to be able to detect changes in performance in adolescent athletes.

76. Energy Expenditure during 24-hour Rowing: A Case Study

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The 2003 Woodvale Atlantic Rowing Race involved rowing from the Canary Islands to Barbados in a