Physiological responses of international female lacrosse players to pre-season conditioning

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ABSTRACT
WITHERS, R.T. Physiological responses of international female lacrosse players to pre-season conditioning. Med. Sci. Sports. Vol. 10, No. 4, pp. 238-242, 1978.—This study examined the changes in body composition, maximum aerobic power (Vo2max) and maximum anaerobic power in seven Australian international women lacrosse players during a 3-month pre-season conditioning program. Monthly tests were conducted and the data were analyzed by an ANOVA repeated measures design and subjected to a polynomial orthogonal test of trend in the event of a significant F-ratio at the .05 level. The trend analysis for relative body fat (X = 24.9 [initial], 22.8 [first month], 23.1 [second month] and 23.1% [third month]) indicated significant linear and quadratic components since the major adjustment had occurred by the end of the first month. The players also experienced an overall average weight loss of 1.35 kg. The mean Vo2max values were: 44.0, 48.6, 52.3 and 52.9 ml/kg x min. Thus aerobic power had plateaued by the end of the second month and the trend analysis accordingly indicated significant linear and quadratic components. Anaerobic lactacid power was measured by Margaria’s stair run. Both the times and power (kpm/kg x sec) exhibited significant linear trends. Post-exercise blood samples taken at the start and end of the 3-month training program indicated a significant increase (P < .05) in lactate (X = 9.0 and 11.8 mmol/l) following a short duration maximum treadmill run.

BODY COMPOSITION, VO2MAX ON TREADMILL, MARGARIA STAIR RUN, MAXIMUM BLOOD LACTATES

Two comparatively recent review articles (6,26) have indicated the availability of research data on the physiological responses to exercise of women of varying ages, nationalities and sporting interests. However, no attention seems to have been focused on international field games players. This study was therefore undertaken for two purposes: to monitor changes in the physiological profiles of seven international female lacrosse players during a 3-month pre-season training program and to obtain descriptive data for comparison with other groups.

METHODS
The subjects comprised the seven South Australian representatives on the national women's lacrosse team which toured the U.S.A. in April and May of 1977. Three of the women had not engaged in strenuous activity since the preceding lacrosse season finished in early September. Two had been playing basketball once a week and the remaining two had been playing one and two competitive basketball games a week, respectively. All players trained twice a day for 6 days a week during the 3-month build-up. This involved a total work time of approximately 10 hours per week with half the time devoted to fitness and the other half to developing lacrosse skills together with their incorporation into small-side games. The principle of overload was applied to all the fitness training. Circuit-training was performed about five times a week. The 6 days per week running program was initially continuous but greater emphasis was gradually placed on interval training. The program aimed at getting the players to peak fitness for the start of the tour in early April.

A preliminary laboratory session was devoted to familiarizing the subjects with all the experimental procedures. Tests were conducted at the end of December, January, February and March for Vo2max, anaerobic lactacid power and body composition. The subjects performed high intensity short duration treadmill runs at the end of December, January, February and March in order to obtain an indication of anaerobic lactacid power. Blood lactate bioassays were conducted only at the end of December and March.

Maximum aerobic power was determined on a Quinton 18-49-C treadmill in accordance with the Froelicher et al. (11) modification of the Taylor, Buskirk and Henschel (35) protocol. The criterion for the attainment of Vo2 max was an elevation in Vo2 of less than 2 ml/kg x min as a result of an increase in treadmill elevation of 2% (30) while the speed was kept constant at 10.5 km/hr. The outlet of a Collins triple "J" high velocity respiratory valve was connected to a Douglas bag assembly by means of a 1.1 m length of 3.8 cm internal diameter corrugated plastic tubing. This enabled expired gas to be collected in 150 l Douglas bags for the last 30-40 sec of each 3-min exercise stage. The sample outlet on the Douglas bag was connected to a drying tower and then to Beckman LB-2 and OM-14 analysers for CO2 and O2 analyses, respectively. Both gas analysers were calibrated prior to each testing session. Lloyd-dried gas samples were measured in triplicate. The gas analysis technique was as follows: (20). T. 861....... j

150 l

The mixing tank

236-242.
session with standard gas which had been checked by Lloyd-Haldane and mass spectrometer analyses. Due to the drift on the OM-14 O2 analyser, it was necessary to calibrate this instrument immediately before each analysis. The contents of the Douglas bag were then pumped through a Singer dry gas meter at a constant flow rate of 100 l/min. Calibration was effected prior to each testing session by pumping air through the gas meter and a flow meter which were in series. A computer program was used to calculate the VO2 values (15) while a CM-5 electrode placement was used to record the electrocardiogram on a Washington oscillograph which had been calibrated at a speed of 25 mm/sec. Heart rates (fr) were determined by measuring the distance between the last 11 "R" waves of the appropriate exercise bout and dividing this distance into 1500 (2).

Anaerobic lactacid power was measured according to the procedure outlined by Margaria, Aghemo and Rovelli (20). The vertical lift between the 8th and 12th stair was .681 m and the best of 8 trials was used in further calculations. Anaerobic lactacid power was measured by setting the treadmill elevation at 20% and running the subjects at individually selected speeds such that the maximum duration they could maintain was 40-60 sec. The speeds were the same for each trial. An antecubital vein was catheterized and 3 ml of blood removed for the purpose of lactate assay according to the enzymatic method described by Roosenberg and Rush (28). Three serial post-exercise blood samples were taken every 2-2½ min.

The specific gravity of the body was calculated by summing the biceps, triceps, suprailliac and subscapular skinfold measurements, which were obtained using Harpenden skinfold calipers, and then employing the regression equation of Durnin and Womersley (7). Reliability coefficients of .95, .97, .94 and .96 had been previously obtained by the investigator for these four sites using 30 subjects. Calculations of the relative body fat were based on the equation given by Siri (33).

Statistical differences between pre- and post-training blood lactate concentrations were analyzed by a "t" test for dependent groups whereas the remaining data were subjected to an ANOVA repeated measures design. The .05 probability level was used for all test of statistical significance. The data for the ANOVA analyses were checked for violation of the assumptions of homogeneity of variance and homogeneity of covariance if contradictory results regarding acceptance/rejection of the null hypothesis were obtained using the conventional and conservative degrees of freedom. Only the body weight data violated these assumptions and the use of the conservative degrees of freedom resulted in acceptance of the null hypothesis (39). In the event of a significant F-ratio, the data were subjected to a polynomial orthogonal test of trend in order to determine the extent to which linear and quadratic functions provided the best fit for the four means.

RESULTS

A physiological profile of each subject at the end of the 3-month pre-season training program is presented in Table 1. The mean aerobic power was 52.9 ml/kg x min (ranging 47.0-57.9), absolute and relative anaerobic lactacid power averaged 81.72 kgm/sec (71.24 - 96.03) and 1.40 kgm/kg x sec (1.23 - 1.56), respectively, and the mean relative body fat was 23.1% (18.4 - 28.2).

The descriptive statistics for each of the four testings, together with the F-ratios for the ANOVA repeated measures designs and summaries of the polynomial orthogonal tests of trend, are given in Table 2. The trend analysis for percentage body fat indicated significant linear and quadratic components since the major adjustment in adipose tissue appeared to have occurred by the end of the first month. The players also experienced an overall average weight loss of 1.55 kg. Analysis of the V02max data resulted in significant linear and quadratic components as aerobic power had plateaued by the end of the second month. The times and relative anaerobic lactacid power scores for the Margaria stair run both exhibited significant linear com-

<p>| TABLE 1. Characteristics of Australian female lacrosse representatives at conclusion of a 3 month conditioning program. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th><strong>Position</strong></th>
<th><strong>Age (yrs)</strong></th>
<th><strong>Height (cm)</strong></th>
<th><strong>Weight (kg)</strong></th>
<th><strong>V02max (l/min STPD)</strong></th>
<th><strong>V02max (mmHg/sec)</strong></th>
<th><strong>V02 pulse (ml/mg/min at V02max)</strong></th>
<th><strong>V02 pulse (ml/mg/min at V02max)</strong></th>
<th><strong>Power (kgm/sec)</strong></th>
<th><strong>Power (kgm/sec)</strong></th>
<th><strong>Relative Body fat (%)</strong></th>
<th><strong>Blood Lactate (mmol/l)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward and attack wing</td>
<td>29.9</td>
<td>165.7</td>
<td>55.5</td>
<td>3.37</td>
<td>57.9</td>
<td>192.4</td>
<td>17.0</td>
<td>122.57</td>
<td>84.61</td>
<td>1.47</td>
<td>18.4</td>
</tr>
<tr>
<td>Straight defence</td>
<td>25.9</td>
<td>162.5</td>
<td>59.2</td>
<td>3.36</td>
<td>56.8</td>
<td>185.2</td>
<td>18.2</td>
<td>127.86</td>
<td>75.75</td>
<td>1.23</td>
<td>23.8</td>
</tr>
<tr>
<td>Straight defence</td>
<td>18.4</td>
<td>171.6</td>
<td>55.7</td>
<td>2.83</td>
<td>50.9</td>
<td>185.7</td>
<td>14.3</td>
<td>116.10</td>
<td>77.77</td>
<td>1.36</td>
<td>23.4</td>
</tr>
<tr>
<td>Straight defence</td>
<td>21.7</td>
<td>165.7</td>
<td>66.1</td>
<td>3.11</td>
<td>47.0</td>
<td>191.1</td>
<td>16.3</td>
<td>104.81</td>
<td>81.25</td>
<td>1.22</td>
<td>28.2</td>
</tr>
<tr>
<td>Straight defence</td>
<td>22.1</td>
<td>165.7</td>
<td>60.7</td>
<td>3.25</td>
<td>53.5</td>
<td>187.5</td>
<td>17.3</td>
<td>132.47</td>
<td>96.03</td>
<td>1.56</td>
<td>22.7</td>
</tr>
<tr>
<td>Straight defence</td>
<td>20.1</td>
<td>157.3</td>
<td>51.75</td>
<td>2.77</td>
<td>53.5</td>
<td>182.9</td>
<td>15.1</td>
<td>122.67</td>
<td>85.44</td>
<td>1.59</td>
<td>23.5</td>
</tr>
<tr>
<td>Straight defence</td>
<td>23.0</td>
<td>159.8</td>
<td>51.8</td>
<td>3.68</td>
<td>50.4</td>
<td>182.9</td>
<td>14.2</td>
<td>91.55</td>
<td>71.24</td>
<td>1.35</td>
<td>21.7</td>
</tr>
<tr>
<td>Mean</td>
<td>23.0</td>
<td>164.0</td>
<td>57.35</td>
<td>3.03</td>
<td>52.9</td>
<td>188.7</td>
<td>16.1</td>
<td>116.86</td>
<td>81.72</td>
<td>1.40</td>
<td>23.1</td>
</tr>
<tr>
<td>± S.D.</td>
<td>3.8</td>
<td>4.7</td>
<td>5.2</td>
<td>1.4</td>
<td>3.8</td>
<td>5.8</td>
<td>1.6</td>
<td>14.24</td>
<td>8.04</td>
<td>1.5</td>
<td>2.9</td>
</tr>
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</table>
TABLE 2: Descriptive statistics and summary of trend analysis.

<table>
<thead>
<tr>
<th></th>
<th>1st Test</th>
<th>2nd Test</th>
<th>3rd Test</th>
<th>4th Test</th>
<th>F-ratio</th>
<th>Total variation between trials accounted for by linear trend</th>
<th>Amount of total variation between trials accounted for by quadratic trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>58.95</td>
<td>56.8</td>
<td>56.8</td>
<td>57.4</td>
<td>3.30</td>
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<td></td>
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<tr>
<td>Mean ± S.D.</td>
<td>6.2</td>
<td>6.3</td>
<td>5.1</td>
<td>5.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Weight (1/min STPD)</td>
<td>2.59</td>
<td>2.76</td>
<td>2.97</td>
<td>3.03</td>
<td>47.52*</td>
<td>865</td>
<td>.829*</td>
</tr>
<tr>
<td>Mean ± S.D.</td>
<td>.29</td>
<td>.31</td>
<td>.26</td>
<td>.29</td>
<td></td>
<td></td>
<td>.27</td>
</tr>
<tr>
<td>Max. VO2 Max. (ml/kg/min STPD)</td>
<td>44.0</td>
<td>48.6</td>
<td>52.3</td>
<td>52.9</td>
<td>45.20*</td>
<td>354.01</td>
<td>232.15*</td>
</tr>
<tr>
<td>Mean ± S.D.</td>
<td>3.8</td>
<td>4.4</td>
<td>3.3</td>
<td>3.8</td>
<td></td>
<td></td>
<td>.29.01*</td>
</tr>
<tr>
<td>Run time in secs for max treadmill run</td>
<td>42.5</td>
<td>46.8</td>
<td>52.5</td>
<td>61.4</td>
<td>48.60*</td>
<td>1394.93</td>
<td>1356.58*</td>
</tr>
<tr>
<td>Mean ± S.D.</td>
<td>6.3</td>
<td>6.7</td>
<td>6.8</td>
<td>7.6</td>
<td></td>
<td></td>
<td>37.03</td>
</tr>
<tr>
<td>Time in ms for Margaria stair run</td>
<td>527</td>
<td>519</td>
<td>503</td>
<td>478</td>
<td>10.60*</td>
<td>010</td>
<td>.009*</td>
</tr>
<tr>
<td>Mean ± S.D.</td>
<td>059</td>
<td>049</td>
<td>047</td>
<td>050</td>
<td></td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td>Power (kgm/sec)</td>
<td>75.12</td>
<td>71.85</td>
<td>76.15</td>
<td>81.72</td>
<td>5.48*</td>
<td>354.33</td>
<td>203.40</td>
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<tr>
<td>Mean ± S.D.</td>
<td>6.95</td>
<td>5.74</td>
<td>6.89</td>
<td>8.04</td>
<td></td>
<td></td>
<td>136.30</td>
</tr>
<tr>
<td>Power (kgm/kg/sec)</td>
<td>126.1</td>
<td>123.7</td>
<td>132.3</td>
<td>139.7</td>
<td>5.84*</td>
<td>354.33</td>
<td>.106</td>
</tr>
<tr>
<td>Mean ± S.D.</td>
<td>1.13</td>
<td>1.23</td>
<td>1.23</td>
<td>1.48</td>
<td></td>
<td></td>
<td>.084*</td>
</tr>
<tr>
<td>Relative body fat (%)</td>
<td>24.9</td>
<td>22.8</td>
<td>23.1</td>
<td>23.1</td>
<td>7.09*</td>
<td>19.58</td>
<td>9.21*</td>
</tr>
<tr>
<td>Mean ± S.D.</td>
<td>3.4</td>
<td>3.3</td>
<td>3.1</td>
<td>2.9</td>
<td></td>
<td></td>
<td>7.72*</td>
</tr>
</tbody>
</table>

*Not significant using conservative degrees of freedom
*Significant at the .05 level

Perhaps the most meaningful comparison which can be effected is that with the subjects used by Dunn and Womersley (7), when validating the technique used in this paper. The mean relative body fat of their 100 female subjects in the age range 20-29 years was 29% (S.D. = 10) which is much higher than the final mean value of 23.1% for the international lacrosse players. However, one ought to bear in mind that regression equations for predicting relative body fat from skinfold measurements are population specific. When compared to other athletic females the international lacrosse players have relative fat values which are higher than those reported for intercollegiate basketball (20.8%, 31); international gymnastics (9.6%, 25) and national and international distance running (15.2%, 36); comparable to those in intercollegiate tennis (24.2%, 14) and intercollegiate swimming (23.2%, 14); but lower than those in South Australian representative softball (26.5%, R.T. Withers and R-G-D. Roberts. Unpublished data).

Maximum aerobic power. The polynomial orthogonal test of trend for VO2 max in ml/kg x min gave statistically significant linear and quadratic components. The data in Table 2 indicates that the improvements occurred during the first 2 months. This emphasizes the need for a lengthy pre-season training period so that the attainment of a good level of aerobic power can act as a foundation for the training of the more task specific anaerobic processes. Similar data were reported by Brown, Harrower and Deeter (3) on 12 pre-adolescent girls who engaged in a 12-week cross-country running program. The majority (18%) of their overall improvement (26%) occurred in the first 6...
weeks. The latter figure is higher than the overall improvement in absolute VO2max of 17.0% registered by the lacrosse players whose relative VO2max increased by the higher figure of 22.2% due to a decrease of 2.6% in body weight. All the other female training studies (8,10,16,17,32,34) were for shorter durations and generally fewer workloads per week than that experienced by the lacrosse players. The largest located increases in aerobic power for similar aged women were 37.3% (10) and 30.3% (8), respectively, but the initial fitness levels of both groups were very low, and large increases were to be expected. Lower improvements of 10.8% (17) and 5.7% (34) were reported on subjects who had higher initial aerobic powers.

No data are available on the mean maximum aerobic power of a cross-section of Australian females in the same age group. Pugh (27) reports the mean VO2max of 95 British women as 39.7 ml/kg x min and this is consistent with the results of Hermansen and Anderson (12) and L. Astrand (1) on Norwegian students and Swedish housewives, respectively. Even after allowing for the fact that all the preceding data was apparently collected on a bicycle ergometer, which has been shown to yield values 10.2 - 11.2% lower than on the treadmill (22), it is apparent that the maximum aerobic power of the lacrosse players is much greater than that of their non-aerobic female counterparts. The values are also high when compared to other sportswomen tested on the treadmill. The South Australian State softball team registered a mean VO2max of 45.4 ml/kg x min (R.T. Withers and R.C.D. Roberts. Unpublished data), intercollegiate basketball players have scored 40.8 and 35.7 ml/kg x min (18,23), intercollegiate field hockey players 42.9 ml/kg x min (18), intercollegiate volleyball players 39.2 ml/kg x min (18), and U.S.A. Olympic speed skaters (19) have an average of 46.1 ml/kg x min. On the other hand, higher values have been recorded on participants in mainly aerobic type activities. International cross-country skiers have scored 40.8 and 35.7 ml/kg x min (29). Five Swedish champion orienteers exhibited a mean VO2max of 58 ml/kg x min (29). Wilmore and Brown (36) reported a mean value of 59.1 ml/kg x min in 11 national and international caliber long-distance runners. Their highest value of 71.1 ml/kg x min was for the holder of the best time in the world for female marathoners (2:49:04.0).

Aerobic Power. No studies were located in the literature on the effect of training on aerobic lactacid power in females. The decreased time for the Margaria (4) and run exhibited a statistically significant linear trend over the 3-month conditioning period. In fact, .009 of the total .01 variation between trials was accounted for by the linear trend. The trend analysis for absolute aerobic power was affected by the decrease in body weight as the mean of 71.85 g/km/sec for the second test was lower than the mean of 5.12 g/km/sec for the first test even though there had been an improvement in average time from 527 to 519 ms. Thus while the F-ratio was significant at the .05 level, neither the linear nor the quadratic trends were significant even though they contributed 203.4 and 136.3, respectively, of the total variation of 354.33 between trials. The relative power data exhibited a significant linear trend; .084 of the total variation of .106 between trials was attributed to the linear component. There would, therefore, appear to be no statistical evidence that the players had reached their maximum anaerobic lactacid power at the conclusion of pre-season training. However, the absence of a control group to a certain extent compromises any interpretation of significant increases even though there was an attempt to control learning by giving the subjects 8 trials in a preliminary testing session. Unfortunately it was not possible to obtain seven matched control subjects who intended maintaining their existing activity pattern for 3 months.

Higher absolute (X = 86.07 g/kg/sec) but lower relative power (X = 1.29 g/kg x sec) scores were registered by the South Australian state women's softball team (R.T. Withers and R.C.D. Roberts. Unpublished data). Lower relative power scores (X = 1.3 g/kg x sec) have been reported on 185 Australian female physical education students in the age range 17-25 years (R.C.D. Roberts. Personal Communication). Coutts (4) has stated that 11 members of Canada's national women's volleyball team had mean absolute and relative power scores of 108.1 g/kg/sec and 1.52 g/kg x sec, respectively. Valid comparisons cannot be made with the rating table in Mathews and Fox (12) since apparently these data were collected when using switchmats, a 6 m runup and negotiating similar height steps three at a time.

The statistically significant increase in post-exercise blood lactate concentration for the short duration maximum treadmill run consequent to training has been found in other training studies (9,17) and in this instance was paralleled by a significant linear trend for the maximum run time. The blood lactates tended to peak at 4 - 5 min post-exercise which is in accordance with data reported by Cunningham and Faulkner (5) on eight male subjects who experienced a similar short exhausting treadmill run. However, it should be emphasised that the concentration of lactate in the blood at any one time would be a function of its production, removal, rate of diffusion from the muscle cells and the total body water available for its dilution. The only training study located using females was that by Kilborn (17) whose similar aged 12 subjects (final X VO2max = 40.8 ml/kg x min) trained 2-3 times a week for 7 weeks on a bicycle ergometer at loads corresponding to 70% of maximum aerobic power. Their mean post-test maximal blood lactate of 11.6 mmol/l was almost identical to that of 11.8 mmol/l for the lacrosse players. Similar average values of 11.3 and 12.4 mmol/l, respectively, were obtained in our laboratory on 13 members of the South Australian women's softball team and by Saltin and Astrand (29) on 10 athletes belonging to Swedish National Teams. Pugh (27) has also reported comparable figures of 10.8 (ranging 8.3-16.2) and 11.5 mmol/l (10.6-12.3), respec-
CONCLUSIONS

Within the limitations of this study, the following conclusions seem justified:

1) The final mean maximum aerobic power of the international lacrosse players is higher than that reported for other classes of female games players, but there is a scarcity of descriptive data in this area.

REFERENCES


