PHYSIOLOGICAL CHANGES AND BLOOD LACTIC ACID VALUES IN BEEF STEERS FED DES UNDER AD LIBITUM, RESTRICTED AND COMPENSATORY CONDITIONS

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Summary

The purpose of this study was to determine the influence of diethylstilbestrol (DES) and differing nutritional regimens on respiratory and heart rates, electrocardiogram (EKG) patterns, rectal temperature and blood lactic acid values of steers. Sixteen Angus steers were fed a 75% concentrate diet ad libitum for a 28-day standardization period. Eight steers were then fed 20 mg DES per steer per day and eight steers served as controls (no DES) during a 28-day ad libitum feeding period followed by a 35-day period of feed restriction during which the animals lost approximately 0.9 kg daily. After this period the animals were fed ad libitum for 60 additional days. The same diet was fed during the entire trial. Data were obtained six times during the trial. Body temperature and blood lactic acid were not affected by the imposed treatments. During ad libitum compared to restricted feeding, respiratory and heart rates were greater (49 vs. 37 respirations/min and 110 vs. 67 beats/min, respectively), the P amplitude was larger (.19 vs. .12 mv) and the Q-T, T and T-P intervals were shorter (.30 vs. .40, .12 vs. .14 and .11 vs. .37 sec., respectively). As heart rate increased, 60% of the compression of the EKG pattern occurred in the T-P interval and 25% occurred in the Q-T interval. DES had little effect on respiratory rate. During ad libitum and restricted feeding, the DES steers generally had a greater heart rate, (99 vs. 92 beats/min.) shorter Q-T and T intervals (.33 vs. .35 and .12 vs. .13 sec., respectively), and lower more erratic T amplitudes (-.06 vs. -.24 mv) than the control steers. These results suggested a DES effect separate from energy intake, and changes in the T amplitude indicated DES may cause small changes in the refractory time of the ventricular muscles. Under the conditions of this study, however, myocardial changes attributed to DES did not appear great enough to affect the efficiency of the heart muscle.

Introduction

Diethylstilbestrol (DES) treatment of experimental animals has caused increased growth, stimulated protein anabolism and decreased carcass fat in ruminants (Ogilvie et al., 1960; Wilson et al., 1963); lowered basal metabolic rate and increased fat deposition in chickens (Bird, 1946); and loss of weight, increased blood pressure and hypertension in rats (Leathem and Drill, 1943). In chickens and dogs, DES treatment was accompanied by changes in heart muscle activity possibly because of shifts in normal hormonal balance (Bouyard and Klein, 1966; Sturkie and Hunsaker, 1957). Recently, Trenkle (1969) outlined the possible role of the endocrine system as a mediator of the physiological response to DES in ruminants. DES implants increased the electrocardiogram (EKG) amplitudes of sheep (Mullick and Murty, 1962) and heart rate in beef heifers (Rumsey and Bond, 1972) during ad libitum feeding. Since the cardiovascular system is the major transport system of the body and is regulated in conjunc-

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This report described EKG patterns, heart and respiratory rates, body temperatures and blood plasma lactic acid values of control steers vs. steers fed DES during periods of maximum, restricted and compensatory growth.

**Experimental Procedure**

Sixteen Angus steers with an initial weight of 276 kg were individually fed a 75% concentrate diet which contained 55% cracked corn, 25% chopped hay, 15% soybean meal, 3% molasses, 1% dicalcium phosphate and 1% trace mineral salt. The diet was fed *ad libitum* to all steers for a 28-day standardization period. Then eight steers were controls and eight were fed 20 mg DES per steer daily while the same diet was fed 1) *ad libitum* for 28 days, 2) then at 2 kg of diet per steer daily for 35 days and 3) then *ad libitum* for an additional 60 days. The steers were fed at 8:00 am and 4:00 pm each day and DES, when fed, was added to the diet at each feeding. Weight changes, feed intakes and plasma amino acids of steers during this experiment have been summarized by Oltjen et al. (1972). Swan et al. (1972) has summarized serum growth hormone and prolactin levels.

Respiratory and heart rates, EKG patterns and rectal temperatures were obtained from all steers six times during the study. EKG patterns were obtained as described by Rumsey, MacEwen and Bond (1967) using the Physiograph-Six system (Narco Bio-Systems Inc., Houston, Texas). Each time an animal was measured, six individual patterns were averaged and the resulting average value for each segment of the EKG pattern was used to represent that animal. The results of EKG Lead II are presented in this report. The measurements were obtained 1) after all steers had been fed the experimental diet (standardization) for 21 days but before feeding DES, 2) 49 days after initiation of *ad libitum* feeding (21 days on DES) but before restricted feeding of the diet, 3) 7 days after feed restriction, 4) 28 days after initiation of restricted feeding or before the second *ad libitum* feeding period, 5) 14 days following the return from restricted to *ad libitum* feeding and 6) 60 days following the return to *ad libitum* feeding. To minimize variation in heart and respiratory patterns caused by animal excitement, jugular catheters were installed and blood samples collected the day after each set of measurements was obtained. Blood samples were collected in heparin during the morning after the am feeding and during the afternoon before the pm feeding. Lactic acid in plasma was determined by a FeCl₃ colorimetric procedure (Rumsey et al., 1967) as described by Langlois (1962).

Analysis of variance techniques were used to statistically test the differences caused by DES and time (Steel and Torrie, 1960), with the error term representing variation among animals within each DES X Time block. Correlations were calculated for all possible combinations of EKG intervals and heart rate for the controls and the DES treated steers. Regression equations were calculated for each pair of measurements that were significantly correlated.

The R amplitude, the P and QRS intervals and rectal temperature were not significantly affected (P > .05) by feed intake or DES treatment.

The physiological measurements that were affected by both DES and feed intake are shown in table 1. Respiratory rate was similar during both *ad libitum* feed intake periods but was significantly lowered (P < .05) during the restricted feeding period, particularly 7 days after feed restriction began. Respiratory rate was not different between the control and DES groups during the *ad libitum* periods but the reduction in respiratory rate after 7 days of restricted feeding was greater (P < .05) for the DES group.

Average heart rate was greater (P < .05) and the Q-T and T intervals were shorter (P < .05) on the basis of analysis of variance for the DES treated steers compared to controls. This trend was consistent across all feeding regimens although individual means were not significantly different as determined by Duncan’s multiple range test. Heart rate and the Q-T and T intervals changed (P < .01) with time during the study. For both the control and DES groups heart rate was greater (P < .05) at 49 days compared to 21 days on *ad libitum* feeding, lower (P < .05) during the restricted feeding period than during the initial *ad libitum* period, and increased (P < .05) during the second *ad libitum* feeding period to a level similar to the initial *ad libitum* period. In general the Q-T and T interval changes were opposite the changes in heart rate except during the restricted feeding period. The T interval increased (P < .05) during the second *ad libitum* feeding period for the control group but not the DES group.

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TABLE 1. EFFECT OF DES AND FEED INTAKE ON RESPIRATORY RATE AND EKG PATTERNS OF BEEF STEERS

<table>
<thead>
<tr>
<th>Days on feeding regimen</th>
<th>Feed intake regimen</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Ad libitum</td>
<td>Restricted</td>
<td>Ad libitum</td>
<td>S.b/ x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory rate, respirations/min. c/</td>
<td>21^a</td>
<td>49</td>
<td>7</td>
<td>28</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>-DES</td>
<td>51.5^e,f</td>
<td>48.0^e,f</td>
<td>35.8^g</td>
<td>40.4^g</td>
<td>49.9^e,f</td>
<td>43.9^f,g</td>
</tr>
<tr>
<td>+DES</td>
<td>50.3^e,f</td>
<td>53.3^e</td>
<td>31.1^h</td>
<td>41.0^g</td>
<td>49.3^e,f</td>
<td>49.3^e,f</td>
</tr>
<tr>
<td>Heart rate, beats/ min. c,d</td>
<td>100.6^e,f</td>
<td>116.4^g,h</td>
<td>58.7^i</td>
<td>68.6^j</td>
<td>108.6^e,f,h</td>
<td>105.5^e,f,i</td>
</tr>
<tr>
<td>-DES</td>
<td>100.6^e,f</td>
<td>116.4^g,h</td>
<td>58.7^i</td>
<td>68.6^j</td>
<td>108.6^e,f,h</td>
<td>105.5^e,f,i</td>
</tr>
<tr>
<td>+DES</td>
<td>99.1^f</td>
<td>126.2^g</td>
<td>66.2^i,j</td>
<td>74.8^j</td>
<td>113.7^e,g,h</td>
<td>111.0^e,i,j</td>
</tr>
<tr>
<td>Q-T interval, seconds c,d</td>
<td>0.324^e</td>
<td>0.274^f,g</td>
<td>0.413^h,i,j</td>
<td>0.416^h</td>
<td>0.316^e</td>
<td>0.333^e</td>
</tr>
<tr>
<td>-DES</td>
<td>0.324^e</td>
<td>0.274^f,g</td>
<td>0.413^h,i,j</td>
<td>0.416^h</td>
<td>0.316^e</td>
<td>0.333^e</td>
</tr>
<tr>
<td>+DES</td>
<td>0.314^e</td>
<td>0.266^e</td>
<td>0.395^h,i,j</td>
<td>0.402^h,i,j</td>
<td>0.297^e,f</td>
<td>0.306^e,f</td>
</tr>
</tbody>
</table>

^aMeasurements obtained during standardization period before the start of DES treatment at 4 weeks.
^bCommon standard error of mean obtained from the balanced analysis of variance.
^cAffected by weeks on experiment (P < .01).
^dAffected by DES (P < .05).
^e,f,g,h,i,jWithin each measurement, means with a common letter in the superscript are not different (P < .05).

The effect of DES treatment on the T amplitude and the concentration of blood plasma lactic acid is shown in table 2. The amplitude was lower (P < .05) for the steers treated with DES than for the controls primarily because of the differences during the 49- to 151-day period. Considerable amplitude fluctuation was noted for the DES steers; however, this fluctuation did not appear to be associated with changes in feed intake.

The concentration of plasma lactic acid was the same for the DES and control steers. The average concentration for the morning samples was greater (P < .01) than for the afternoon samples and this difference was not affected by ad libitum vs. restricted feed intake. Differences among sampling days were similar for both the control and DES steers and these differences were not explainable on the basis of feeding regimen.

P amplitude and P-R and T-P intervals were affected by feed intake (table 3) but not by DES treatment. The P amplitude was not significantly changed during the first ad libitum

TABLE 2. EFFECT OF DES ON THE T AMPLITUDE AND BLOOD LACTIC ACID OF BEEF STEERS

<table>
<thead>
<tr>
<th>Days on experiment</th>
<th>Control</th>
<th>DES</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T amplitude, millivolts c/</td>
<td>-0.070</td>
<td>-0.242</td>
<td>-0.038</td>
<td>-0.059</td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>Blood plasma lactic acid, mg/100 ml. d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>am</td>
<td>18.3</td>
<td>13.8</td>
<td>16.1</td>
<td>13.7</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>pm</td>
<td>14.9</td>
<td>10.5</td>
<td>13.4</td>
<td>10.5</td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>

^aMeasurements obtained during the standardization period before the start of DES treatment at 4 weeks.
^bSee footnote b, table 1.
^cDES treated steers were less than the controls (P < .05).
^dSamples collected in the am were greater than pm samples (P < .01).
Table 3. Effect of the Level of Feed Intake on EKG Patterns of Beef Steers

<table>
<thead>
<tr>
<th>Days on feeding regimen:</th>
<th>Ad libitum</th>
<th>Restricted</th>
<th>Ad libitum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49</td>
<td>7</td>
</tr>
<tr>
<td>Measurement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P amplitude, millivolts&lt;sup&gt;c&lt;/sup&gt;/s</td>
<td>.164&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.161&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.140&lt;sup&gt;e,f&lt;/sup&gt;</td>
</tr>
<tr>
<td>P-R interval, seconds&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.172&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.146&lt;sup&gt;f&lt;/sup&gt;</td>
<td>.168&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>T-P interval, seconds&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.134&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.079&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.131&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Measurements obtained during standardization period before the start of DES treatment at 4 weeks.

<sup>b</sup>See footnote b, table 1.

<sup>c</sup>P < .01.

<sup>d</sup>P < .05. e,f,gWithin each measurement, means with a common letter in the superscript are not different (P < .05).

Feeding period: it decreased during the restriction period and increased (P < .05) during the second ad libitum period. The changes in the P-R and T-P intervals were generally opposite the changes noted for heart rate.

Correlation coefficients were determined for all possible pair combinations of EKG interval and heart rate measurements in the control and DES groups. Although these heart measurements were obtained from the same animals at low and high heart rates, correlation and regression techniques were used as an indicator of how changes in heart measurements were related. Heart rate was negatively correlated (P < .01) with the Q-T (.54, P < .01) and T-P (.89, .89) intervals for the control and DES groups, respectively, and with the P-R interval (-.37, P < .05) for the control group. For the control and DES groups, respectively, significant positive correlations (P < .01) were found between the T-P and T intervals (.53, .53) and Q-T and T-P intervals (.76, .79). The T-P and T intervals were significantly correlated for the control steers (.54, P < .01) and for the DES steers (.34, P < .05). The P-R interval for the control group was correlated with the Q-T (.39, P < .01) and P (.35, P < .05) intervals and for the DES steers the P-R and T intervals were positively correlated (.43, P < .01).

Regression equation values are shown in table 4 for each pair of significantly correlated

Table 4. Effect of DES on the Selected Regression Equations Calculated for EKG Interval and Heart Rate Measurements

<table>
<thead>
<tr>
<th>Abscissa</th>
<th>Ordinate</th>
<th>-DES</th>
<th>+DES</th>
<th>-DES</th>
<th>+DES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>P-Rb</td>
<td>.157</td>
<td>.166</td>
<td>-.001</td>
<td>&lt;-.001</td>
</tr>
<tr>
<td></td>
<td>Q-Tc</td>
<td>.341</td>
<td>.333</td>
<td>.002</td>
<td>&lt;.002</td>
</tr>
<tr>
<td></td>
<td>Tc</td>
<td>.129</td>
<td>.122</td>
<td>.005</td>
<td>&lt;.005</td>
</tr>
<tr>
<td></td>
<td>T-Pc</td>
<td>.174</td>
<td>.190</td>
<td>.005</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>P-R</td>
<td>Pc</td>
<td>.074</td>
<td>.074</td>
<td>.257</td>
<td>.146</td>
</tr>
<tr>
<td>Q-T</td>
<td>P-Rc</td>
<td>.157</td>
<td>.166</td>
<td>.268</td>
<td>.133</td>
</tr>
<tr>
<td></td>
<td>Tc</td>
<td>.131</td>
<td>.120</td>
<td>.149</td>
<td>.344</td>
</tr>
<tr>
<td>T-P</td>
<td>Q-Tc</td>
<td>.129</td>
<td>.122</td>
<td>.135</td>
<td>.187</td>
</tr>
<tr>
<td></td>
<td>Tb,d</td>
<td>.345</td>
<td>.329</td>
<td>.137</td>
<td>.231</td>
</tr>
</tbody>
</table>

<sup>a</sup>a is the ordinate value at the average abscissa value and b is the change in the abscissa for each 10 units change in the ordinate.

<sup>b</sup>Average b value significant from zero (P < .05).

<sup>c</sup>Average b value significant from zero (P < .01).

<sup>d</sup>Regression coefficients for the control and treated steers are different (P < .10).
measurements from the control and DES steers. Over the range of measurements observed in this study, all the b values averaged across the control and DES groups were significant (P < .05). There were some apparent differences in b values between the control and treated steers but the differences were not significant except for the regression of T-P and T (P < .10).

Changes in the EKG intervals, based on the regression equations, are shown graphically in figure 1 as heart rate increased from 60 to 120 beats per minute in both the control and DES steers. As heart rate increased, the major interval change was a reduction in the T-P interval (P < .01) with smaller but significant reductions occurring in the Q-T and T intervals (P < .01) and the P-R interval (P < .05).

Discussion

A typical growth response was obtained for the steers in the present study. Daily gains (kg) for the DES and control steers were 1.32 vs. 0.91, -1.55 vs. -1.22 and 1.74 vs. 1.34 during the ad libitum, restricted and ad libitum feeding periods, respectively (Oltjen et al., 1972). During both ad libitum feeding periods the DES steers consumed a similar quantity of feed, but gained 38% faster and were 28% more efficient than the control steers. However, the lack of differences in blood lactic acid, body temperature and respiratory rate between the control and DES steers indicated a minimal metabolic stress. Also, daily feeding of DES did not cause abnormal shifts in the activity of the heart muscle, although there were some myocardial changes within normal physiological limits (Manning, 1959).

Heart rate was 7.4% greater when DES was fed. Feed intake was not different between the control and DES steers and, therefore, the faster heart rate was not a result of increased energy intake (Rumsey et al., 1970). The effect of DES on heart rate may have been mediated through a general increase in cellular metabolism. An increase in cellular metabolism would be consistent with increased growth hormone (Trenkle, 1969). However, in the present study serum growth hormone levels were not affected by feeding DES (Swan et al., 1972). Bouyard

![Figure 1. EKG interval changes in control and DES treated steers as heart rate increased from 60 to 120 beats per minute.](image-url)
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altering carcass composition and feedlot perform-
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