CHAPTER – III
EFFECT OF SWIMMING AS AN EXERCISE ON THE SKELETAL MUSCLE GLUCOSE METABOLISM IN DIABETIC MALE ALBINO RATS

In the previous chapter the augmented mobilization and utilization of carbohydrate in the muscles of rat subjected to a programme of swimming exercise lead to the present study. i.e. the effect of swimming exercise on the skeletal muscle glucose metabolism in diabetic male albino rats.

The studies on the glucose metabolism in the muscles of the two groups viz. 1. Diabetic rats – non exercised (DM) and 2. Diabetic rats / exercised group (DEM) revealed the following results, and the same were compared with that of the normal control (CM) rats.

Diabetes was induced in rats by intra peritoneal administration of streptozotocin (STZ).

RESULTS

a. The glucose metabolism of skeletal muscle in diabetic male albino rats:

Normal Control Vs Diabetic Animals

The glucose levels indicating the glucose mobilization, utilization and the glucose metabolism in gastrocnemius muscle of diabetic male albino rats
were compared with that of normal control rats, and the results were analysed (Table 17-19 & Fig: 16-27).

The glycogen content in the diabetic rat muscle (DM) significantly increased (19.84%) over that of CM.

The activity level of phosphorylase 'a' the active form was depleted (57.2%) in diabetic muscle (DM) with a non significant change in the activity level of the inactive form i.e. phosphorylase 'b' when compared to that of CM. The total phosphorylase activity however depleted (18.88%) significantly in DM over that of CM. The free glucose content was also higher (38.4%) in DM over that of CM. The FDP-aldolase activity level showed considerable inhibition (15.66%) with the accumulation of lactic acid (58.8%), in DM when compared with that of CM. The tissue pyruvate content was increased (19.15%) in the diabetic muscle in relation to normal control muscle.

The activity level of NAD – Lactate dehydrogenase (LDH) was significantly lowered (24.28%) in DM from that of CM. The enzymes of citric acid cycle succinate dehydrogenase (SDH) and malate dehydrogenase (MDH) showed significant decreased activity levels in DM (47.6% and 19.5% respectively) over that of CM.
Levels of Glycogen, phosphorylase 'a', 'b', 'ab' activities in normal control (CM) and diabetic rat gastrocnemius muscle (DM). Each value represents of six observations. Mean ± SD '+' and '-' indicate percent increase and decrease over the control muscle, 'P' denotes level of statistical significance and N.S. non significance.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Component</th>
<th>Control Muscle (CM)</th>
<th>Diabetic rat muscle (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Glycogen (mg /g wet wt.)</td>
<td>3.98 ± 0.14</td>
<td>19.84 ± 0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P&lt;0.001</td>
<td>4.77 ± 0.17</td>
</tr>
<tr>
<td>2.</td>
<td>Phosphorylase 'a' (µ mol pi / mg protein/h)</td>
<td>0.76 ± 0.04</td>
<td>-57.2 ± 0.04</td>
</tr>
<tr>
<td>3.</td>
<td>Phosphorylase 'b' (µ mol pi / mg protein/h)</td>
<td>1.2 ± 0.07</td>
<td>-5.4</td>
</tr>
<tr>
<td>4.</td>
<td>Phosphorylase 'ab' (µ mol pi / mg protein/h)</td>
<td>1.8 ± 0.12</td>
<td>-18.88 ± 0.12</td>
</tr>
</tbody>
</table>
TABLE 18

Levels of Glucose, aldolase activity, lactate and pyruvate content in normal control (CM) and diabetic rat gastrocnemius muscle, (DM). Each value represents of six observations. Mean ± SD '⁺' and '⁻' indicate percent increase and decrease over the control muscle. 'P' denotes level of statistical significance.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Component</th>
<th>Control Muscle (CM)</th>
<th>Diabetic rat muscle (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Glucose (mg /g wet wt.)</td>
<td>1.25 ± 0.1</td>
<td>+38.4 P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.73 ± 0.13</td>
</tr>
<tr>
<td>2.</td>
<td>Aldolase (µ moles of FDP cleaved / mg protein/h)</td>
<td>1.43 ± 0.08</td>
<td>-15.66 P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.206 ± 0.17</td>
</tr>
<tr>
<td>3.</td>
<td>Lactate (mg/g wet wt)</td>
<td>4.03 ± 0.36</td>
<td>+58.8 P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.4 ± 0.52</td>
</tr>
<tr>
<td>4.</td>
<td>Pyruvate (mg/g wet wt.)</td>
<td>2.61 ± 0.11</td>
<td>+19.15 P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.11 ± 0.4</td>
</tr>
</tbody>
</table>
TABLE 19

Levels of LDH, SDH, MDH and G-6-PDH activity in normal control (CM) and diabetic rat gastrocnemius muscle, (DM). Each value represents of six observations. Mean ± SD '+' and '-' indicate percent increase and decrease over the control muscle, 'P' denotes level of statistical significance.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Component</th>
<th>Control Muscle (CM)</th>
<th>Diabetic rat muscle (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>LDH</td>
<td>0.07 ± 0.007</td>
<td>0.053 ± 0.004</td>
</tr>
<tr>
<td>2.</td>
<td>SDH</td>
<td>1.079 ± 0.01</td>
<td>0.565 ± 0.03</td>
</tr>
<tr>
<td>3.</td>
<td>MDH</td>
<td>0.082 ± 0.01</td>
<td>0.066 ± 0.004</td>
</tr>
<tr>
<td>4.</td>
<td>G-6-PDH</td>
<td>1.86 ± 0.1</td>
<td>1.053 ± 0.1</td>
</tr>
</tbody>
</table>
Glucose –6 – Phosphate dehydrogenase, the marker enzyme of the hexose monophosphate shunt also showed depleted activity level (43.38%) in DM over the corresponding level of CM.

b. The glucose metabolism of skeletal muscle in diabetic exercised male albino rats:

Diabetic Rat Muscle Vs Diabetic Rat Exercised Muscle:

The glucose metabolism in the diabetic rat gastrocnemius muscle was compared with that of diabetic exercised rat and the results were analysed (Tables 20-22 Fig : 28-39).

The diabetic – exercised rat muscle, (DEM) in relation to that of diabetic rat (DM) muscle had reduced glycogen content (15.77%). The phosphorylase 'a' activity was stepped up in DEM with a lowered activity of the inactive form, phosphorylase 'b' in comparison to DM. The overall total phosphorylase activity ('ab') increased (15.07%) in DEM from that of DM. The free glucose content in DEM depleted (14.45%) over that of DM. The FDP-aldolase activity was enhanced (28.19%) in DEM. The lactate content was decreased (22.96%) in DEM from that of DM. The pyruvate content showed a slight depletion in DEM over that DM.
The accumulation of glycogen in the diabetic muscle could be due to decreased glycogenolysis. This storage poly-saccharide was brought into the first stage of glycolysis by an auxiliary enzyme phosphorylase, which brings about the glycogenolysis (Harper, 2000). The study of phosphorylase activity revealed inhibited activity of active phosphorylase 'a' with a non-significant change in the inactive form i.e., phosphorylase 'b'. The glycogen phosphorylase of skeletal muscle occurs in two forms, the active form (phosphorylase 'a'), which is a tetramer. This tetrameric phosphorylase 'a' can be dissociated into inactive form (phosphorylase 'b') which is a dimer, by phosphorylase phosphatase. The reconversion of phosphorylase 'b' into the active form was brought about by phosphorylase kinase. The interconversions of these two forms exerts regulation on glycogenolysis (Lehninger, 2000).

The lactate dehydrogenase activity and the enzymes of citric acid cycle, SDH and MDH were elevated (28.3%; 42.48% and 43.94% respectively) in DEM in comparison to DM. The glucose – 6-phosphate dehydrogenase activity level was also higher (24.9%) in DEM when compared with that of DM.
DISCUSSION

Normal Control Vs Diabetic Animals:

The decrease in the phosphorylase 'a' 'b' and 'ab' activities suggest the decrease in the enzyme content in the DM muscle. The D-glucose units of glycogen gain entrance into glycolytic sequence through the sequential action of the glycogen phosphorylase. Thus phosphorylase is situated at an important point between the fuel reservoir and the enzymatic apparatus for utilizing the fuel i.e. glycolysis (Harper, 2000). The observed decrease in the phosphorylase activity might be responsible for the accumulation of glycogen fuel due to non-utilization of the same.

Similarly the glucose content was also accumulated in the DM muscle. A further probe into the glycolysis revealed inhibited activity level of FDP – aldolase. Aldolase cleaves the hexoses into two trioses in glycolysis (Harper, 2000). It's decreased activity level in the present study reveals the decreased level of operation of the glycolytic sequents.

However the observed accumulation of lactate in DM muscle, inspite of lowered level of operation of glycolysis suggests its formation from some other sources or its decreased mobilization. The activity level of NAD-LDH was significantly decreased in the DM muscle since NAD-
LDH is a measure of mobilization of lactate into citric acid cycle, its decrease reveals the decreased mobilization of lactate, possibly leading to its accumulation. The enzyme NAD-LDH reversibly converts lactate into pyruvate where the latter enter the citric acid cycle. The increased level of pyruvate in DM muscle might be due to the less mobilization into citric acid cycle.

To analyse the extent of operation of citric acid cycle, the aerobic metabolism, the activity levels of succinate and malate dehydrogenases were determined.

The activity levels of both the enzymes were decreased in the DM muscle, suggesting the inhibition of aerobic pathway. This decreased operation of citric acid cycle substantiates the accumulation of pyruvate in the DM muscle. Similar decrease in the glycogenolysis, anaerobic metabolism, the glycolysis and aerobic metabolism (or) the citric acid cycle operation was reported in diabetic animals (Brekke et al. 1982; Large and Beycot. 1999; Parpieva Kazakov, 2001.)

Glucose 6-phosphate dehydrogenase activity level was depleted in the DM muscle. Glucose-6-phosphate dehydrogenase is the marker enzyme in hexose-monophosphate pathway and is a measure of mobilization of hexoses into the hexose monophosphate path way.
Further it also generates NADPH and pentose sugars, the essential raw materials needed for lipogenesis and nucleic acid synthesis. The observed decrease of glucose – 6- phosphate dehydrogenase in the present study reveals decreased rate of lipogenesis and nucleic acid synthesis.

Glucose 6-phosphate dehydrogenase activity level was depleted in the DM muscle. Glucose-6, phosphate dehydrogenase is the marker enzyme in hexose-mobilization of hexoses into the hexose monophosphate path way. Further it also generates NADPH and pentose sugars, the essential raw materials needed for lipogenesis and nucleic acid synthesis. The observed decrease of glucose – 6 – phosphate dehydrogenase in the present study reveals decreased rate of lipogenesis and nucleic acid synthesis.

Thus the diabetic rat muscle had the accumulation of fuel due to the non-utilization or mobilization of the same through both anaerobic and aerobic pathways and also through hexose monophosphate shunt.

**Diabetic Animals Vs Diabetic Exercised Animals :**

The diabetic albino rats subjected to the programme of swimming exercise for a period of 30 days revealed an entirely different pattern of glucose metabolism, to that of diabetic animals.
The diabetic exercised animal muscle (DEM), in relation to that of diabetic animal (DM) had decreased levels of glycogen, suggesting its mobilization towards energy release to meet the energy demands of the induced work in the DEM muscle. The observed increase in the phosphorylase 'a' activity supports the increased glycogenolysis of the DEM muscle. The inactive form of the phosphorylase might have been converted into the active form, as the phosphorylase 'b' activity is decreased in the DEM muscle. The total phosphorylase as revealed by the phosphorylase 'ab' activity was elevated. This observation indicates that the increased phosphorylase was due to both inter conversions and as well as de novo synthesis of the enzyme. This enhanced phosphorylase activity might have mobilized the glycogen leading to its depletion as observed in the DEM muscle.

Similarly, glucose content in the DEM muscle was also decreased suggesting its probable mobilization towards energy release. The FPP-aldolase activity was significantly elevated in DEM muscle from that of DM, which indicates the enhanced operation of glycolysis. A significant decrease in lactate content and a slight decrease in pyruvate content in DEM suggest the mobilization into the aerobic pathway, the TCA-cycle. The increased activity level of NAD-LDH supports the mobility of lactate into TCA-cycle. As a result of this enhanced mobilization of citric acid
cycle intermediaries, the activity levels of the SDH and MDH might have been elevated in the DEM. Thus the DEM muscle had stepped up mobilization of carbohydrate fuels through anaerobic and aerobic pathways.

The study on glucose-6-phosphate dehydrogenate revealed an increased mobilization of hexose through hexose monophosphate pathway.

In general the study on the glucose metabolism revealed the stepped up energy fuel mobilization and energy production through both anaerobic and aerobic pathways, which might have been responsible for the observed increased functional efficiency in DEM muscle over that of DM.

The deranged glucose mobilization and utilization pattern in diabetic rat was found to be set back on 'rails' towards normal condition was due to subjecting the diabetic animals to a programme of swimming exercise.
#### TABLE 20

Levels of Glycogen, phosphorylase 'a', 'b', 'ab' activities in diabetic rat muscle (DM) and diabetic rat exercised muscle (DEM). Each value represents of six observations. Mean $\pm$ SD '+' and '-' indicate percent increase and decrease over the DM, muscle. 'P' denotes level of statistical significance.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Component</th>
<th>Diabetic rat muscle (DM)</th>
<th>Diabetic rat Exercised muscle (DEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Glycogen (mg/g wet wt.)</td>
<td>4.77 ± 0.17</td>
<td>-15.77 P&lt;0.001 4.02 ± 0.17</td>
</tr>
<tr>
<td>2.</td>
<td>Phosphorylase 'a' (μ mol pi/mg protein/h)</td>
<td>0.325 ± 0.02</td>
<td>+221.84 P&lt;0.001 1.046 ± 0.12</td>
</tr>
<tr>
<td>3.</td>
<td>Phosphorylase 'b' (μ mol pi/mg protein/h)</td>
<td>1.135 ± 0.13</td>
<td>-44.14 P&lt;0.001 0.634 ± 0.04</td>
</tr>
<tr>
<td>4.</td>
<td>Phosphorylase 'ab' (μ mol pi/mg protein/h)</td>
<td>1.46 ± 0.12</td>
<td>+15.07 P&lt;0.1 1.68 ± 0.13</td>
</tr>
</tbody>
</table>
TABLE 21

Levels of Glucose, aldolase activity lactate and pyruvate content in diabetic rat muscle (DM) and diabetic rat exercised muscle (DEM).

Each value represents six observations. Mean ± SD '+' and '-' indicate percent increase and decrease over DM, muscle, 'P' denotes level of statistical significance.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Component</th>
<th>Diabetic rat muscle (DM)</th>
<th>Diabetic rat Exercised muscle (DEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Glucose (mg /g wet wt.)</td>
<td>1.73 ± 0.13</td>
<td>-14.45 P&lt;0.01</td>
</tr>
<tr>
<td>2.</td>
<td>Aldolase (μ moles of FDP cleaved / mg protein/h)</td>
<td>1.206 ± 0.17</td>
<td>+28.19 P&lt;0.21</td>
</tr>
<tr>
<td>3.</td>
<td>Lactate (mg/g wet wt.)</td>
<td>6.4 ± 0.52</td>
<td>-22.96 P&lt;0.01</td>
</tr>
<tr>
<td>4.</td>
<td>Pyruvate (mg/g wet wt.)</td>
<td>3.11 ± 0.4</td>
<td>-5.79 P&lt;0.05</td>
</tr>
</tbody>
</table>
TABLE 22

Levels of LDH, SDH, MDH and G-6-PDH activity in diabetic rat muscle (DM) and diabetic rat exercised muscle (DEM). Each value represents of six observations. Mean ± SD '+' and '-' indicate percent increase and decrease over the DM, muscle, 'P' denotes level of statistical significance.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Component</th>
<th>Diabetic rat muscle (DM)</th>
<th>Diabetic rat Exercised muscle (DEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>LDH (μ moles of formazan formed / mg protein/h)</td>
<td>0.053 ± 0.004</td>
<td>+28.3 P&lt;0.001</td>
</tr>
<tr>
<td>2.</td>
<td>SDH (μ moles of formazan formed / mg protein/h)</td>
<td>0.565 ± 0.03</td>
<td>+42.48 P&lt;0.001</td>
</tr>
<tr>
<td>3.</td>
<td>MDH (μ moles of formazan formed / mg protein/h)</td>
<td>0.066 ± 0.004</td>
<td>+43.94 P&lt;0.001</td>
</tr>
<tr>
<td>4.</td>
<td>G-6-PDH (μ moles of formazan formed / mg protein/h)</td>
<td>1.053 ± 0.1</td>
<td>+24.97 P&lt;0.001</td>
</tr>
</tbody>
</table>
SUMMARY

1. The advances in Science and technology have provided rapid mechanization and automation, where the amount of work performed by a particular individual reduced alarmingly. Natural physical activity has been replaced by a variety of labour saving devices and generally affluent standard of living. This type of mechanization has resulted in obesity, hypertension and diabetes, leading to the incidence of cardiovascular disease (CVD).

2. Physical exercise burns calories, which will help to maintain healthy weight. Exercise can improve blood circulation and reduce cholesterol and high blood pressure. A daily programmed physical exercise combined with a meal plan can control diabetes without the need for medication.

3. The utility procedures adopted and the studies to evaluate the therapeutic value of physical exercise to mobilize and utilize the glucose and to maintain healthy blood glucose levels during impaired glucose metabolism such as diabetes are scanty – Hence the present study was undertaken to evaluate the effectiveness of regular physical activity in promoting glucose mobilization, utilization and averting the probable adversaries due to the
incidence of type II diabetes mellitus, and induced hyperglycaemia in male albino rats.

4. The human subjects were divided into two groups, viz. 1. Normal active men of age group 19-22 and 2. men with type II diabetes of age group 42-52. The blood glucose mobilization / utilization pattern was assessed in the above two groups under the influence of a programme of cycle ergometer exercise for a duration of 60 min. and 30 min respectively.

5. The blood glucose levels in the exercising subjects of normal active men at various intervals of 1 hour period (i.e. 0th, 10th, 20th, 30th, 40th, 50th, 60th minute) were recorded. The blood glucose level in the above subjects showed a decrease trend from that of the initial value, consistently till 30th minute. At 25th minute of exercise programme a glucose drink was provided to all the exercising subjects. This is to study the blood glucose utilization pattern during the exercise programme.

6. At 40th minute of exercise programme the blood glucose level increased significantly more than the values at '0' minute in all the subjects.
7. The above increment in the blood glucose level may be due to the carbohydrate drink provided to the exercising subjects at 25\textsuperscript{th} minute, and the same might have been absorbed and mobilized in the blood for further utilization to meet the energy demand due to the induced work load through cycle ergometer exercise.

8. The blood glucose levels reduced significantly in all the subjects at 50\textsuperscript{th} and 60\textsuperscript{th} minute of exercise and the values at 60\textsuperscript{th} minute were reduced below the initial value at '0' minute.

9. The second group namely men with type II diabetes mellitus were allowed for an exercise programme of 30 minute on the cycle ergometer. The blood glucose levels in all the subjects decreased significantly after the exercise programme in comparison to that of before exercise.

10. The decreased blood glucose levels in both the groups during exercise and after exercise programme might be due to the increased mobilization of glucose into skeletal muscle and thereby into glycolysis and Kreb's cycle so as to generate more ATP and energy rich molecules to meet the demand of work accomplishment during the exercise programme.
11. The decreased blood glucose levels in both the normal active men and men with type II diabetes during exercise programme might be due to either increased muscular sensitivity to the hormone insulin or due to increased synthesis of glucose transporter protein such as GLUT4 in muscle:

12. A study on glucose metabolism of the skeletal muscle of both normal and diabetic rats under the influence of swimming exercise programme has been undertaken to throw more light on the utilization of glucose.

13. The male albino rats were categorized into four groups, where the first one was normal rats – control (CM), the second one was normal rats – subjected to swimming exercise (EM), third one was diabetes induced rats (DM) and the fourth group was diabetic rats – subjected to swimming exercise (DEM).

14. The gastrocnemius muscle of normal rats exposed to a scheduled swimming exercise programme (EM) had shown an entirely different carbohydrate utilization pattern when compared to that of the muscles of normal control rats (CM).

15. The increased mean activity of phosphorylase 'a' indicates the increased glycogenolysis in the EM. The phosphorylase 'b'
activity was decreased, as the inactive phosphorylase 'b' might have been converted into active phosphorylase 'a'. The increased total phosphorylase content might be due to the de novo synthesis of the enzyme.

16. The increased glucose level in the EM when compared to that of CM might have been due to the increased glucose mobilization into the muscle due to exercise programme.

17. The FDP – aldolase activity was significantly elevated in EM from that of CM indicating the enhanced level of operation of glycolysis.

18. The stepped up glycolysis was also indicated by accumulation of lactate in the EM. The increased activity level of NAD – LDH in EM supports the possibility of mobilizing the accumulated lactic acid into TCA-Cycle.

19. As a result of the above enhanced mobilization of citric acid cycle intermediaries, the activity levels of SDH and MDH might have been elevated.

20. The increase in the TCA-Cycle operation indicates the increased oxidative potential of the exercised muscle.
21. The decreased activity level of glucose-6-phosphate in EM suggests the reduced level of mobilization of carbohydrates through hexose monophosphate shunt.

22. The diabetic rat skeletal muscle (DM) glucose metabolism was compared with that of the normal control muscle (CM).

23. The decreased phosphorylase 'a' 'b' and 'ab' activities suggest the decrease in the enzyme content in the DM muscle. The accumulation of glycogen supports the decrease activity level of phosphorylase 'a'.

24. The glucose content was also accumulated in the DM muscle. A further probe into the glycolysis revealed inhibited activity level of FDP-aldolase, suggesting decrease level of operation of the glycolytic segments.

25. The accumulation of lactate in DM muscle, inpite of lowered level of operation of glycolysis suggests its formation from some other sources or its decreased mobilization.

26. The activity level of NAD-LDH was significantly decreased indicating the decreased mobilization of lactate into citric acid cycle thereby leading to its accumulation.
27. The increased level of pyruvate in DM muscle might be due to the less mobilization into citric acid cycle.

28. The activity levels of both the enzymes were decreased in the DM muscle, suggesting the inhibition of aerobic pathway.

29. The activity level of Glucose-6-phosphate dehydrogenase was depleted in the DM muscle, indicating the depleted hexose monophosphate pathway.

30. The diabetic albino rats subjected to the programme of swimming exercise for a period of 30 days revealed an entirely different pattern of glucose metabolism to that of diabetic animals.

31. The glycogen levels in the DEM decreased when compared with that of DM suggesting its mobilization towards energy release. The observed increase in phosphorylase 'a' activity supports increased glycogenolysis.

32. The phosphorylase 'b' activity decreased the possible conversion of the inactive enzyme into active phosphorylase 'a'.

33. The total phosphorylase 'ab' activity was elevated, which might be due to their inter conversion and as well as de novo synthesis of the enzyme.
34. The glucose level in the DEM muscle was decreased, with an increased FDP – aldolase activity level suggesting the enhanced level of operation of glycolysis.

35. A significant decrease in lactate content and a slight decrease in pyruvate content in DEM suggest the mobilization into the aerobic pathway, the TCA-cycle.

36. The enhanced levels of mobilization of citric acid cycle intermediaries lead to the increased activity levels of the enzymes SDH and MDH in the DEM muscle.

37. The study on the glucose-6- phosphate dehydrogenase revealed an increased mobilization of hexose through hexose monophosphate pathway.

The study on the glucose metabolism revealed the stepped up energy fuel mobilization and energy production through both anaerobic and aerobic pathways which might have been responsible for the observed increased functional efficiency in DEM muscle over that of DM.

38. It can generally be concluded that the physical exercise programme i.e. cycle-ergometer exercise programme enhanced the blood
glucose mobilization / utilization to meet the energy demands developed due to the physical activity in normal activemen and as well as in men with type II diabetes mellitus suggesting the therapeutic value of physical exercise programme in maintaining a healthy blood glucose levels during diabetes mellitus and therefore might avert the development of the adversaries due to diabetes which might have been otherwise set in.

The deranged glucose mobilization / utilization pattern and glucose metabolism in diabetic rat was found to be set back on 'rails' to normal condition due to subjecting the diabetic rats to the programme of swimming-exercise.