Introduction

The rapid urbanization with average urban growth rate of 3.2% from 1951 – 1991 and is expected to touch 33.16% by the year 2016 and change in lifestyle. Women are constantly exposed to stressful environment which precipitates increased secretion of stress combating hormones like epinephrine, nor-epinephrine and cortisol. These hormones have effect on basal metabolism of an individual. Adding up to her hormonal profile, there is cyclical secretion of estrogen and progesterone during her reproductive years which have individual, interactive and sometimes opposing physiological actions on metabolism.

As women constitute about 48% of total Indian population, growing women's movement, largely led by educated urban women forms one among the more important social developments in contemporary India. Exposure to chronic stress leads to deficiencies of immune status and also nutrients like vitamin C, calcium and magnesium. An additional allowance for energy expenditure may be needed in these women.

The amount of energy required by an individual is dependant on BMR and physical activity level.

Basal metabolism of an individual depends on genotype, hormonal status, environmental conditions and anthropometry. In human beings, basal energy production may more easily be determined by indirect calorimetry, (Using Benedict – Roth apparatus), where measurements are made utilizing rate of oxygen consumption ($V_o_2$), which is a measure of energy liberation.

The present study is done by serial measurements of whole body basal oxygen consumption and BMR during various phases of menstrual cycle. Stress level is assessed in all the three phases using pre-tested structured self- administered questionnaire. Different parameters are recorded, tabulated, statistically treated & concluded.

Methodology

The study is done on 40 healthy, unmarried female students of Bangalore Medical College, Bangalore. The subjects were selected on a purposive sampling basis from those who volunteered to participate in the study and were screened to satisfy the inclusion and exclusion criterion.
Thorough history was taken, including menstrual history and complete clinical examination was done before accepting them as subjects for the study. The written, informed consent was taken from the subjects. The laboratory and experimental setup were shown to the subjects and trial mouth breathing through Benedict – Roth metabolism apparatus was done with nose clipped. Those who still volunteered to participate in the study were taken as subjects. This was done to prevent their discontinuation in the middle of the study.

Subjects were instructed to visit the laboratory for BMR recording during each phase of menstrual cycle: 1-5th day during menstrual phase (MP), 9-12th day during follicular phase (FP), and 19-22nd day during luteal phase (LP) and were selected to represent menstrual, follicular and luteal phases respectively. Phases were corroborated with the period of ovulation, as judged from daily basal oral temperature of subject throughout the cycle. Follicular scanning was done only on days nearing ovulation indicated by temperature chart because of practical difficulties.

Different subjects started their metabolic rate estimation in different phases of menstrual cycle: 12 of them started in menstrual phase, 16 in follicular phase, 12 in luteal phase, to rule out the training effect (if any). Bell’s Adjustment Inventory students form was given previous day of recording and STAI-State form on the day of recording, in each phase. Subjects had their dinner early, the previous night, at around 7 pm and stayed in the laboratory and had sufficient sleep. The recording was done on the scheduled day, early morning, at around 7 am in fasting state. They were instructed not to strain themselves physically, the previous day and also avoid high calorie diet.

Subjects were instructed to bring a relative or a friend with them, to decrease their anxiety. The subject was made to lie down on a comfortable couch with head elevation of 20 – 30 degrees and allowed bed rest for 30 minutes. The BMR was recorded by closed- circuit method (indirect calorimetry) using Benedict – Roth apparatus. Procedure was explained once again to the subject. Recording was done for a period of 6 minutes. The procedure was repeated during the next two

1) BMR Vs phases of Menstrual cycle

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std Error</th>
<th>t-value</th>
<th>Df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MP</td>
<td>50.43</td>
<td>5.357</td>
<td>.847</td>
<td>1.384</td>
<td>39</td>
<td>&gt;0.174</td>
</tr>
<tr>
<td>FP</td>
<td>50.32</td>
<td>5.330</td>
<td>.842</td>
<td>37.06</td>
<td>39</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2 MP</td>
<td>59.50</td>
<td>5.782</td>
<td>.914</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FP</td>
<td>50.32</td>
<td>5.330</td>
<td>.842</td>
<td>36.70</td>
<td>39</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LP</td>
<td>59.50</td>
<td>5.782</td>
<td>.914</td>
<td>S</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S – significant, NS – Not significant.

2. Stress vs. Menstrual cycle

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std Error</th>
<th>t-value</th>
<th>Df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MP</td>
<td>29.18</td>
<td>8.292</td>
<td>1.311</td>
<td>2.512</td>
<td>39</td>
<td>&lt;0.016</td>
</tr>
<tr>
<td>FP</td>
<td>28.45</td>
<td>7.854</td>
<td>1.242</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 MP</td>
<td>29.18</td>
<td>8.292</td>
<td>1.311</td>
<td>2.831</td>
<td>39</td>
<td>&lt;0.007</td>
</tr>
<tr>
<td>LP</td>
<td>28.43</td>
<td>7.851</td>
<td>1.241</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 FP</td>
<td>28.45</td>
<td>7.854</td>
<td>1.242</td>
<td>0.183</td>
<td>39</td>
<td>&gt;0.855</td>
</tr>
<tr>
<td>LP</td>
<td>28.43</td>
<td>7.851</td>
<td>1.241</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S – significant, NS – Not significant.

Fig. 1: Bar diagram showing the mean values basal metabolic rate

Fig. 2: Pie diagram showing the mean values of STAI stress score
Fig. 3: Pie diagram showing the mean values of BAI stress score

Table-3: Statistical inference based on paired samples student’s t-test on BAI stress scale

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>t-value</th>
<th>Df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP</td>
<td>53.63</td>
<td>14.927</td>
<td>2.360</td>
<td>1.978</td>
<td>39</td>
<td>&gt;0.055</td>
</tr>
<tr>
<td>FP</td>
<td>55.18</td>
<td>16.681</td>
<td>2.637</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MP</td>
<td>53.63</td>
<td>14.927</td>
<td>0.471</td>
<td>39</td>
<td>&gt;0.640</td>
</tr>
<tr>
<td>LP</td>
<td>54.05</td>
<td>16.889</td>
<td>2.670</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>FP</td>
<td>55.18</td>
<td>16.681</td>
<td>1.441</td>
<td>39</td>
<td>&gt;0.157</td>
</tr>
<tr>
<td>LP</td>
<td>54.05</td>
<td>16.889</td>
<td>2.670</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S = significant, NS = Not significant.

3. Stress vs. BMR

Table 4: Mean and standard deviation of BMR (kcal/hour) in different STAI and BAI scores

<table>
<thead>
<tr>
<th>STAI Score</th>
<th>MP Average ± std. deviation</th>
<th>FP Average ± std. deviation</th>
<th>LP Average ± std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40</td>
<td>49.317 ± 4.677</td>
<td>49.367 ± 4.7</td>
<td>58.437 ± 4.965</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>58.258 ± 2.528</td>
<td>58.915 ± 1.36</td>
<td>69.09 ± 3.287</td>
</tr>
<tr>
<td>BAI score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (24-44)</td>
<td>49.563 ± 5.195</td>
<td>49.384 ± 5.171</td>
<td>58.866 ± 5.911</td>
</tr>
<tr>
<td>Unsatisfactory (45-60)</td>
<td>50.601 ± 5.371</td>
<td>50.492 ± 5.410</td>
<td>59.487 ± 5.584</td>
</tr>
<tr>
<td>Very unsatisfactory (60+)</td>
<td>51.077 ± 5.936</td>
<td>50.92 ± 5.758</td>
<td>60.23 ± 6.526</td>
</tr>
</tbody>
</table>

Table 4 shows that BMR increases with increase in STAI & BAI scores.

Figs 4-9 show correlational analysis between BMR, STAI AND BAI (total adjustment score) stress scale in MP, FP and LP, respectively.
phases of menstrual cycle in each subject. The experiment was carried out under almost similar environmental conditions, besides maintaining basal conditions with the cooperation and understanding by the subjects. BMR was calculated for each subject at three different phases, along with assessing their stress level and psychological status and comparisons made for any variations. BMR (kcal/hour) was calculated using O₂ consumption (ml/min) corrected in different phases of menstrual cycle.

The psychological status or stress level of subjects were assessed using two sets of questionnaires, which are pre-tested structured self-administered questionnaires and scores were evaluated, in each phase of menstrual cycle.

1. Bell's Adjustment Inventory (BAI)
2. State Trait Anxiety Inventory, State Form (STAI-Form X-1)

Results and analysis
The data collected have been statistically analyzed and discussed. The correlation analysis, ANOVA and scatter plots with regression lines are developed wherever necessary. 'T' test and 'P' value are applied to find out statistical significance of changes of parameter. Conclusions are drawn based on outcome of this statistical treatment.

Discussion
The present study was undertaken to evaluate the effect of different phases of menstrual cycle on basal metabolic rate and also to find out the effect of stress, in women in Bangalore, on basal metabolic rate.

The table 1, Bar diagram (Fig 1) shows significant increase in BMR during luteal phase. The increase in BMR (and O₂ consumption) during LP can be explained as follows:

Increased levels of both estrogen and progesterone, with predominant effect of progesterone, characterize luteal phase. These hormones have varied physiological actions, which can influence metabolism. Progesterone increases the sensitivity of respiratory centers to carbon dioxide, thus causing hyperventilation, increased oxygen intake and decreased alveolar and arterial carbon dioxide.  

Progesterone has proteolytic action, increases basal body temperature and is known to increase body heat production. Solomon et al showed that secretion of Progesterone during menstrual cycle coincided with the BMR changes during the menstrual cycle.

The rise in metabolic rate during LP can also be due to increased food intake during LP as shown by Dalvit and Barz et al. There is also increase in salt preference during LP of menstrual cycle, which might be associated with raised progesterone level.

Studies also have shown that the plasma level of magnesium alters throughout the cycle with increased levels during LP, which might be one of the reasons for rise in BMR during LP.

Danielle Day et al suggested that sex hormones may influence Resting Energy Expenditure (REE) and O₂ uptake via sympathetic nervous system mediated mechanism and that sex hormone suppression decreases REE. They found the SNS support of REE to be greater in mid luteal phase when estrogen and
progesterone are elevated, than during suppression by GnRH antagonist treatment.

This finding of increase in BMR (and O₂ consumption) during LP is similar to the findings of Solomon et al, Webb, Bisdee et al, Das and Jana, Meijer, Horton et al and Danielle Day et al and is not with the studies done by Frascarola, Piers et al, Weststrate, Tai and others.

The slight insignificant fall of BMR (and O₂ consumption) during FP can be explained as follows:

The FP is under the influence of estrogen. Solomon et al has suggested that estrogen does not play a dominant role in BMR phenomenon, as it fell to its lowest level during periovulatory period in their study when estrogen levels are at highest. The other reason can be low levels of plasma magnesium during FP.

### Stress Vs phases of menstrual cycle

The stress level, as assessed by STAI-State form and BAI-Student form in each phase of menstrual cycle shows no significant variations in different phases of menstrual cycle except for significant increase in STAI-State anxiety during MP (Table 2 and 3).

The increase in state anxiety (STAI) during MP can be explained as:

Some women experience premenstrual syndrome characterized by tension, fluid retention, pain, behavioral and mood changes, autonomic reactions, less concentration etc. this syndrome has both physical and psychological components. Premenstrual mood changes are thought to arise from an increased arousal of CNS, which leads to heightened sensitivity to events and situations, which may increase both positive and negative feelings. The increase in anxiety (STAI-state) during premenstrual period was shown by Golub in his study, compared to that of intermenstrum.

Brooks and others have also shown premenstrual symptoms to be more in those who presume to be in premenstrual period compared to that of intermenstrual period.

The no change in stress level during different phases as by BAI score and between FP and LP as in STAI State score can be explained as follows:

The change in the level of stress and anxiety during menstrual cycle depends on the level of stress combating hormones – cortisol and growth hormone, throughout the menstrual cycle. These hormones were shown to remain nearly same in different phases in response to psychological stress by Abplanalp and others.

The stress level also depends on the catecholamine concentrations. The study done by Danielle Day et al showed that no significant differences in Epinephrine and Nor-Epinephrine levels were found in different testing phases of the menstrual cycle.

The present study is in agreement with the findings of Golub, Abplanalp and others and Danielle Day et al and is in disagreement with findings of Beck et al, Genazzani et al, Lindheim et al and Manhem and others.

### Stress Vs metabolic rate

The stress levels of all the 40 subjects were assessed in each phase of menstrual cycle and this was compared with the BMR obtained during corresponding phases of the cycle.

The Tables 4, 5 and graphs (figs 4-9) shows increase in BMR with increase in stress score, significant with STAI and insignificant with BAI.

The increased BMR with increased stress level can be explained as follows:

Activation of the HPA axis (CRF, ACTH, and cortisol) is one of the most thoroughly characterized neuroendocrine responses to stress. The catabolic, energy mobilizing and thermogenic actions of cortisol can increase the metabolic rate. Also, maximum release of catecholamines can increase metabolic rate 30 – 80 % by virtue of the stimulatory effects of these substances on the catabolism of carbohydrates and fats.

The researches done in this field shows a significant relationship between the level of anxiety and cortisol responsivity (and metabolic rate) in response to psychological stress. Abplanalp et al in their study used an interview session as psychological stressor and found that post interview state anxiety (STAI) tended to be above median, and that both the hormone...
responsivity (cortisol and growth hormone) to psychological stress were significantly related to the level of anxiety following stressful experience.

Bphnen and others in their study showed rise in cortisol levels during continuous 4-hour of mental task. They also showed individual variations in cortisol response to be high.

The studies conducted on animals also shows increase in metabolic rate as in Hildesheimer et al study, a rise of 30% was found in guinea pigs exposed to prolonged emotional stress compared to anaesthetized group. According to McGregor and others, a large rise in energy expenditure was found despite of low levels of activity, in rats, in response to psychological stress that peaked at CS offset.

The exposure to chronic stress is also known to cause deficiency of nutrients- vitamin C, calcium, magnesium, and vitamin B₃ as adrenal cortex uses them, if not replaced. Hence additional allowance of energy may be needed in urban women exposed to stress to combat its chronic adverse effects.

**Conclusions**

The following conclusions are drawn at the end of the study.

1) The BMR (and O₂ consumption) increases during LP, which is a postovulatory phenomenon. This increase can be attributed to progesterone effect. The stress level assessed by state anxiety (STAI) shows significant increase during MP, which may be attributed to premenstrual anxiety. The BAI score did not vary significantly between phases.

2) The BMR increases with stress level (significantly with STAI and insignificantly with BAI), which may be due to catabolic and thermogenic actions of stress combating hormones.

3) As stress level remains same throughout the cycle, except for increase in state anxiety (STAI) during MP, the increase in BMR (and O₂ consumption) during LP is not due to stress factor.

4) Estimation of female sex hormones and stress hormones during different phases may reveal more facts. Estimation of these hormones could not be undertaken due to practical problems.

**References**

15. Das TK, Jana H. Basal oxygen consumption during


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Specialist: a man who knows more and more about less and less

William J Mayo