Nutrition Paradox and the evolving health crisis in the State of Kerala, India

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Abstract:

The health status of the State of Kerala, India, was hailed as the best example of 'good health at low cost', in the late 1980s. Currently, Kerala is experiencing a high burden of non communicable diseases at younger age, and is currently the diabetic capital for India, with static levels of childhood stunting (25%). This double burden of disorders of under-nutrition and over-nutrition in the society, 'the nutrition paradox', in Kerala could be the harbinger of what is going to happen in India and the rest of the developing world. The present review aims to highlight the vicious cycle of low birth weight, over-nutrition in childhood and adolescence, early onset risk factors in women, perpetuating low birth weight and or babies with abnormal intrauterine programming in their progeny, as the driver of this nutrition paradox and younger age escalation of non communicable disease risk factors and diseases. The two factors which make the developing countries different from the developing countries are this younger age escalation of risk factors and the inability of the anthropometric markers of body adiposity to predict the risk. Both the features can be explained by the 'sarcopenia and insulin resistance seen in abnormally programmed babies at birth' which is perpetuated in child hood and adolescence, by insulinogenic nutrition, and declining physical activity. Adolescence is the last opportunity, to build the best body composition. Attaining good lean body mass at peak adolescence especially in women is suggested as the best option to break this vicious cycle. This could be the cost effective strategy which developing countries should adopt in the wake of the United Nations High Level meeting on the prevention on non communicable diseases.

The nutrition paradox in Kerala.

The picture of an obese mother taking an undernourished child to the clinic was pictured as the nutrition paradox by Benjamin Caballero.1 The Indian State of Kerala illustrates this nutrition paradox with static prevalence of childhood under-nutrition and steady increase in obesity in women in the reproductive age group (Table 1).2,3 The nutritional status of 25% of children below the age of three years is stunted and is remaining static over the last 15 years, where as the overweight/ obesity in urban women in Kerala has reached 34% in 2006.4 Percentage of babies born with low birth weight (< 2.5kg) has increased from 17.2% (1992-93) to 24.7% (2005-6) during the same period.5,6 Low birth weight children, grow up as stunted children and have high prevalence of insulin resistance, and non communicable disease risk factors.7,8 This could be a factor in the exponential increase in the cardio-metabolic risk factors in women in the reproductive age group, seen in India.9,10 Obese mothers, maternal short stature, gestational dysglycemia and gestational hypertension result in low birth weight in the offspring.11,12 This increase in maternal (in-utero) risk factors could be the cause for increasing low birth weight babies in Kerala. It is equally important

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to note that the prevalence of Low birth weight babies are remaining static in other developing countries like Sri Lanka where the epidemiologic transition is almost in par with Kerala. 1,12,13 Similarly the state of Andhra Pradesh in India has also registered an increase in Low birth weight babies during the NFHS survey periods. 1 Low middle income countries have a heavy burden on Low birth weight children as well as non communicable diseases. 14,15 Understanding the contribution of Low birth weight and nutrition transition to this chronic disease burden is therefore crucial.14,15

Table 1: selected parameters of nutritional status in Kerala in National Family Health Surveys (NFHS).2

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>TOTAL Children &lt;3yrs (stunted %)</td>
<td>32.8</td>
<td>28</td>
<td>26.5</td>
</tr>
<tr>
<td>Children &lt;3yrs (wasted %)</td>
<td>13.7</td>
<td>13</td>
<td>15.6</td>
</tr>
<tr>
<td>Children: &lt;3yrs (underweight %)</td>
<td>22.1</td>
<td>21.7</td>
<td>21.2</td>
</tr>
<tr>
<td>Women (BMI &lt; 18.5 %) 15-49 yrs of age</td>
<td>-</td>
<td>18.7</td>
<td>12.5</td>
</tr>
<tr>
<td>Women (BMI &gt;= 25 %) 15 – 49 yrs of age</td>
<td>-</td>
<td>20.6</td>
<td>34.0</td>
</tr>
<tr>
<td>Percentage of low birth weight babies</td>
<td>17.2</td>
<td>16.4</td>
<td>24.7</td>
</tr>
</tbody>
</table>

Evolution of nutrition paradox in Kerala.

Kerala is the most advanced Indian state in epidemiologic transition. 16 This happened over a period of last 30 years in par with globalization.17 In 1960’s Kerala was the best example of a nutritionally stunted state, with lowest per-capita calorie consumption in India.18,19 The health achievements were hailed as good health at low cost, achieved because of high female literacy and good public distribution system, transformed itself over the next 30 years into a state of high morbidity due to non communicable diseases as illustrated in table 2.4,21,24 It has a heavy burden of non communicable disease risk factors, like diabetes, hypertension, dyslipidemia, obesity, alcohol tobacco consumption and physical inactivity.4 The age adjusted cardiovascular mortality in Kerala (490/Lakh) is now as high as that of Finland in 1970s.25 The driving force of this transition is best explained as insulinogenic nutrition characterized by a positive energy balance with increasing supply on one hand and declining energy needs on the other.26,27

Table 2 summarizes the documented change in calorie consumption and life style related diseases reported in various studies from Kerala.

Table 2: Per-capita increase in calorie consumption and lifestyle related diseases

<table>
<thead>
<tr>
<th>Year</th>
<th>Calorie consumptiona, b, c (Cons: Units/day) Rural Urban</th>
<th>BMI ≥ 25 in rural women as %d,e</th>
<th>DMf</th>
<th>HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-62</td>
<td>1631 1554</td>
<td>1.5/ U2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971-72</td>
<td>1610 1658</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1972-73</td>
<td>1559 1723</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1972-74</td>
<td>1534 1760</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975-79</td>
<td>1978</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>1884 2049</td>
<td>2.4/ U8.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988-93</td>
<td>2140</td>
<td>12.2 3.5 16.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993-94</td>
<td>1965 1966</td>
<td>2.4/ U8.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996-97</td>
<td>2106</td>
<td>15.8 11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-99</td>
<td>2231</td>
<td>19.5 16.3 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-06</td>
<td>2014</td>
<td>30.9/ U44.8 22/ U17.1 36.7</td>
<td></td>
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</tbody>
</table>

R stands for Rural and U for Urban and the superscript numbers denote the source of information where information is available the data denoted rural women (considered being the most disadvantaged section). Data on hypertension is non stratified. BMI: body mass index as Kg/m² DM: Diabetes mellitus, HT: hypertension.

Positive energy balance:

Kerala being a food deficient state, caught in globalization easily adopted marketed food products, like biscuits, chocolates, health drinks, colas, non vegetarian foods and alcohol.18,26,27 Per-capita alcohol consumption is highest in India. Consumption of non-vegetarian products, eggs, health drinks and marketed food products are almost double compared to the rest of Indian states.28 On an average, calorie consumption in Kerala increased by more than 500 Kcal/ person and is by far the highest change compared to the rest of the states.26,28 Kerala has the best human wealth index in India, which is double the Indian average, based on the availability of 33 domestic commodities like fridge, grinders, vacuum cleaners, washing machines, and transport vehicles.29 This has contributed to substantial decline in transported related, work related and leisure related physical activity. In the absence of direct studies on time trends in physical activity, these could be the best indicators of decline in physical activity in Kerala. This positive energy balance generated by increasing calories consumption and decline in physical activity constitutes the insulinogenic nutrition which drives the non communicable disease epidemic.27 Few cohort follow up studies in India have substantiated the contribution of epidemiologic transition to the high
prevalence of non communicable disease risk factors in India. This New Delhi Birth cohort started in 1970 followed up till date in an urban middle class population, showed evolution of metabolic syndrome in 29% of the individuals, which correlated with increase in body mass indices in adolescence onwards. Similar study from south India, observed both low birth weight and adolescent BMI predicted adult onset insulin resistance and diabetes.

This positive energy balance is maximal for Kerala women, and they are now the heaviest in India in terms of body mass indices, being next only to Delhi and Punjab. This has adversely affected women. Among the four behavioral risk factors driving the affecting the non communicable disease epidemic both tobacco use and alcohol consumption are not initiated in women in Kerala during adolescence and reproductive age group. Women in Kerala are mostly home makers, or house wives and their labor participation is one of the lowest in India. Most of the household work in Kerala is mechanized. Largest consumer of home appliances such as washing machine, grinders, and vacuum cleaners is in the state of Kerala. Further the energy cost infections, and energy cost of maintaining body temperature is lower in Kerala given the good health facilities, and tropical climate. Kerala women have the lowest fertility rates below 2 compared to > 2.5 for the rest of India, over the last two decades which contributed further saving on calorie cost of pregnancy and lactation. The cohort follow up study from New Delhi and Vellore also, women had the maximal increase in obesity.

Thus the two behavioral risk factors namely unhealthy diet and physical inactivity are the driving forces for the escalation of non communicable disease risk factors in women in Kerala and is perpetuated further by the cultural believes which have a gender dimension in Kerala. To mention a few are the concepts of big is beautiful and healthy, food should not be wasted, women should cover their body, and girls after menarche should refrain from out door activities.

Concept of big is beautiful, is illustrated by the popular actors, who make their appearance in television and cinema. Their massive figure leaves a lasting impact on Kerala people as a target they should attain, at least with their children. This leads to process of feeding small children with frequent and large food portions. Most of the marketed products and refined Indian rotti, (Paratha) are now favorite food of Kerala children. Average salt consumption in South India, is almost double the recommended daily allowance. The left over food in the Kitchen is additionally consumed by the Kerala women, because of the persistent thought that food should not be wasted. Covering the whole body in their traditional clothes is increasingly becoming popular among Kerala women, and is a major hindrance to physical activity in a tropical climate. At least 40% of body needs to be exposed to 2 hours in the sun to attain adequate blood levels of vitamin D in India. Kerala women now have very low levels of vitamin D than what is recommended. Though the academic pressure during the adolescent age group is heavy in both sexes in South India, studies have shown that girls drop more than the boys in physical activity, which could be the reflection of the socio-cultural factors.

The health status of women in Kerala

The younger age escalation of non communicable diseases in women was initially observed in hospital admission reports for myocardial infarction during a period of 20 years from 1967 to 1987. This period was associated with expansion of medical facilities, increasing population age and improved knowledge of the disease. But increase was more marked in younger age group and more in women where the female male ratio for admission declined from 23:1 to 9:1. The just completed Kerala Acute Coronary Syndrome (ACS) Registry also confirmed the same with majority of the ACS (75%) occurring before the age of 70 years, and a further decline in male female ratio for admission to 4:1. In a large community survey in Kerala, the age adjusted stroke mortality was double that in United States and Japan and the gender related decadal delay was absent. Loss of this biological delay in the onset of cardiovascular diseases in relation to globalization formed the basis of ‘Go Red for Women’ Campaign by the American Heart Association. Breast cancer prevalence in women in Kerala, as per the regional cancer registry, has increased over 6 times in the last three decades.

The epidemiologic transition in Kerala has adversely affected women's health in the reproductive age group as well. Kerala women in the reproductive age group are obese. The recent NCD survey in Kerala had a 3.7% prevalence of diabetics below the age of 30yrs. and all were women. The hypertension survey in children of Kerala had shown a significant step increase in girls in the adolescent age group, and it was above the US standards, unlike boys. Survey under the Community Intervention for Health in adolescent children showed that prevalence of hypertension in Kerala Girls is higher than boys. The younger age escalation of risk factors occurring in other sites in India shows an exponential increase in women in the reproductive age group. Gestational diabetes in South India has shown a four fold increase, from 4 to 16% form late 1990s to 2008. Polycystic ovarian disease, which is known marker for adult onset diabetes and cardiovascular disease, is now an emerging epidemic (>10%) in adolescent girls in Kerala.
The altered nutrition cycle and the genesis of early life growth perturbation:

The main factors leading to positive energy balance in women in the reproductive age group in Kerala as outlined generates a hyper insulinemic state in them, which is the fore-runner of the cardiometabolic risk factors. This was encouraged with the hope to break the vicious cycle of nutritionally stunted mother giving birth to low birth weight babies who then grow up as nutritionally stunted children and adolescents. This insulinogenic nutrition turned out to be counter productive as evidenced by the exponential increase in cardiometabolic risk factors in the women of reproductive age group in the last three decades (table 2). Though the components of positive energy balance could be universal, the people of Kerala were more susceptible to this because of the high prevalence of low birth weight and child hood stunting and the specific socio-cultural factors peculiar to women in Kerala. Low birth weight babies and stunted children have lower body water and metabolic insult of high calorie diet and postprandial changes could be higher in them.

Low birth weight babies in India are known to be sarcopenic. Low birth babies have the substrate for the genesis of non communicable disease risk factors. Similarly Low birth weight babies are insulin resistant. Women in India have 10 fold risk of developing gestational diabetes. To what extend the low birth weight children contribute to this increased risk is currently unknown, but could be substantial. Follow up of children born to diabetic mothers show an earlier development of cardiometabolic risk factors in a cohort follow up study from South India. Gestational diabetes mellitus could also increase the chances of gestational hypertension and low birth weight babies and cause a variety of growth perturbations in the offspring.

The increase in maternal obesity, gestational diabetes, and hypertension are documented factors for persistence of Low birth weight babies in Kerala. This vicious cycle can be perpetuated by a number of other micronutrient factors also. Vitamin D, B₁₂ and folic acid are now implicated by community studies. Vitamin D synthesis is 6 times lower in dark skinned people and lack of outdoor physical activity and social custom of covering the body, perpetuates this deficiency. Further women need 4 times more vitamin D during the reproductive age group; no wonder vitamin D deficiency in women is the order of 60% in women in this tropical climate. Vitamin D has a major role in the prevention diabetes and cardio-metabolic risk factors.

Though there is increasing prevalence of obesity and non communicable disease risk factors and diseases, the odds ratio for predicting the risk for overweight and abdominal girth are only modest in this population. Another population survey in Kerala also did not show the correlation between BMI and the adult onset diabetes and cancer. Development of non communicable disease risk factors at lower body mass indices is a reflection of metabolically obese normal weight individuals where sarcopenia and adiposopathy drives the metabolic abnormalities. Three patterns can be recognized in the relation between diabetes and obesity. Those with appropriate adipocyte response become obese and then become diabetic in the older age group, well illustrated by the developed world where the prevalence of obesity is above 30% with 10% of the population being diabetic. Evolution of diabetes in the reproductive age group is supposed to explain the high prevalence of diabetes and obesity in Pima Indians. Maternal dysglycemia activates the fetal pancreas, which in turn generates macrosomic babies. This early stimulation of beta cell function leads to premature beta cell failure. Such children end up in dysglycemia during their reproductive life perpetuating early onset of diabetes and macrosomic babies who then grow up as obese dysglycemic mothers. One the other hand sarcopenia and insulin resistance drives the epidemic in the developing world where in the prevalence of hypertension, and cardiovascular risk factors could precede the evolution of diabetes and morbid obesity because of the adiposopathy. This dissociation between the prevalence of hypertension and obesity is now well illustrated in developed and developing world. The younger age escalation of risk factors in the reproductive age group can perpetuate itself, to generate a vicious cycle. The early life growth perturbations, perpetuates younger age escalation of risk factors, which in turn generates a new set of children with abnormal programming as shown in figure 1. Therefore developmental origin of the adult onset diseases (DOAD) and in-utero risk factors could be a major driving force for this double burden, now noted in Kerala over the last 30 years. Obesity is the driving force for the non communicable disease epidemic in the developed world and could precede the onset of risk factors and diseases. Earlier onset of risk factors in developing countries is heralded by in utero risk factors and sarcopenia, and low birth weight. Low HDL which is a marker of hyper-insulinemia and declining physical activity is now seen in > 50% of adolescents. The younger age escalation of risk factors in women in reproductive age group has now evolved as the worst subset in perpetuating this vicious cycle.

Sarcopenic adiposity and insulin resistance of low birth weight babies and stunted children are perpetuated by lack of outdoor physical activity. Both the factors which make the developing world distinct, namely the younger age escalation of risk factors and failure of adiposity markers to predict the risk factor and diseases can be explained by the proposed new nutrition cycle (figure 1).
Old nutrition cycle \hspace{2cm} New nutrition cycle

Figure 1: the nutrition cycle old and new depicted by the dark cycles and thin arrows. The lighter circle and short arrows show the drivers and the dark arrow the final outcome.

60% of the insulin sensitivity in the body is generated by skeletal muscle, but loss of muscle mass is an unavoidable accompaniment of aging.\textsuperscript{85} The resultant insulin resistance is aggravated by the endocrine metabolic programming, endothelial dysfunction, and the insulinogenic nutrition. The most affected are the children with abnormal in-utero endocrine programming.\textsuperscript{86} Improving the lean muscle mass during child hood and adolescence is the best way to minimize the metabolic derangement and postpone the younger age onset of risk factors.\textsuperscript{25} Driving force for the current epidemic in Kerala is the energy dense nutrition and the lack of physical activity perpetuated by the heavy academic pressure and the dress code which hinders physical activity in a tropical climate. The development of metabolic risk factor in the reproductive age group further perpetuates the in utero programming maintaining the vicious cycle.

**Strategies for breaking the vicious cycle**

The behavioral changes which can favorably reduce these risk factors in the reproductive age group are to encourage outdoor physical activity and healthy diet from childhood.\textsuperscript{77} It is in this context the recent high level meeting of the United Nations General Assembly on Non Communicable diseases gains it relevance to the State of Kerala.\textsuperscript{88}

Strategies for prevention of lifestyle related diseases are well known, but needs to be targeted to tackle the components of this vicious cycle.\textsuperscript{64} The data from Kerala clearly points to the fact that women in Kerala form the early victims for the new nutrition cycle, because of the exponential increase in risk factors. Risk of Heart attack in women in the younger age group has increased at least 5 times in Kerala and diabetes at least 4 times in the last three decades.\textsuperscript{25} Adolescent women in Kerala are neither habituated to the use of tobacco nor alcohol. But by social custom, girls are forced to wear clothes covering the whole body, and to remain indoors after adolescence. Exposure of at least 40% of the body for 2 hours is needed to generate adequate vitamin D levels in adolescent children.\textsuperscript{50} This radical change in lifestyle characterized by physical inactivity which is enforced at menarche is marked by a step increment in blood pressure as noted by the survey done in children.\textsuperscript{49} Adolescent children should be relieved of the academic tension, and encouraged to take part in outdoor sports, and provided a heart healthy diet and exercise friendly dress code. Energy dense marketed foods are highly insulinogenic.\textsuperscript{26} The hyper-insulinemia generated by such foods could be worse for low birth weight babies given their sarcopenia and lower body volume.\textsuperscript{66} Frequent smaller feeds could minimize this hyper-insulinemic metabolic insult.

The process of breaking the new nutrition cycle is summarized in figure 2. Achieving the best possible body composition at peak adolescence could be the best way to postpone the early onset of cardio-metabolic risk factors in Kerala. The Go red for women campaign for women initiated by the American Heart Association and the World Heart Federation seems to be most relevant for Kerala.\textsuperscript{39} Energy dense nutrition can not be a universal prescription for malnutrition. It needs to be tailored to induce proportionate body growth and composition. The Vitruvian man outlined by da Vinci centuries ago could represent that idealism.\textsuperscript{10}

Figure 2: Line diagram to disrupt the new nutrition cycle. Reducing the energy dense food substances and improving physical activity during childhood and adolescence will ensure proportionate growth and health during reproductive age group there by avoiding the abnormal in-utero programming which lays the foundation for the early age onset of cardio-metabolic risk factors.
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