Keynote Address

Identification of subjects for university research: some highlights of research experience of a public servant

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The Vice Chancellor, Members of the Senate, Distinguished, Scholars, Ladies and Gentlemen,

Introduction

May I express my deep appreciation to the Vice Chancellor for the invitation extended to me to participate at the inaugural ceremony of the Sixth Academic Session of the University.

I am delighted to see a large percentage of the academic faculty of the University present in this august assembly. My thoughts go back to the days when I served as a Council Member in the formative years of the University 1983-1996 and my humble contribution for the University's development.

This year's Academic Sessions will be another land mark event in the annals of the University to enhance the reputation already gained as a centre of excellence in providing quality education and research.

The organisers of the Sessions and the presenters of research papers will no doubt win the admiration and should be congratulated. The objective of my brief presentation is to offer some random thoughts in the identification of subjects for research and to present a brief resume of my research experience.

Identification of subjects for University research

General criteria

Subjects selected for research should be relevant and the findings to make a lasting contribution to knowledge, to depict the vision and mission of the University

A frame work for research and a data bank

Having conceptualized the ideal expected, a researcher will assess the prevailing status and adopt devices to fill the gaps by the application of research methodology. It is a discipline by itself. A blue print cannot be applied to all situations.

It will be useful to establish a research data bank to store relevant information with periodical updating to conform to a policy adopted by the Senate. Apart from over two dozen research papers published by me, information about 19000 unpublished folk verses collected by me was deposited in the National Archives, a chapter on History of Local Government written by me to the Presidential Commission report 2000, **සගරජ මාහිමියන් ගැන අප්‍රකට තොරතුරු හා විපරම් පත්‍ර (2002). සරම් මුදලිතුමාගේ පිං පොත (2008)** are a few of the many useful references suitable for inclusion in the data bank along with similar information carefully selected.

A special claim

> Matara as a region was famous as an abode of scholars in the past and the reputation which spread widely is echored in a wonderful verse, the last two lines of which I like to quote;
>
> "සව් සත පුරුදු වූ මාතර පළාත ය
> ලෙව් සත කියති උගතුන්ගේ නිකේතය"
>
> "The Matara region proficient in all arts is acclaimed as the abode of scholars by the people"

There are historical justifications for this claim. What I want to emphasize is that the University of Ruhuna as the premier educational institution in Matara has a duty to safeguard and carry forward this reputation. This is only a minor deviation, but relevant my theme.

Selection of research areas

University is endowed with the research environment and a vast scope in the selection of subjects for research. Due to time constraint I will refer to the research potential in medical education with the justification of subjects suggested and list out other topics for your consideration.

Medical Education

Allopathy and Ayurveda serve as the two main systems having their teaching programmes conducted by the medical facilities at University level. While the western medical education has made steady progress the Ayurveda system is lagging behind. A comparative study will be beneficial to both sectors - Ayurveda will be more benefited. With a long tradition in Ayurveda it has become a part of Sri Lankan culture. Such a research will among other findings be able to induce traditional practitioners to pass on secrets of the healing art retained as <u>Guru musti</u> (teachers fist).

In my opinion an induction course in the University curricula on Ayurveda in western educational system (Allopathy) and Allopathy treatment in Ayurveda will be beneficial and remove the current prejudices.

Eradication of Dengu

Dengu has taken epidemic proportions. The impact on the eradication programme is not felt. The local authorities legally responsible for community health promotion attach low priority. Field Health Officers do not tender effective technical guidance. The success depends on the fullest co-operation of the people and a commitment of the three stake holders viz local authorities, public health officers and the rate payers. The National Dengu Eradication Programme can provide the funds. A research study by the Community Health Department of the Medical Faculty will be able to recommend a result oriented programme.

My own experience in Matara to eradicate filariasis has some relevance. The incidence of micro-filariasis which was as high as 2.4 p.c. at the beginning of 1965 was brought down to .5 p.c. by the end of the same year as the Urban Council, the officers of the anti- filariasis campaign and the rate payers actively participated in the implementation of the programme drawn up by me which included a massive Sramadana to clear all the breeding places.

Further research of Acupuncture treatment

A UNU study has traced the Sri Lanka's claims as the exponents of acupuncture treatment, now widely practised. This tradition had been retained by the traditional practitioners from Kottegtoda, Dickwella. There is scope for further research in the light of information preserved in OLA mss available in the Museum Library Colombo and in recent publications.

Research inputs for Southern development

Areas of interest

1. Kingdom in history and archeology.
2. Monuments and sites in Hambantota district
3. The fame of Tissamaharama as an ancient seat of learning.
4. Agricultural productivity of Hambantota District.

Research topics relevant to the immediate environment.

Subject areas proposed;

1. Cultural renaissance of the Kandyan Period- ushered in by Ven. Welivita Saranankara Thero – (18^{th} C)
2. Ven. Karatota Dhammarama and his pupilarly succession.
3. Mudliyars of Matara.
4. Dutch Star Fort, its past, present and future.
5. Further research on Devinuwara.
6. Unpublished literary works of the Matara period. (On the lines of Dr. P.B.J. Hewawasam's doctoral thesis 1966)
7. Demolition of old building in Matara - A memory of a city

These are random thoughts for consideration.

A resume of research experience of a public servant

My records of public service spanning nearly 5 decades from 1955 is memorarable because of the many research opportunities I explored. I spent the first thirty three years as a public servant, and held many responsible positions. After my premature retirement I served as a University Academic in Postgraduate teaching for 9 years (1989-1998), Chairman of the Presidential Commission of Local Govt. Reforms (1998-1999) and later as a Consultant of the Central Bank of Sri Lanka for 5 years (2000-2004). I have won a modest reputation as a scholar public servant. My official duties provided opportunities during my early career to issue several publications connected with public functions organized by me. මාතර සාහිත්‍යංධාරා is one of the highlights.

Post Graduate studies: A Critical study of Kadaim pot

Two years after my entry into public service after my first degree as an Assistant Commissioner of local Govt. I was fortunate to complete the Master Degree of the Peradeniya University and register for the PhD which I completed under the supervision of professors Senarath Paranavitana, P.E.F. Fernando, and Ananda Kulasuriya.

The subject selected was a study of Kadaim pot – the boundary books – written on ola during the medieval period of Sri Lanka's history. Those documents apart from recording boundary demarcation during various times from Gampola to Kandy period (15 to 18 centuries) were repositories of reliable informations on political, social and religious conditions of the country. They were widely consulted by British Administrators during the British Colonial Era. They failed in their attempts to conduct a scientific study due to reasons beyond their comprehension which included the variant readings in the manuscripts. More over they could not collect a sufficient number of manuscripts for a detailed study.

I was able to collect a large number of Ola mss preserved as family heirlooms by individuals to supplement copies found by me from libraries in Sri Lanka and from the British Museum library London. My research contributions included the demarcation by fixed boundaries of the Tri Sinhale, individual Dissavas like Matale based on the Matale Kadaim pota, settlement of 24000 captives brought to the island by king Gajabahu in the 1st century B.C. and correcting some incorrect interpretation of historical events in the Kandyan Period.

Survey department supplied 6 new maps to illustrate the territorial divisions. One focal point of the demarcation of the Tri Sinhale was the confluence of Piga Oya with Mahaweli Ganga at Katugastota. Several colour photographs, line drawings were used as illustrations.

The Ministry of Cultural Affairs published my thesis in 1978, republished it in 1997 and issued all together 4000 copies for sale. This book was selected as the best research publication for the award in 1978. It was later translated and published in English under the title "Boundary Divisions of Medieval Sri Lanka" by the author. This was accepted a model thesis due to the quality of research, lay out of chapters, valuable appendix, bibliography and index.

A University normally allows 42 months of paid leave for a doctoral study. I am glad to announce that I completed my thesis without taking leave and without any out side support. But I was rewarded.

Post Doctoral Publications

Legal Environment for Local Government published for the Post Graduate Institute of Management in 1992 and Pradeshiya Sabha Seva in 1998 were research publications to serve identified needs of selected groups. While the former filled the gap in the area of legal education at Post Graduate Level, the latter was intended to educate amateur politicians elected to Pradeshiya Sabhas without a background knowledge of the working of this new type of local authority.

The second book was issued as an author publication and was accepted as the most authentic account to understand Pradeshiya Sabhas and the services expected from them. It was translated into Tamil later by the Ministry of Local Government and is now been sold in the Northern and Eastern Provinces.

Heritage publications for the Central Bank of Sri Lanka, three sets of heritage publications covering Southern, Sabaragamuwa and the Central provinces were written by me in Sinhala and in English and published by the Central Bank of Sri Lanka. These books titled "රුහුණු ප්‍රවේණිය", "Heritage of Ruhuna", "සබරගමුව ප්‍රවේණිය", "Heritage of Sabaragamuwa", "කඳුරට ප්‍රවේණිය", "Heritage of Kandurata" were complied to a format to contain research findings relating to major historical natural and cultural sites falling within the nine districts covering the three development banking areas of Ruhuna, Sabaragamuwa and Kandurata.

Complete literature survey, field visits, collection of data at seminars held, were scientifically analysed in the compilation of these heritage publications. Maps, line drawings and photographs were used as illustrations with features such as selected bibliography alphabetical index in each publication. These works appeal to historians, archeologists and to the ordinary readers. The high quality of the research findings were evaluated by the scholars and by the media. I was delighted to read some of them including a very complementary observation made by a Senior Professor of history of the University of Paradeniya who had remarked that the two heritage publications on Kandurata have even surpassed A.C. Lawrie's Gazetteer of the Central province in coverage as I had covered even Walapone which Lawrie had excluded.

ලේකම් මිටි විමර්ශනය – A Critical Examination of Secretarial Records of the Kandyan Administration is the outcome of a research lasting nearly four years (2005-2008). A research on Lekam miti which was as important as Kadaim pot had not been attempted for a scientific study.

Maha Lekam of the Kandyan Administration, second highest officer in the official hierarchy was responsible for the compilation, revision and updating of these secretarial records. Of the four types of Lekam miti identified in my study the Mahalekam was directly responsible to the King in the compilation of Kathal and Hi Lekam miti used for revenue administration. Other Lekam miti such as Dunukara lekam miti, Disa lekam miti and Maha lekam miti were compiled to meet the needs in the administration and were kept with the respective territorial divisions under the four Maha dissavas, eight Dissavas and nine Rate mahattayas.

The information arranged in the eighteen chapters and the appendix containing the text of ten Lekam miti used in the study, together with seventeen other historical records with such features as a bibliography, alphabetical index, together with maps, flags of divisions, line drawings make the research interesting.

It is important to mention that out of the 48 Lekam miti used for this research 7 were found by the author from sources other than the libraries. A highlight in this publication is the three colour map supplied by the Survey Department which will serve as a ready reckoner to understand the Kandyan kingdom which is discussed in a detail in chapter seven. Kadaim pot and Lekam miti will supplement our understanding of the Kandyan administration and the many facets connected there with. Hence the research value of these two publications.

Conclusion

Dissemination of research based knowledge should reach the decision makers and the public apart from the academic community within the University system. The formulation of the policy for the above purpose is a challenge for the dons within the University.

Eventually it will help to project the image of the University and its identity.

Let me offer my personal blessings for the success of academic and research programs of the University of Ruhuna and end my presentation invoking Saraswathie the Goddess of Learning by the recital of a Sloka containing her blessings.

Ma te dukkham Kadacit
kvacidapi samaye – pustakenakulatvam sastre vade kavitve prasaratu tava dhir mastu kuntha kadacit

May there be no unsatisfactory feelings any day any time in literary pursuits. May your wisdom expand in arts and sciences, in debate, poetic talents without any contraction of thoughts.

Thank You!

Oration of the Sixth Academic Sessions

Micronutrient deficiencies in at-risk populations: what should be our focus?

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Nutrition plays an important role in human growth and development. Nutritional status during infancy and adolescence is important as the health outcomes later in life are strongly influenced by growth during these periods. Malnutrition is a condition that develops when the body does not get appropriate amounts of macro and micronutrients that are needed for growth and maintenance of healthy tissues and organ functions due to poor eating habits or lack of food. Macronutrients (protein, carbohydrate, fat and calcium) are required by the body in relatively large amounts to provide with energy for its daily tasks and to repair damaged cells and tissues. In contrast, the micronutrients (vitamins, trace elements and phytochemicals) are required by the body in smaller amounts. These are responsible for various physiological functions, but cannot be synthesised in sufficient quantities by the body. As such, an adequate supply of micronutrients through food is required to promote better nutrition.

Inadequate nutrition exerts its most detrimental impact not only in infancy and childhood but also in prepubertal growth as well. Nutrient needs are increased throughout childhood, reflecting continuing growth of all body systems. However, adolescence requires the greatest total energy intake of all the life stages (1), as the body undergoes a highly metabolically active state. During adolescence, males begin to increase their energy intake well above that of most females. Inadequate intake of nutrients and energy during this time can potentially impede growth and delay sexual maturation. Supplementation programmes and interventions provided before puberty will have the most beneficial growth and development outcomes (2).

Micronutrient malnutrition, a term commonly used to refer to vitamin and trace mineral deficiency diseases, is a widespread problem throughout the world affecting especially young children and women of reproductive age, with severe health and economic consequences (3). Diseases related to Vitamin A deficiency, iron deficiency anaemia (IDA) and iodine deficiency are among the most common forms of micronutrient malnutrition. Two billion people are estimated to suffer from low iron storage, 1.9 billion from low iodine levels and 250 million preschool children from vitamin A deficiency (4). Evidence is growing that deficiency of other micronutrients such as vitamins C, D, thiamin, niacin, riboflavin, folate, and minerals like calcium, selenium and zinc can also significantly affect population health (4).

Micronutrient deficiency alters the physiological functions before they are manifested clinically. Subclinical forms of iron, iodine and vitamin A deficiencies that occur during foetal and early post-natal periods affect the individual's physical growth and immunological and cognitive maturation in ways that may be irreversible (5). Thus, micronutrient deficiencies can have an immense impact on the learning ability of children and adolescents causing a vast loss of human potential and productivity leading to a vicious cycle of malnutrition, underdevelopment and poverty affecting already underprivileged groups.

Today, epidemiology of micronutrient deficiencies is not evaluated per individual micronutrient; neither is prevention and treatment strategies developed. This is because deficiencies regularly occur in combinations of micronutrients. The low-income diets based on cereals and legumes have little or no fruits, vegetables and animal source foods, and thus are especially low in absorbable iron and vitamin A. Low iron bioavailability is a major factor in the etiology of iron deficiency (6) and, low dietary retinol, low intake and poor bioavailability of pro-vitamin A carotinoids are likewise the major factors in the etiology of vitamin A deficiency (7). Plant based diets are also low in zinc, riboflavin, vitamin B_6 and B_{12} and lack of fruits would cause shortage in vitamin C and folate (8). Deficiencies of all these micronutrients could coexist with deficiencies of iodine and selenium (depending on the locality) (9). As multiple micronutrient deficiencies co-exist, it is therefore possible that a deficiency of one micronutrient influences the etiology, prevention and treatment of another micronutrient deficiency (9).

Some micronutrients have mutually beneficial or synergistic effects, i.e. providing more of one micronutrient will improve the status/ metabolism of another, while some micronutrients interact negatively with one another, i.e. providing too much of one micronutrient will impair the status of another micronutrient. Thus, designing and interpreting programmes to combat micronutrient deficiencies requires a thorough knowledge of micronutrient interactions (10).

Generally zinc and iron show a mutually negative interaction pattern. This relationship was first evaluated in humans by Soloman and Jacob (11) looking at the effect of oral iron on zinc absorption. They found that iron lowered the zinc uptake (measured in plasma) at a molar ratio of 2:1. It was thought that these two elements would compete against each other only when given in water solution and possibly not when food is present. This was confirmed by Sandstrom *et al* (12), who studied zinc absorption at physiological intakes. These studies strongly suggested that iron and zinc may compete when given as supplements, but not when given as food fortificants (10). In a supplementation study among Indonesian infants (13) it has been shown that giving iron alone significantly reduced the iron deficiency and prevalence of anaemia while giving zinc alone reduced the zinc deficiency. Iron supplementation did not negatively affect plasma zinc concentrations and zinc supplementation did not increase the prevalence of anaemia. However, iron supplementation, when combined with zinc, was shown to be less effective in reducing the prevalence of anaemia. A negative effect of zinc on iron absorption has also been shown in another study among infants of 6-12 months (14).

Adolescence – at risk population

Little is known about growth of adolescents in both developed and developing countries, compared to younger and older age groups. One reason for this gap in knowledge is the lack of an internationally agreed method to interpret the complications in anthropometric indices arising out of puberty-related growth spurt. Thus there are pressing research needs, notably to develop adolescent-specific anthropometric reference data, for better documentation of adolescents' nutritional status, and to assess the cost-effectiveness of multi-nutrient dietary improvements (or supplements).

Is Micronutrient deficiency among adolescence a problem in Sri Lanka?

As in the other countries in Asia, Sri Lanka faces widespread health and nutrition problems. Micronutrient deficiencies strike both children and women and surveys showed that deficiencies in iron, iodine, and vitamin A are the most damaging forms (15). Anaemia is a major public health problem in Sri Lanka, affecting all segments of the population and contributing to increased morbidity and mortality rates. Anaemia prevalence in 1973 was estimated as 38% among men, 68% among women, 70% among primary schoolchildren, and 52% among preschool children (16). The prevalence was 60% among pregnant women in 1988–89. The next national survey on prevalence of anaemia (third national nutrition and health survey) conducted between 1994 and 1995, reported (in 1996) that anaemia prevalence was 45% among preschool children, 58% among children between 5-11 years, 36% among adolescents (17). Among women, 45% of non-pregnant and 39% of pregnant women were anaemic. In 1999, Food and Agricultural Organization (FAO) reported that the prevalence of anaemia was 40 percent among pregnant women and 45 percent among children <5yrs of age (18). In 2001 the prevalence was estimated as 32% among non-pregnant women, 30% among pregnant women, 22% among adolescents, 21% among primary school children, and 30% among preschool children (19).

There have been no reports on zinc status in the Sri Lankan school children until we undertook the present study. However, folic acid status among adolescent girls and non-pregnant, non-lactating young women in Colombo has been studied and published recently (20), which showed that 43% had low serum folic acid concentrations and 47% had low iron stores with an anaemia prevalence of 12.9 %.

The research programme

In this presentation I will discuss the findings of my research programme on 'assessment of growth, dietary intake and micronutrient status during adolescence and efficacy of multiple-micronutrient supplementation'. Schools are usually the most efficient channel for delivering health interventions to adolescents and school-based surveys and are most often used to assess the need for different interventions. As such, a school based sample for these investigations was selected.

Study I: Assessment of growth, dietary intake and micronutrient status during adolescence

Selection of sample

The study population consisted of school children between ages 12 and 16 years attending schools in the Galle District. However, in order to facilitate constant monitoring over the long study period without incurring huge transportation costs, public schools attached to Galle city (zonal) education office were considered in selecting the subjects using multi stage cluster sampling technique. These schools serve mainly the middle class families and a lesser number from the upper and lower classes. The schools were first stratified according to the students' gender: female, male and coeducational schools. Next, two coeducational schools and one female school were randomly selected. Since the age is strongly correlated with the school classes in Sri Lanka the students were stratified based on their class. All the students from the selected classes were considered eligible for the study. This sampling procedure yielded a total of 1150 students, who were registered in the 43 selected classes. The Principals of the selected schools and the class teachers were briefed about the research project and then the subjects and their parents were informed by a letter which described in detail the procedures involved in the study. Nine hundred and forty five (945) children who presented written consent from their parents were enrolled in the study.

The study sample (n= 945) was sufficient to detect a prevalence of 50% of any micronutrient deficiency with a confidence interval of ± 5%, and a power of 90%. Calculation of sample size was based on the average weight and standard deviation (SD) of adolescent females reported in a previous study (21). The total sample required was 890 with an expected standard deviation from the population mean of 1.0 Kg for measuring the growth without affecting the measurements of dietary intake.

Experimental techniques

All the children (n=945) were subjected to a comprehensive physical examination, including measurements of body weight and height. Height was obtained using a portable stadiometer with a precision of ±0.1 cm with readability upto 200 cm. Each child was measured barefooted, standing up straight with head in the Frankfurt plane, and gentle upward pressure was applied under the mastoid processes by the measurer after the head-piece had been brought into contact with the occiput. Weight was measured using a portable beam balance with non-detachable weights (Bauman, Germany) with a precision of ±0.1kg and readability upto 100 Kg. Each child was measured wearing the school uniform but without shoes. Both instruments were checked for zero error before commencing each anthropometric session, and all the measurements were obtained over a period of two weeks. Their general health status were also documented.

The dietary survey was carried out on all subjects using 24-hour recall method on three random schooling days (from Tuesday to Thursday at the school) by trained interviewers, using a pre-tested questionnaire. The questionnaire was also used to seek information on age and sex of the subjects and, among females, the date of menarche. For assessment of micronutrient status, a sample of venous blood (5mL) was obtained from each subject, which was assessed for Hb, and serum levels of zinc, folate and ferritin.

Laboratory Analysis

The concentration of Hb in venous blood was measured by the photometric cyanmethaemoglobin method. To measure serum ferritin (SF) and folate, a solid phase immunoradiometricassay was employed. Serum zinc determination was done using flame atomic absorption spectrophotometry.

Statistical analysis

The 1978 NCHS/WHO growth reference curves were used from Epi-info version 3.0 (2003) to generate Z scores of weight-for-age (underweight indicators), and height-for-age (stunting indicators). BMI for age Z-score was used as an indicator to define wasting in this age group. Z score of -2.0 was defined as the cut-off value for above indicators (22). Percentile curves of Center for Disease Control (CDC) 2000 for BMI of males and females (2-20 years of age) were used to define obesity and thinness. Those who were above the 85^{th} percentile were defined as obese below 5^{th} percentile was the cut-off for thinness. Because the distributions of Hb, serum zinc and SF values were skewed; they were log transformed in all calculations. For presentation, these variables were transformed back to the original scale and presented as mean±SD. Anaemia was defined as a Hb concentration <120g/L, depleted iron stores as SF <12μg/l, IDA as anaemia with SF ≤ 30μg/L. Subjects with SF concentration >250μg/L were further investigated for sub-clinical infections. Folate deficiency was defined as serum folate concentration ≤ 6.80nmol/L (≤ 3.0ng/L), and zinc deficiency as serum zinc concentration ≤ 9.95 μmol/L (≤ 650μg/L).

Results

Sample characteristics

Of the total sample of 945 school children there were 361 (38.2%) males and 584 (61.8%) females. Even though the details of their socio-economic background were not documented, it was observed that children not only from Galle city zone but also from suburbs and rural areas also attended the randomly selected schools for the study. Therefore it was assumed that the sample will represent all communities and all socio-economic levels in Galle. Out of 584 females, 260 (44.52%) had not attained menarche by the time the data collection was completed. The mean age at menarche was 13.9±1.3 years in the study sample.

Growth patterns

The mean weight, height and BMI of the study population are tabulated in Table 1 with their mean z-scores on weight-for-age (WA) and height-for-age (HA) based on the NCHS median and mean z-scores on BMI-for-age generated from CDC 2000.

Prevalence of malnutrition

The overall prevalence of wasting was 31.2%, affecting 43.2% of males and 23.8% females (Table 2). The prevalence of thinness among males remained over 50.0% except at the age of 15 years (prevalence was 45.5%) with overall figure of 57.6% (p=0.143). However, the prevalence of thinness among females was significantly dropped from 50.5% at 12 years to 30.1% at 16 years of age (p<0.001) with over all prevalence of 37.7%. Obesity was prevalent in 1.4 % of males and 2.4% of females. The prevalence of obesity was negligible in comparison to the prevalence of underweight, wasting and thinness of the sample studied. A recent national survey on adolescent nutritional problems in Sri Lanka (23) revealed that the prevalence rates of underweight, stunting and overweight were 47.2%, 28.5% and 2.2%, respectively. It appears that except for stunting (18.4% in this study) rates of underweight (=wasting) and overweight (=obesity) seem to be similar to the national survey (23). Although this study sample was drawn from children of 12-16 years of age, the data of the national survey was obtained from adolescents of 10-15 years of age. Therefore, both studies do not represent the adolescent population defined by WHO as subjects from 10 through 19 years of age (24).

Dietary Intake

Energy and macronutrient intake

In Table 3, the median energy intake is presented by sex with other dietary constituents. The dietary intake of energy was 5.36 MJ for males and 5.37MJ for females. Similarly there was no significant difference in protein intake between sexes. Energy and protein intakes by both sexes increased with age and mean intakes of these nutrients show exponential increases with age.

Table 1. Anthropometric indices of the total sample

Variable	Males Mean	SD	Females mean	SD	All mean	SD	p-value
N	361	5	84		945		
Weight (kg)	36.7	9.0	37.9	8.1	37.4	8.5	0.037
Height (cm)	150.9	10.8	149.3	7.8	149.9	9.1	0.012
BMI	15.9	2.3	16.9	2.6	16.5	2.5	<0.001
WAZ[2]	-1.84		-1.53		-1.65		<0.001
HAZ[3]	-1.15		-1.14		-1.14		0.865
BMIZ[4]	-1.80		-1.18		-1.42		<0.001

[2] WAZ - weight-for-age z-score [3]HAZ - height-for-age z-score derived from Epi-info version 3.0 (2003) of the 1978 CDC/WHO growth reference curves.
[4] BMIZ - BMI-for-age z-score derived from Epi-info version 3.0 (2003) of the CDC 2000 growth reference curves.

Dietary micronutrient Intake

This is the first time that the dietary micronutrient (iron and zinc) intake in this age group was studied in Sri Lanka. Even though dietary iron intake was satisfactory (median of 11.3 mg per day) zinc intake was too low (median of 0.5mg/day). Zinc intake was higher in males (Table 3) than in females (P< 0.001).

The non-consecutive three day 24-hour dietary recall to collect information on dietary intake was used in this age group. In the national survey on nutritional problems among adolescents (23), eating pattern and food consumption during the previous week were studied using a food frequency questionnaire in a representative sub sample. It was revealed that rice was the most popular among children than other cereals, including bread and yams. All the children had consumed rice daily and more than 90% of them consumed rice more than one serving per day.

Energy and macronutrient intake

Sixty two percent (62%; n=452) of the subjects did not have breakfast before attending school. Since children were the only informants, it is also likely that they under-reported the dietary intake. Since they do not prepare the food, even if they remember the dishes consumed, it is likely that they do not state clearly the key ingredients. In the present survey we did not reject under-reported subjects for several reasons. As it has been reported elsewhere (27) if over-reporting is also assumed to be present in the results, the exclusion of presumed under-reporters can cause the results to be biased.

Another reason is that the calculation of a cut-off value for rejection requires specific information about the physical activity level of the adolescents, which is not available in this study. Horwath (28) reported that 13% of the young female students he studied followed a weight-reduction diet at the time they were recording their intake. As such, it is likely that at any time a proportion of the subjects are voluntarily restricting their intake, and therefore they are providing records that reflect their low caloric intake. Differences in energy intake also seem to be accompanied by differences in the distribution of macronutrients.

In the present study, it appears that, both dietary macro (energy and protein) and micro (iron and zinc) nutrient intakes by both sexes increase exponentially with age. However, for the study population as a whole, the dietary intake of the macro and micro nutrients is around 50-60% of the recommended daily allowances (RDA). Growth was strongly correlated with dietary intake of calories, protein and iron, but not with zinc intake in our study. This study documented that nearly two third of study subjects did not have their breakfast before attending school which could be a reason for low energy intake. The learning abilities, mental alertness and cognitive powers of young children are said to be significantly affected when optimum protein, calorie and micronutrient requirements are not met (29). Therefore a nutrition intervention programme to prevent such adverse effects in school children is essential to ensure a healthy, mentally alert population that is equipped with intellectual abilities. It is such a population that can provide the required human resource for progress and development in our country.

Table 2. Percentage prevalence of nutritional deficiencies (underweight, stunting, wasting, thinness and obesity) of the study population

Characteristic	Sex	Age (years)					all ages	p-value
		12	13	14	15	16		
Underweight[2]	Male	43.4	46.7	39.8	33.3	46.4	42.1	
	Female	41.2	27.6	24.0	36.0	39.1	33.4	
	Total	42.0	35.1	30.2	34.9	47.1	36.7	*0.004*
Stunting[3]	Male	13.2	17.3	19.3	13.6	32.1	19.9	
	Female	10.3	13.8	16.3	25.6	21.2	17.5	
	Total	11.3	15.2	17.5	20.4	25.0	18.4	*0.410*
Wasting[4]	Male	47.2	46.7	41.0	36.4	45.2	43.2	
	Female	37.1	21.6	19.4	23.3	21.2	23.8	
	Total	40.7	31.4	32.5	28.9	29.6	31.2	*<0.001*
Thinness[5]	Male	54.7	58.7	53.0	45.5	59.5	54.3	
	Female	50.5	31.0	26.5	33.7	30.1	33.2	
	Total	52.0	41.9	35.8	38.8	40.4	41.3	*<0.001*
Obesity[6]	Male	--	--	4.8	1.5	--	1.4	
	Female	--	2.5	3.9	3.5	1.9	2.4	
	Total		--	1.6	4.2	2.6	1.3	*2.00*

[1] 2-sample t-test comparing males and females [2] defined as WAZ score >-2.0 [3] defined as HAZ score >-2.0 [4] defined as BMIZ score >-2.0 [5] defined as less than 5th centile of BMI [6] defined as more than 85th centile of BMI

Table 3. Dietary Intake (median±Interquartile range) of the study sample

Variable	Dietary Intake among			p-value
	Males (n=233)	Females (n=496)	All (n=729)	
Energy intake (MJ)	5.36±0.68	5.37±0.72	5.36±0.71	0.666
Protein Intake (g)	28.70±3.50	28.80±3.00	28.80±3.15	0.948
Dietary iron (mg)	11.40±1.30	11.30±1.30	11.30±1.30	0.649
Dietary zinc (mg)	0.66±0.98	0.37±0.74	0.49±0.87	<0.001

[1] 2-sample t-test comparing males and females

Table 4. Micronutrient status of the study population[1]

Variable	Males	Females	Total	p-value
Haemoglobin (g/L)	119.62±14.8	114.64±13.8	116.57±11.3	<0.001
Serum Ferritin (μg/L)[2]	35.21±4.69	28.65±5.18	29.41±1.77	<0.001
Serum Folate (nmol/L)	5.91±0.63	5.90±0.87	5.86±2.13	0.806
Serum Zinc (μmol/L)	9.64±0.72	8.93±0.70	8.60±3.35	0.004

[1] 2-sample t-test comparing males and females [2]results expressed in geometric mean ±variance

Blood and serum assessment for Micronutrients

Haemoglobin status and prevalence of anaemia

The mean concentration of Hb in males (119.62±14.8g/L was significantly higher (p< 0.001) than in females (114.64±13.8g/L, Table 4). In the sample studied the prevalence of anaemia among males and females were 49.6% and 58.0% respectively and the difference was significant (p <0.001). Overall 54.8% of the children were anaemic, of which 1.6% had severe anaemia (Hb <80g/L). However, the age correlated positively with Hb concentrations (r= 0.1; p <0.001).

Serum ferritin and iron deficiency anaemia

Males had a significantly higher (p<0.001) geometric mean (35.21±4.69μg/L) of SF concentration when compared with females (28.65±5.18μg/L) in females (Table 4). SF concentration with age has shown a negative trend (r= –0.1; p <0.001) in both sexes. Depleted iron stores were observed in 7.0% of males and 11.2% of females in this study population (Table 5) but these changes were not statistically significant (p=0.45).

Serum zinc and zinc deficiency

Males had mean serum zinc level of 9.64μmol/L, where as females had 8.93μmol/L (Table 4). When a cut-off of 9.95μmol/L was used zinc deficiency was seen in 51.5% of males and 58.3% of females.

Serum folate and folate deficiency

There was no difference (p=0.81) between females (5.90±0.87nmol/L) and males (5.91±0.63nmol/L) in the serum folate status (Table 4). Folate deficiency was found in 54.6% of males and 52.5% of females (p=0.81). The age correlated negatively with serum folate concentrations (r= –0.1; p <0.001).

Concurrent micronutrient deficiency

The importance of concurrent micronutrient deficiencies in developing countries is now recognized; their existence is often appreciated after the disappointing responses to single micronutrient supplementation programmes (30). Furthermore, focusing on several micronutrients instead of just one is important not only for treating micronutrient deficiencies but also for screening and identifying high risk groups. Iron deficient subjects in our study had a 1.8-fold risk (CI, 1.1-3.0) of being folate deficient and a 1.7-fold risk (CI, 1.2-2.6) of being zinc deficient. Zinc deficient subjects had a 1.3-fold risk (CI, 1.0-1.8) of being iron deficient and a 1.2-fold risk (CI, 0.9-1.7) of being folate deficient. 20.5% and 24.0% of zinc deficient individuals were also deficient in iron and folate respectively. 16.0% of subjects were deficient in both iron and folate.

Conclusions

The main aim of this study programme was to determine the nutritional deficiencies in at-risk population such as school children in Sri Lanka and to focus on most appropriate strategies which can potentially be used to minimize such deficiency status. Galle was used for this purpose as it has all characteristics that determine a normal cross-section of a Sri Lankan population.

Majority of children consumed a diet deficient in energy. The diet was also poor in nutrient density and cannot meet their micronutrient requirements. This, though not completely unexpected, is a matter of serious concern and need to be noted at the highest national levels. Breakfast is an important meal in the diet and plays a beneficial role in the performance of school children. However, 62% of children usually skipped breakfast before going to school. Results of this survey provide important information on planning national intervention programmes. Therefore, an awareness programme on food diversity, eating practices and adverse effects of inadequate intake of important nutrients should be created among school children. Some of these programmes can be best implemented if they are included in the curriculum as part of 'health and well-being'.

My studies had established that a wider range of important micronutrient deficiencies exist and more significantly, there are interactions between them that need to be fully understood. This may be one key to national development. Considering the information that I have elicited from study I, an intervention was planned planned to be conducted among school children to supplement with both iron and zinc.

Study II efficacy of multiple-micronutrient supplementation

Strategies for Controlling Micronutrient Deficiencies

The principles for effective control of micronutrient deficiencies are covered authoritatively and in detail in a number of recent publications. The Institute of Medicine (IOM) of the US National Academy of Sciences (NAS) recently published the results of extensive consultations and in associated background papers (31). An expert consultation on "Strategies to Accelerate Programs to Reduce Iron Deficiency" was convened and broad consensus on key issues (32) was provided.

A conventional framework of "supplementation, fortification, food-based approaches, and public health control measures", has been laid out. Within the framework, supplementation and fortification can be universal or targeted; and "food-based approaches" refer to nutrition education, food production, and "food-to-food fortification", meaning mixing of staple food stuffs at the household level. The "public health control measures" (as formulated in the NAS report) are immunization, parasite control, water sanitation, control of diarrhoeal diseases and acute respiratory infections, and personal sanitation / hygiene. In the long run, fortification is likely to play a central role in the control of most micronutrient deficiencies in Asia, as it has already been established in the developed world. But a mix of strategies will be needed to reach this stage.

A medium-term strategy should be to build on current programmes and experience in supplementation, fortification, and food-based approaches. It should include research in a number of areas, including the effects of the deficiencies and their extent and effective control. Research of this nature will almost certainly establish a wider range of important micronutrient deficiencies, and, crucially, the interactions between them. This may be one key to progress. A better focus should be on multiple micronutrient fortification and supplementation, and this should be a central feature of a new strategy. Setting policies and designing programmes for addressing micronutrient deficiencies need detailed and extensive information. With the current information generated in this study I have planned and conducted an iron and zinc intervention trial to improve the nutritional status of the school children in Galle.

Selection of Sample

The same school children were invited to participate for a micronutrient supplementation trial (over a period of nine months) to assess the efficacy of supplements and study the interaction of micronutrients (iron and zinc). 845 children received parental consent for the supplementation study. This was a placebo controlled double blind randomized trial (of 4 groups) and the required sample size was calculated to be 180 per group to demonstrate a 15% reduction in the prevalence of anaemia within the study duration. The value of α was taken as 0.05 (95% confidence) and that of β as 0.1 (90% power) for these calculations. To allow for approximately a 25% attrition rate, we needed 200 children per group. Of the 845 children only 821 met the following inclusion criteria:

1. Haemoglobin (Hb) level $\geqslant$ 80.0 g/L. Those who had Hb below this level (n=5) were severely anaemic and were referred for further investigations and treatment.
2. Children not suffering from inflammatory conditions, acute or chronic diseases and on any drug treatment other than paracetamol or antihistamines for minor ailments. (4 were excluded with chronic diseases and on treatment.)

3. Currently not consuming nutrient supplements. (15 children excluded from the study.)

Experimental technique

All the children eligible to participate in the study (n=821) were randomized into one of four groups (iron only; zinc only; iron and zinc combined; and placebo) after stratification using their classroom assignment. A letter was given to their family physicians requesting notification if they wished to prescribe additional micronutrient supplements during the study period. All were treated for parasites by giving mebendazole 500mg as a single oral dose approximately two weeks prior to commencement of the study and six months after.

The composition of micronutrient supplement used in the study was decided on the daily recommended allowances published by the WHO (33) for zinc (14mg) and global guidelines for iron supplementation (50mg) provided by the INACG (34). Using these recommendations a ratio of iron to zinc of 3.6:1 was obtained. The capsules were manufactured by Astron Limited (a leading private Pharmaceutical Company in Sri Lanka) under the special approval granted by the Director, Drug Regulation Authority of the Ministry of Health, Sri Lanka.

Raw materials used were ferrous fumarate and zinc sulfate monohydrate with the filling agents' anhydrous lactate and magnesium stearate as lubricating agent. These food grade raw materials are being used for capsule preparation by Astron Limited as well as the Sri Lanka Pharmaceutical Manufacturing Corporation (SPMC). Four different types of capsules were made but each with identical capsule covers. The composition of capsules was as follows;

Iron only - ferrous fumarate (76.05mg), lactose anhydrous (278.22mg), magnesium stearate (5.7mg)

Zinc only - zinc sulfate monohydrate (19.22mg), lactose anhydrous (335.06mg), magnesium stearate (5.71mg)

Iron and zinc - ferrous fumarate (76.05mg), zinc sulfate monohydrate (19.18mg), lactose anhydrous (249.0mg), magnesium stearate (5.71mg)

Placebo - lactose anhydrous (354.29mg), magnesium stearate (5.71mg)

Average filling weight - 423.0mg

Further, the mineral content in capsules was tested at the Chemical and Environmental Division of the Industrial Technology Institute, Colombo using flame atomic absorption spectrometry (f-AAS). The quality and moisture content control were conducted at the investigational laboratory of Gamma Pharmaceuticals, Sri Lanka. The supplementation was initiated by giving two capsules daily to each subject through the class teacher, to be consumed at the time the daily attendance is marked. Further, the subjects were instructed not to have a meal for about two hours after the capsules were taken. Teachers were instructed to monitor the consumption of capsules by all the subjects. A double blind technique was used where neither the subjects nor their teachers/investigators knew the contents of the capsules. The investigator supplied the capsules bi-weekly to the class teachers who were asked to sign on a given checklist while issuing capsules to the study subjects. The records were randomly checked by the investigator.

At the end of the first 10 weeks of supplementation, there was a long school vacation (7 weeks) for the children of female school, while the other two schools had shorter (3 weeks) vacations. The parents' compliance and motivation were found satisfactory as we were able to continue supplementation daily during the vacation as well. The parents were issued the capsules to be given to children two hours after the breakfast during the vacation.

An interim assessment was performed after 18 weeks of supplementation. Weights and heights were recorded, a brief medical examination was conducted and 3ml of venous blood was drawn for the determination of Hb, serum zinc and ferritin. Supplementation was continued for another 18 weeks (9 months in all) before the final assessment, a procedure similar to that of the interim assessment. The experimental design of the study is illustrated in Figure 1.

Statistical analysis

Differences between groups in anthropometric indices and concentration of biochemical parameters at initial, interim and post-intervention stages in the supplementation trial were investigated using multivariate analysis of variance (MANOVA) repeated-measures design with supplement type as a between-subject factor (four groups) and treatment effect (baseline compared with interim/ final) as a within-subject factor. Baseline values for weight-for-age z score (in 2 classifications: <-2.0 and ≥ -2.0), height-for-age z score (in 2 classifications: <-2.0 and ≥ -2.0), Hb (in 2 classifications: <120.0 and ≥120.0g/L), serum zinc concentration (in 2 classifications: <9.95 and ≥ 9.95μmol/L), SF concentration (in 2 classifications: <30.0 and ≥ 30.0μg/L) were also included in the analysis as between-subject factors to correct for their possible confounding influence on the change in weight, height, Hb, serum zinc and SF. The chi-square test was used to compare prevalences of deficiencies between groups. Pearson correlation coefficients were used to investigate the relationship between micronutrients status and anthropometry with treatment effect. P-values <0.05 were considered significant. Data were analyzed using SPSS version 10.0 (SPSS Inc., Chicago).

Results

Effect of supplementation on anthropometry

Following 18 weeks of supplementation (interim analysis) all four groups had a significant within-group improvement (p<0.001) in anthropometry (i.e., weight, height, BMI, WAZ and HAZ) from their respective baseline values. Combine supplemented group had shown a significant improvement (p=0.01) in mean height measurement over the controlled placebo group (Table 5). There was no difference in the supplementary effect on mean weight improvement during this period between groups. The BMI was significantly different in the combine supplemented group than in the other three intervention groups at baseline (p<0.05), at six months (p=0.01) after the intervention. Weight-for-age z score was also significantly different over the other groups in the combine supplemented group at baseline (p<0.05) and at interim analysis (p=0.01) as well (Table 5).

With nine months of supplementation (final assessment), all four groups had a significant within-group improvement (p<0.001) in anthropometry from their respective values at interim analysis. There was no difference in improving weight and height of the supplemented groups when compared with the placebo group. The difference in height shown by the combine supplemented group at interim analysis disappeared. However, the difference shown by combine supplemented group in BMI over the other three intervention groups persisted (p=0.02).

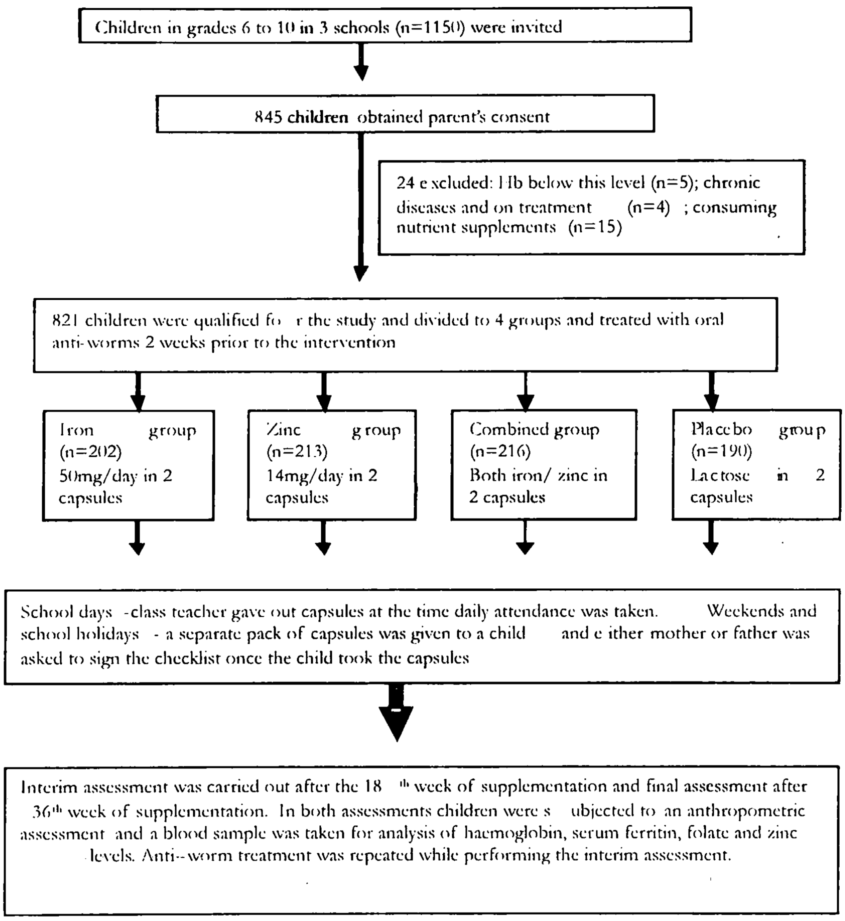

Figure 1. Study designs of the assessment of growth, dietary intake and micronutrient status in adolescence and efficacy of multiple-micronutrient supplementation

Mean change in the placebo group was 0.53Kg and 0.73cm during the period of intervention. The iron alone group had 0.89Kg gain in weight and 1.0cm in height respectively. The zinc alone group had 2.27Kg gain in weight and 2.37cm gain in height whereas combined supplementation had achieved 1.52Kg and 1.63cm gain in weight and height respectively. The zinc only supplemented group had significant improvement (p=0.01) in WAZ when compared with the placebo group. The increase in HAZ in the zinc supplemented groups (zinc only, p=0.003; combine supplemented, p=0.01) were significant when compared with the placebo group. After correcting for confounding effects of age and the respective baseline values of weight, height and BMI, the zinc supplemented groups had the best anthropometric improvement.

Effect of supplementation on biochemical indices

Mineral supplementation has shown a positive effect in improving Hb status of the study subjects. Three intervention groups (iron, zinc and combine supplemented groups) had significant improvements at both assessments when compared with the placebo group (Table 6). The iron only group had gained the highest increase in Hb at the interim (18.19g/L) and the final assessments (31.10g/L) followed by combine supplementation (11.02 and 19.47g/L respectively). Zinc only group also had a significant improvement over the placebo group during the nine months of intervention (12.89g/L improvement; p =0.02).

The prevalence of anaemia was found to be 70.3% in the iron group at baseline; this was reduced to 14.5% after 4.5 months of supplementation and to zero percent after the intervention. In the combine supplemented group anaemia prevalence was reduced from 64.8% to 19.3% at the interim assessment and finally it reached to 0.6%. The zinc supplemented group also had a reduction from the initial prevalence of 52.6% (26.1% at the interim and 9.1% at final assessment) but the placebo group had shown only a slight reduction to 34.3% from the initial figure of 38.9% (Figure 2).

Table 5. Effect on anthropometry with micronutrient supplementation[1]

Group	n	Iron	n	Zinc	n	Combined	n	Placebo
Weight (Kg)								
Baseline	202	37.35 (7.45)	213	37.11 (8.42)	216	38.42 (8.91)	190	37.23 (8.77)
Interim	193	37.93 (7.40)	201	38.18 (8.48)	199	38.59 (8.57)	181	37.60 (8.83)
Final	161	38.31 (7.45)	166	39.36 (8.23)	172	40.58 (8.92)	143	37.44 (7.54)
Height (cm)								
Baseline	202	150.24 (8.49)	213	149.86 (9.61)	216	149.78 (8.12)	190	150.82 (9.14)
Interim	193	150.76 (8.51)	201	150.98 (9.36)	199	150.14 (8.03)[a]	181	151.40 (9.23)
Final	161	151.11 (8.20)	166	152.03 (9.18)	172	151.98 (7.96)	143	150.57 (8.72)
BMI								
Baseline	202	16.39 (2.26)	213	16.35 (2.44)	216	16.95 (2.72)[b]	190	16.19 (2.53)
Interim	193	16.53 (2.17)	201	16.58 (2.47)	199	16.96 (2.59)[b]	181	16.22 (2.51)
Final	161	16.64 (2.25)	166	16.87 (2.39)	172	17.31 (2.98)[b]	143	16.38 (2.26)
WAZ								
Baseline	202	-1.69 (0.76)	213	-1.51 (1.23)	216	-1.24 (0.93)[c]	190	-1.59 (0.96)
Interim	193	-1.71 (0.77)	201	-1.54 (0.88)	199	-1.33 (0.92)[c]	181	-1.78 (0.94)
Final	161	-1.70 (0.78)	166	-1.52 (0.90)[d]	172	-1.24 (0.98)[c]	143	-1.94 (0.78)
HAZ								
Baseline	202	-1.37 (0.94)	213	-1.23 (1.07)	216	-1.08 (0.95)	190	-1.20 (1.05)
Interim	193	-1.34 (0.99)	201	-1.23 (1.07)	199	-1.14 (0.95)	181	-1.39 (1.05)
Final	161	-1.33 (0.97)	166	-1.27 (1.10)[e]	172	-1.08 (1.00)[e]	143	-1.66 (0.97)

[1]Results expressed as mean (SD) [a]Mean height of the combine supplemented group shown a significant improvement (p=0.012) over the placebo at interim analysis

[b]BMI of the combine supplemented group was significantly different (p=0.003) through out the intervention

[c]WAZ of the combine supplemented group was significantly different (p=0.001) through out the intervention

[d]WAZ of the zinc only group was significantly improved after the intervention (p=0.012)

[e]HAZ of the zinc supplemented groups had significant improvement with supplementation -zinc only (p=0.003), combine (p=0.005) and shown no difference between the two groups

The difference observed in the SF concentration of the iron and combine supplemented groups at baseline was eliminated by the time of the interim analysis. Both groups had more than 30.0μg/L improvement (mean level of 60.39 in iron and 60.15μg/L in combine; $p=0.994$). There was no difference in SF between the zinc and the placebo groups (mean level of 39.12 and 39.51μg/L respectively; $p = 0.07$) during this period (Table 6).

This relationship continued throughout the intervention period. Figure 3 illustrates that iron stores have improved in the iron supplemented groups. The baseline prevalences of iron deficiency of over 60% had reduced to less than 2% (iron only had 1.9% and the combine supplemented group had 1.7% prevalence after the intervention).

Similar to the improvement of iron stores with the iron supplemented groups, serum zinc levels improved in the zinc supplemented groups (Table 6). However, there was no significant treatment effect at interim analysis. The zinc only group had a mean change of 4.29μmol//L by interim assessment and the combine supplemented group had a mean change of 3.75μmol/L ($p=0.82$).

Table 6. Effects on biochemical parameters following micronutrient supplementation[1]

	n	Iron	n	Zin	n	Combined	n	Placebo
Haemoglobin (g/L)								
Baseline	202	112.12 (13.83)[b]	213	118.31 (13.27)	216	116.58 (9.57)[c]	190	122.18 (12.85)[a]
Interim	193	130.49 (9.79)[b]	201	126.55 (11.77)[b]	199	127.57 (9.53)[b]	181	120.60 (12.97)[a]
Final	161	141.71 (8.67)[b]	166	130.74 (10.05)[c]	172	135.64 (8.68)[b]	143	121.52 (12.45)[a]
Serum Ferritin (μg/L)								
Baseline	202	21.50 (18.81)[b]	213	37.15 (20.48)[a]	216	27.73 (17.55)[c]	190	40.86 (23.37)[a]
Interim	193	60.39 (28.07)[b]	201	39.12 (18.98)[a]	199	60.15 (26.27)[b]	181	39.51 (20.40)[a]
Final	161	88.73 (36.99)[b]	166	44.43 (23.39)[a]	172	84.51 (32.15)[b]	143	38.32 (19.04)[a]
Serum Zinc (μmol/L)								
Baseline	202	10.67 (3.58)[a]	213	7.95 (3.04)[b]	216	8.41 (3.02)[b]	190	10.53 (2.71)[a]
Interim	193	11.07 (2.45)	201	12.26 (2.76)	199	12.27 (2.63)	181	10.99 (2.07)
Final	161	11.70 (2.82)[a]	166	14.68 (3.38)[b]	172	14.25 (3.58)[b]	143	11.12 (2.11)[a]

[1]Results expressed as mean (SD)

[a,b,c,d]Values with same superscripts are not significantly different

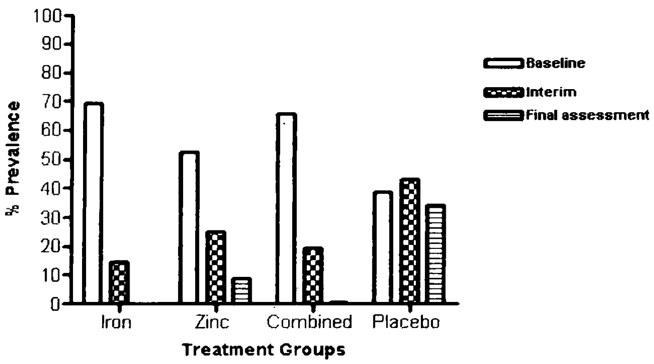

Figure 2 Prevalence of anaemia (haemoglobin <120g/L) at baseline, interim assessment and at the end of the intervention

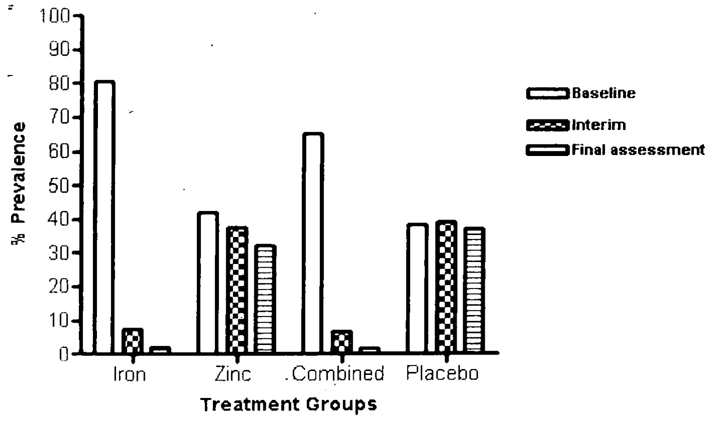

Figure 3. Prevalence of low iron stores (serum ferritin <30μg/L) at baseline, interim assessment and at the end of the intervention

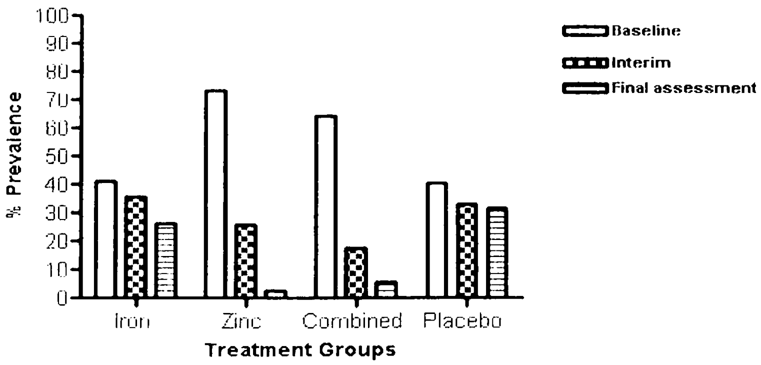

Figure 4. Prevalence of zinc deficiency (serum zinc <9.95μmol/L) at baseline, interim assessment and at the end of the intervention

After 9 months of micro nutrient supplementation mean serum zinc levels in the zinc supplemented groups (zinc only and combined supplemented) had significantly improved over the other two groups ($p<0.001$) and shown no difference between these two groups ($p=0.32$). The zinc supplemented groups were also able to overcome their high prevalences of zinc deficiency. The zinc group had baseline prevalence of 73.2% which was reduced to 20.2% by interim assessment and further to 2.4% by the final assessment whereas, the prevalence in the combine supplemented group had fallen from 62.0% at baseline to 17.8% at interim and 5.8% at final assessment respectively (Figure 4)

Conclusions

The strengths of this study included its randomized, double blind design and the supervised administration of the supplements. Except for differences in the relative proportions of boys and girls and the minor differences in initial biochemical status, the groups were similar at baseline. Sex and anthropometric / biochemical variables were also controlled during the statistical analyses. Thus, any differences in the outcomes were likely be due to the supplementation treatment intervention. This study on the effect of single or combined iron and zinc supplementation in adolescent school children provides evidence that supplementation of iron and zinc either alone or in combination has no effect in improving growth (weight, height and BMI). However, 9 months of zinc supplementation (zinc alone and combined with iron) had a significant treatment effect on WAZ and HAZ over the iron alone supplementation.

It can be concluded that the linear growth of children with lower height and WAZ can positively be improved by zinc supplementation. This study has provided evidence that combined iron and zinc supplementation is optimum and had a clinically and statistically significant effect on growth of school children. In situations where a supplementation strategy is more feasible than a food-based approach, innovative dose regimens for the provision of these micronutrients are needed.

This study demonstrates that supplementation with multiple micronutrients can be useful in reversing stunting in Sri Lankan school children. Severe to moderate forms of anaemia were successfully treated in children who received iron supplementation. Furthermore, the high initial prevalence of children with low zinc and iron stores was reduced significantly with micronutrient supplementation during the study. Finally, iron supplementation was shown not to negatively affect plasma zinc concentrations and supplementation with zinc did not increase the prevalence of anaemia.

The randomized, double blind design and the carefully supervised administration of the supplements resulted in scientifically validated improvement in the micronutrient status and growth of study subjects. Severe to moderate forms of anaemia were successfully treated in children who received iron supplementation. Furthermore, the high initial prevalence of children with low zinc and iron stores were reduced significantly with supplementation. Finally, iron supplementation was shown not to be negatively affect plasma zinc concentrations and supplementation with zinc did not increase the prevalence of anaemia. However, the presence of zinc in combined supplementation reduced the effectiveness of iron. Therefore a long term supplementation with multiple micronutrients (iron and zinc) can be useful to reverse stunting in Sri Lankan school children and effective in accelerating pubertal and catch-up growth. Improvement in micronutrient status of school children will result in greater efficiency and productivity of the school system in Sri Lanka. Increase in productivity will eventually reduce the wastage that currently occurs in education expenditure.

General conclusions of the study programme

1. This study will establish a reference point by which priorities for programme content are determined as well as a baseline from which improvement in deficiency prevention can be measured.
2. The great majority of children consumed a diet deficient in energy. The diet was also poor in nutrient density and cannot meet their micronutrient requirements.
3. Severe to moderate forms of anaemia were successfully treated in children who received iron supplementation. Furthermore, the high initial prevalence of children with low zinc and iron stores was reduced significantly with micronutrient supplementation during the study
4. Long term supplementation with multiple micronutrients (iron and zinc) can be useful to reverse stunting in Sri Lankan school children and effective in accelerating pubertal and catch-up growth.

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Oral Presentations