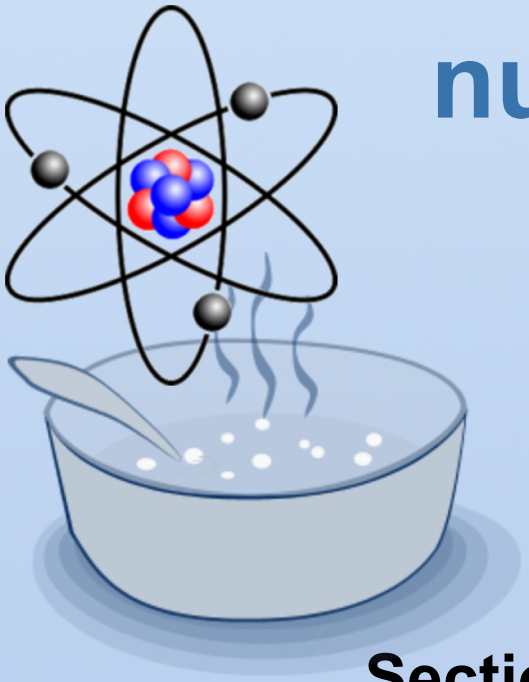
IAEA
International Atomic Energy Agency

Atomic Moms: using stable isotopes to measure the nutrition of children and mothers



Cornelia Loechl, PhD

Section Head, Nutritional and Health-Related Environmental Studies

What to expect?

- What is the IAEA?
- What is IAEA‘s role in nutrition programmes?
- Examples of ongoing projects
- Examples of study findings
- How does the IAEA build capacity and reach out?

International Atomic Energy Agency

- IAEA is an specialized technical agency of the United Nations System;
- Established in 1957 as the world's "Atoms for Peace" organization;
- Works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies;
- Headquarters in Vienna with offices in Geneva, Tokyo, Toronto, and New York.

IAEA Mandate

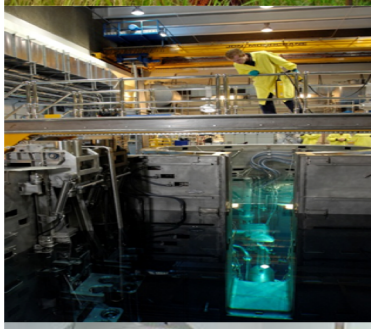
“Atoms for Peace and Development”

To seek to accelerate and enlarge the contribution of nuclear techniques to peace, **health and prosperity** throughout the world.

Department of Nuclear Sciences & Applications

- Human Health
- Environment
- Food and Agriculture (Joint Division with FAO)
- Water Resources
- Radioisotope Production and Radiation Technology
- Nuclear Science





IAEA's Sub-Programme 'Nutrition for Improved Health'

Enhance Member State capabilities to combat malnutrition in all its forms and to address environment related nutrition issues for better health throughout the life course:

- Maternal, infant and young child nutrition;
- Prevention and control of obesity and non-communicable diseases;
- Health effects of the environment.

IAEA's Contribution to the Global Efforts in Nutrition

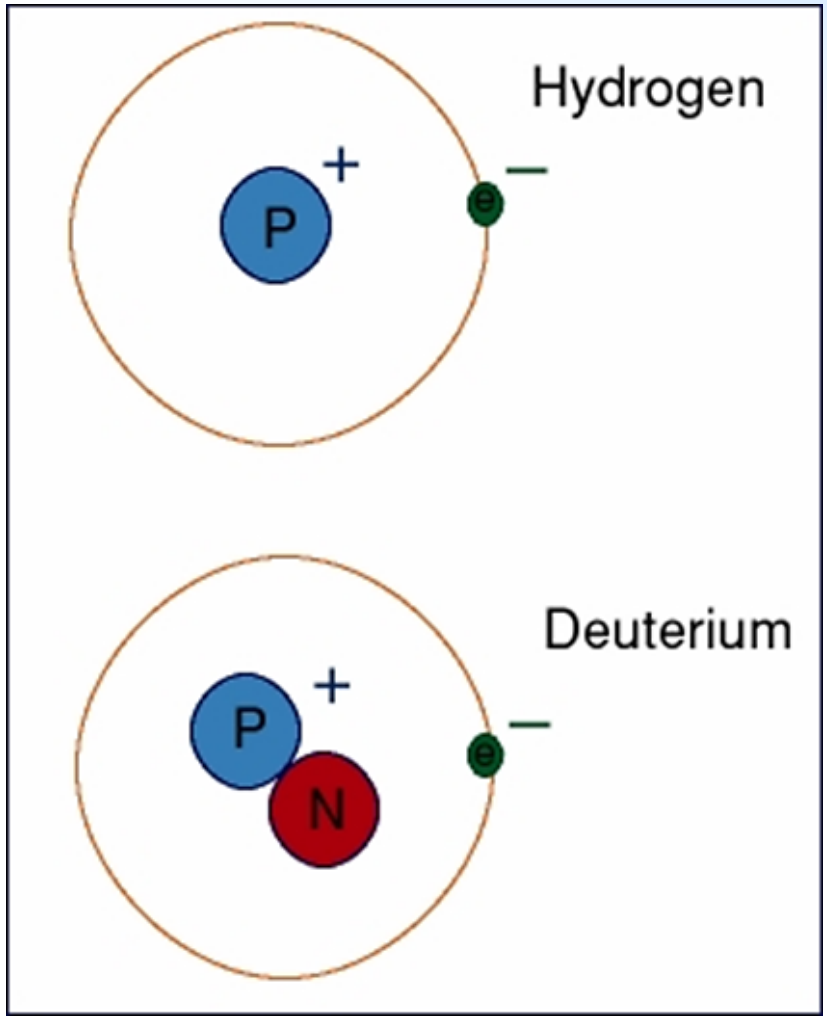
The IAEA's work complements the work of other players in nutrition through encouraging the use of stable isotope techniques (safe and non radioactive) in design and evaluation of nutrition interventions.

What is an Isotope?

- Isotopes of an element have the same the number of protons in the nucleus (atomic number)

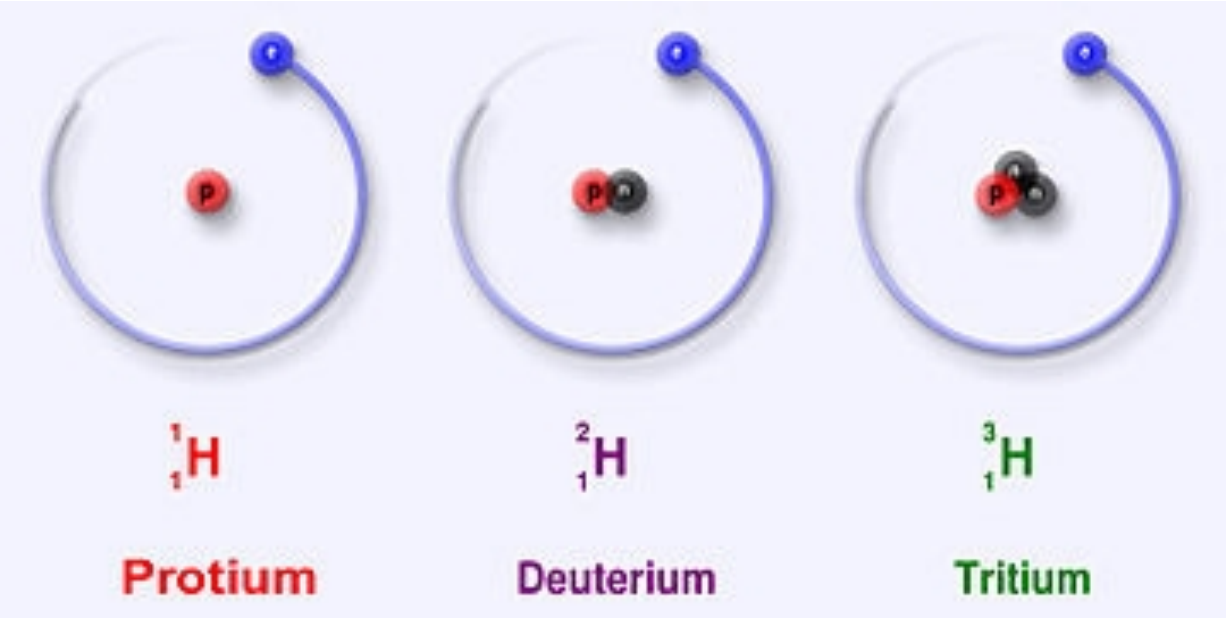
but

- Different atomic mass (the sum of number of protons + number of neutrons)



Isotopes of Hydrogen

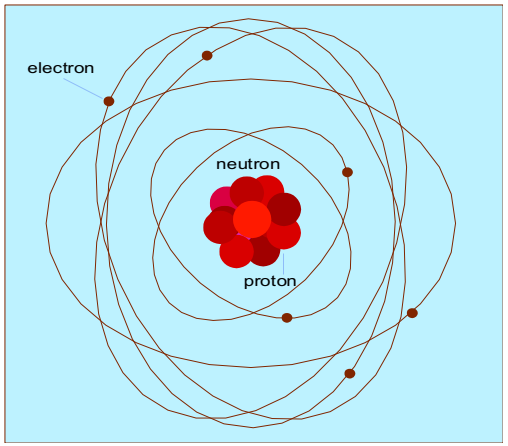
Hydrogen has 3 isotopes:



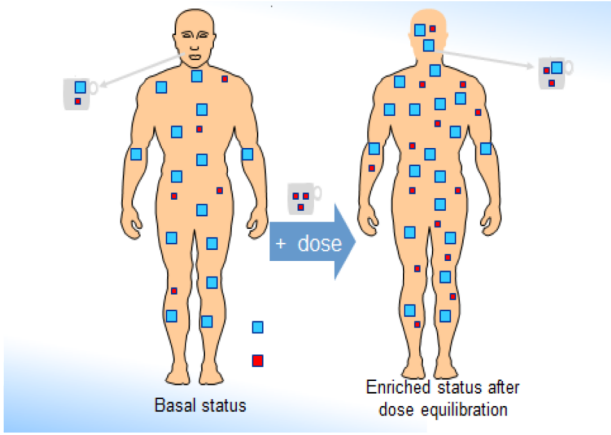
^{1}H	^{2}H	^{3}H
1.00794 99.985%	2.0141 0.015%	t½ =12.32yrs
Stable	Stable	Cosmogenic/ anthropogenic

Summary on stable isotopes

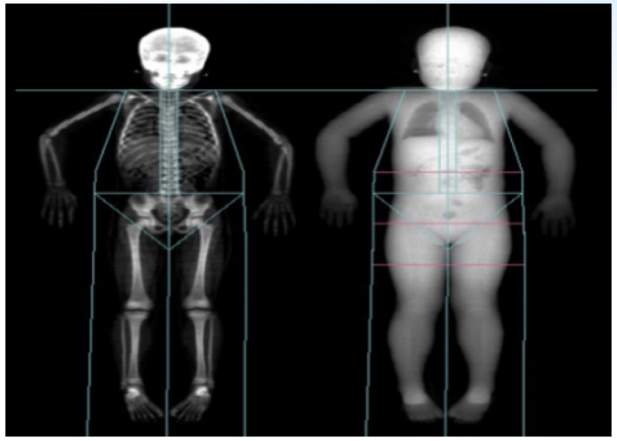
- Unlike radioisotopes which are unstable, stable isotopes are safe and emit no radiation
- Stable isotopes occur naturally in our environment and our organism (natural abundance)
- We use stable isotopes that are less present in nature
- Need to collect baseline sample
- Suitable for all ages (pregnant women, lactating mothers, children)
- Can be used in community settings



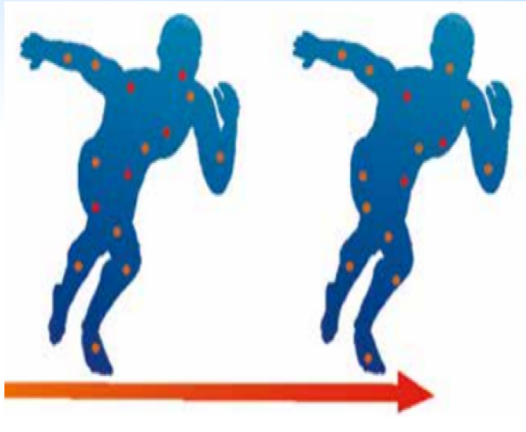
Nuclear Applications in Nutrition



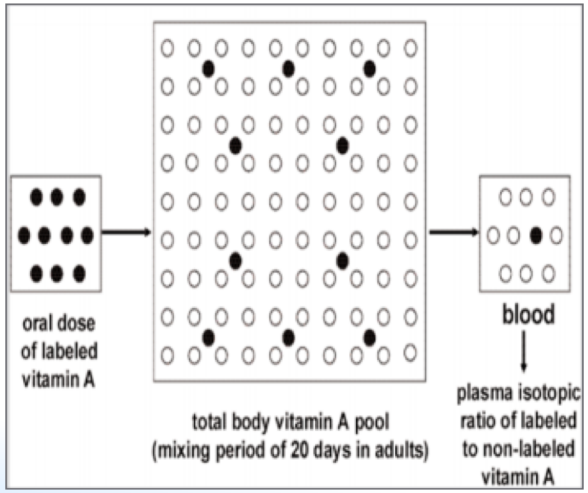
Body composition



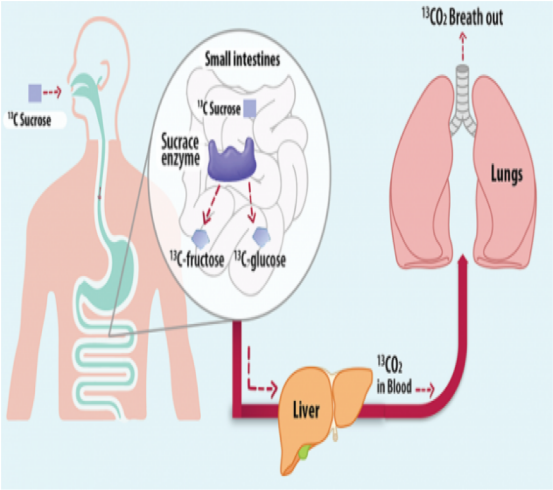
Bone Density



Total energy expenditure



Micronutrient bioavailability and Vitamin A pool size



Environmental enteric dysfunction

Breastfeeding patterns

Support Mechanisms of IAEA

Coordinated Research Projects

- Call for research proposals
- Respond to research questions
- Small group of research institutes
- 4-5 years
- Small annual grants
- Regular coordination meetings

Technical Cooperation Programme

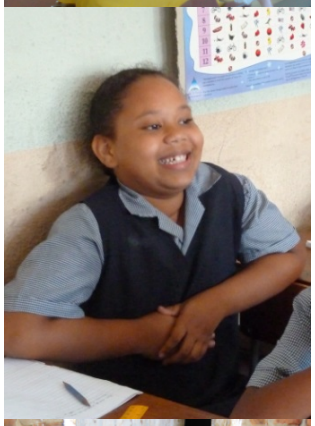
- Project submission from Member States
- Building and strengthening capacity to use stable isotope techniques
- Biannual planning and implementation cycle
- Training, expert advice, equipment, sample analysis, data management/analysis

No funding of field logistics!

Coordinated Research Projects

Areas of ongoing research projects:

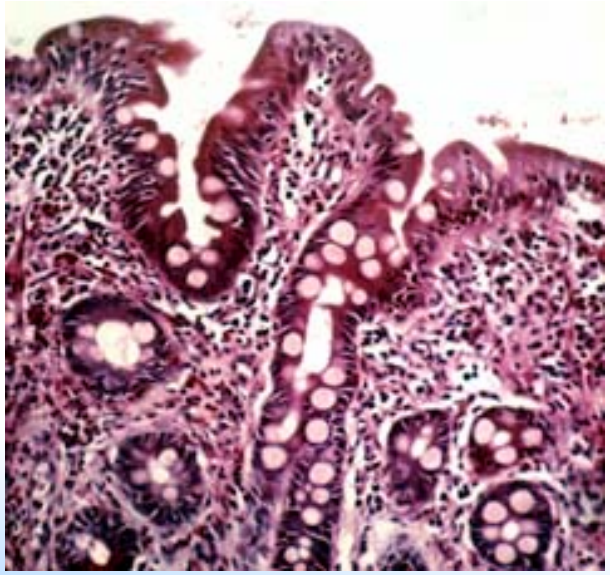
- Infant feeding (breastfeeding), infant growth and body composition
- Childhood obesity
- Micronutrient nutrition (Vitamin A, Iron, Zinc)
- Optimizing nuclear techniques to assess vitamin A status and the risk of excess vitamin A intake
- Agriculture for improved nutrition
- Protein bioavailability from plant based diets
- Application of stable isotope techniques in EED assessment
- Link between Early Life Nutrition and Later Childhood Health



Application of stable isotope techniques in environmental enteric dysfunction (EED) assessment

Exposure to unsanitary environment as found in many low and middle income countries leading to:

- Altered intestinal structure and function
- Reduced nutrient absorption
- More permeability to harmful microflora



No simple non-invasive methods to diagnose and classify EED.

New research project:

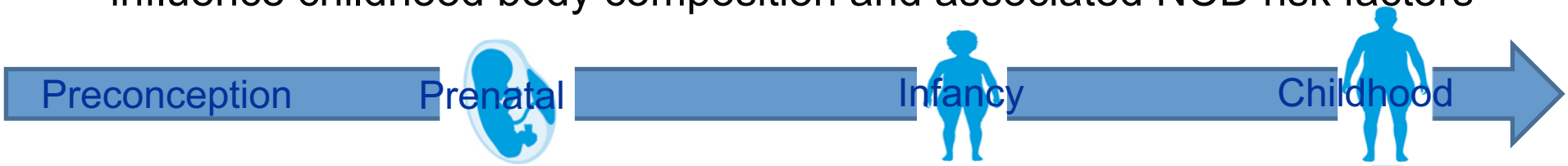
Develop non-invasive stable isotope based breath test using labelled sucrose

2 main phases:

1. Optimisation of existing 13C SBT protocol and validation by biopsy.
2. Assessment of the applicability of validated 13C SBT in EED diagnosis among children in settings where EED risk is high and linking it to growth pattern.

Applying Nuclear Techniques to Understand the Link between Early Life Nutrition and Later Childhood Health

- To investigate the relationship between the first 1000 days and later childhood body composition
- To explore whether interventions during the first 1000 days can influence childhood body composition and associated NCD risk factors



Cohort A – mother received intervention from preconception and child from birth

Preconception	Pregnancy	Infancy	Childhood

Cohort B – mother received intervention in pregnancy

Pregnancy	Infancy	Childhood

Cohort C – Child received previous intervention in infancy

Infancy	Childhood

Cohort D – No intervention received

Preconception	Pregnancy	Infancy	Childhood

TC Projects

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TC projects – national, regional:

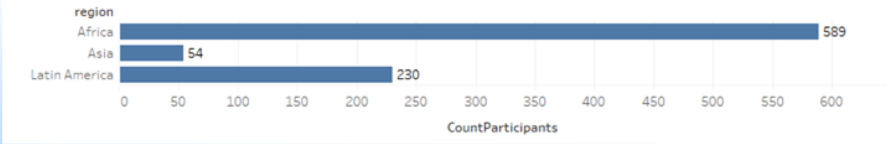
- Childhood obesity/double burden of malnutrition
- Breastfeeding
- Recovery from malnutrition
- Vitamin A
- Iron bioavailability in context of food fortification
- Healthy Aging

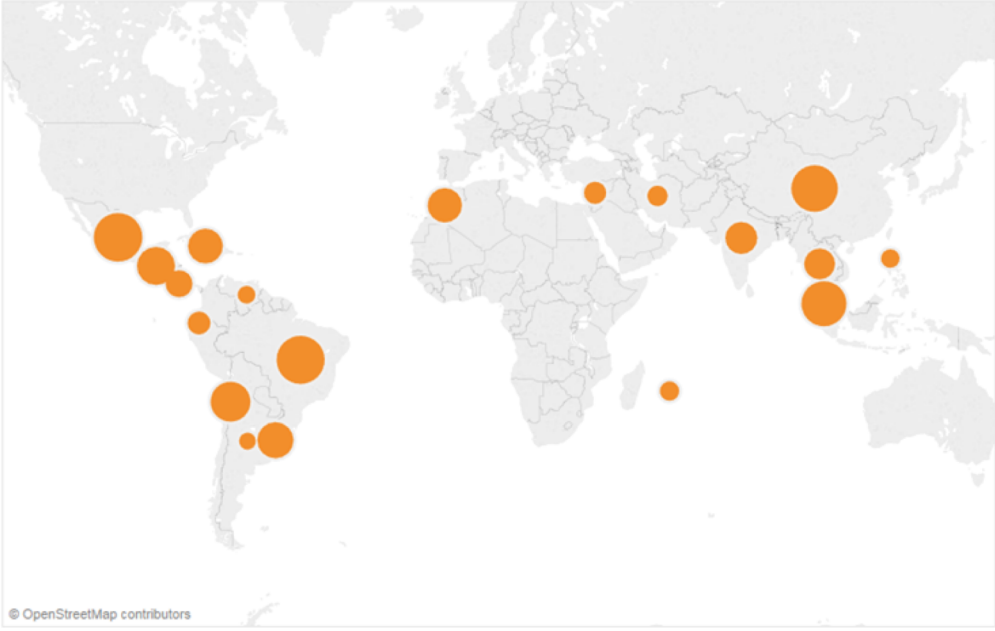
1 Interregional:

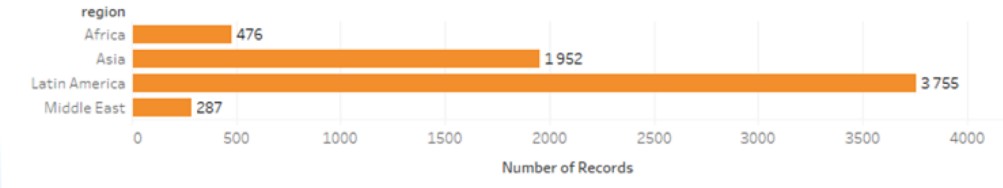
- On stunting prevention in collaboration with UNICEF, IADB

Databases

Two pooled databases on breastfeeding practices and risk factors for childhood obesity from CRP and TC projects





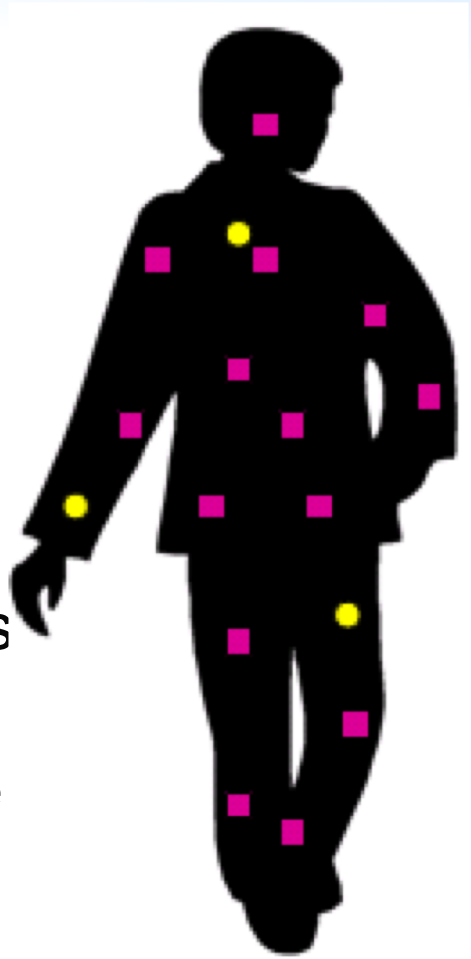


Breastfeeding Practices

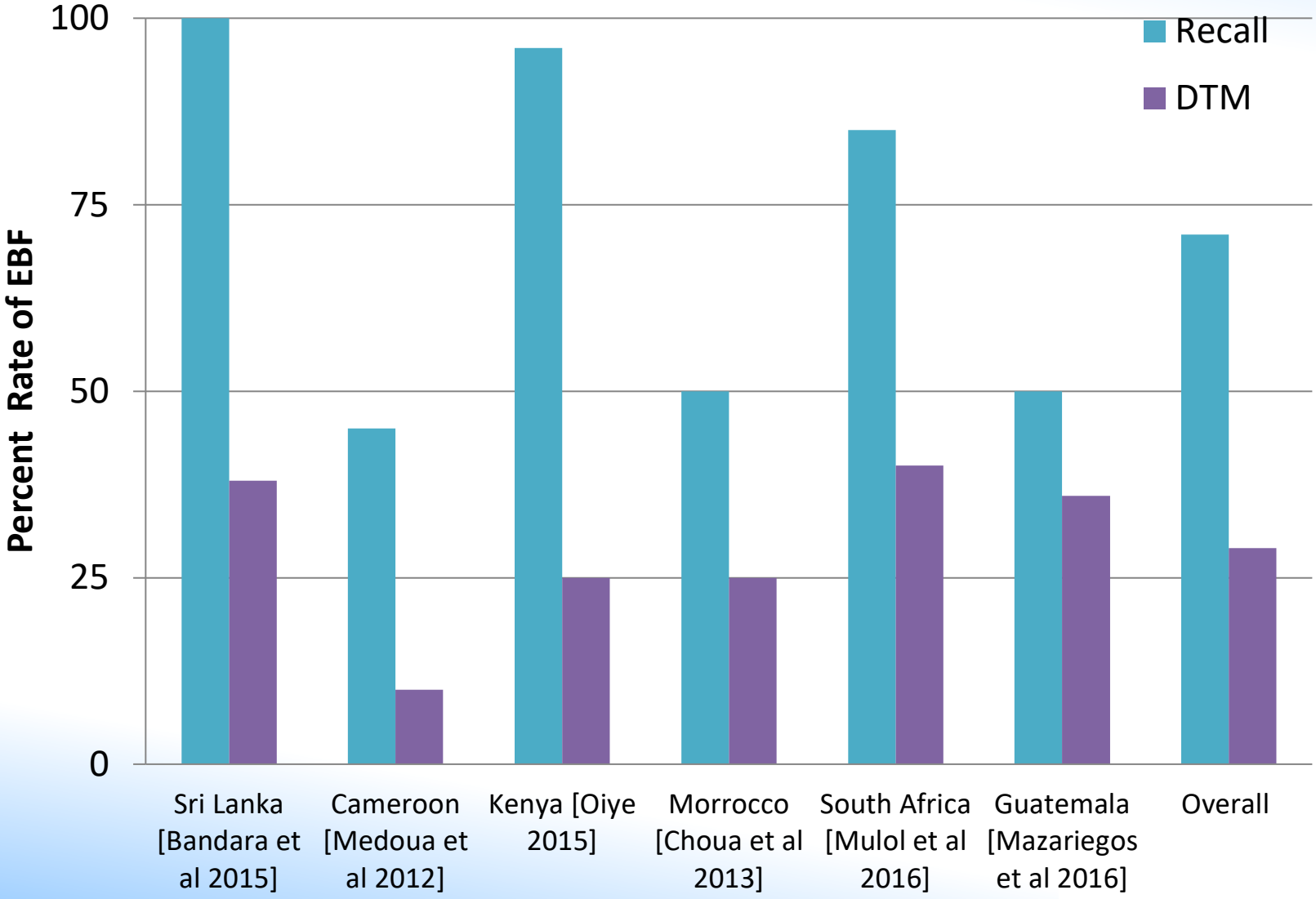
Body composition

Body composition by deuterium dilution – how does it work?

1. Collect baseline sample before drinking accurately weighed dose of deuterium that mixes with body water evenly within a few hours; collect 2 post-dose samples (3-4 h in saliva; 5-6 h in urine)
2. Measure deuterium abundance before and after equilibration of the dose
3. Calculate total body water and fat-free mass using appropriate hydration factor
4. Determine amount of fat mass as difference between body weight and fat-free mass (2-compartment model)



Assessment of interventions aimed at promoting exclusive breastfeeding – validating mothers' reports and monitoring WHA target



Breastfeeding Patterns & Body Composition at 12 months

IAEA

Maternal & Child Nutrition

DOI: 10.1111/mcn.12338

Original Article

Association of 6 months of exclusive breastfeeding with higher fat-free mass in infants in a low-resource setting with high HIV prevalence in South Africa

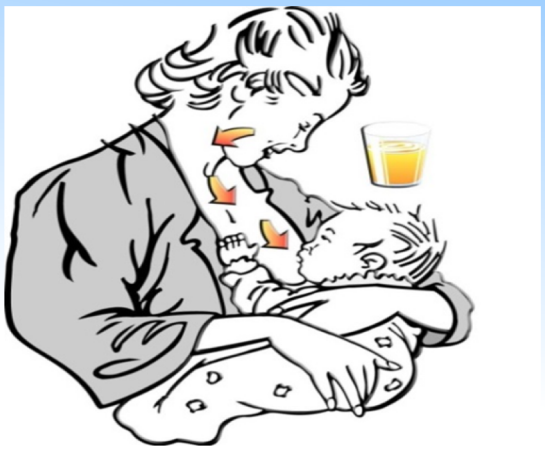
Matern Child Nutr. 2017 Apr;13(2).

Helen Mulol and Anna Coutsoudis

Department of Paediatrics and Child Health, University of KwaZulu-Natal, Durban, South Africa

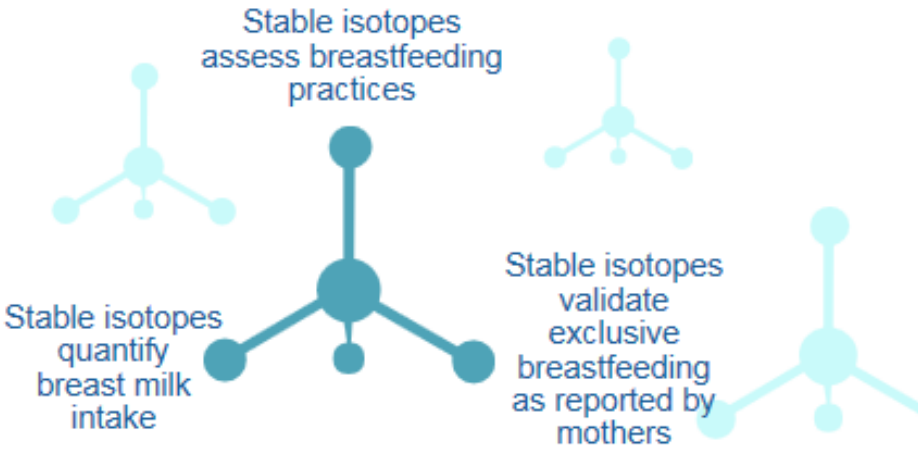
Results showed that infants who were exclusively breastfed for 6 months had a higher per cent fat-free mass at 12 months compared with infants who were not exclusively breastfed for 6 months ($P<0.05$).

Deuterium dose-to-mother technique – how does it work?



1. Mother consumes a single oral dose of deuterated water
2. Deuterium mixes with mother's body water
3. Infant consumes deuterium through mother's milk
4. Saliva is sampled from the mother and infant for 2 weeks
5. Amount of deuterium is analysed
6. Amount of breast milk consumed and amount of water from sources other than breast milk is calculated

IAEA's Role in Breastfeeding Promotion



IAEA supports Member States to verify the accuracy of information on exclusive breastfeeding in the first six months

IAEA assesses interventions to promote optimal breastfeeding practices and monitors progress of achieving the targets.

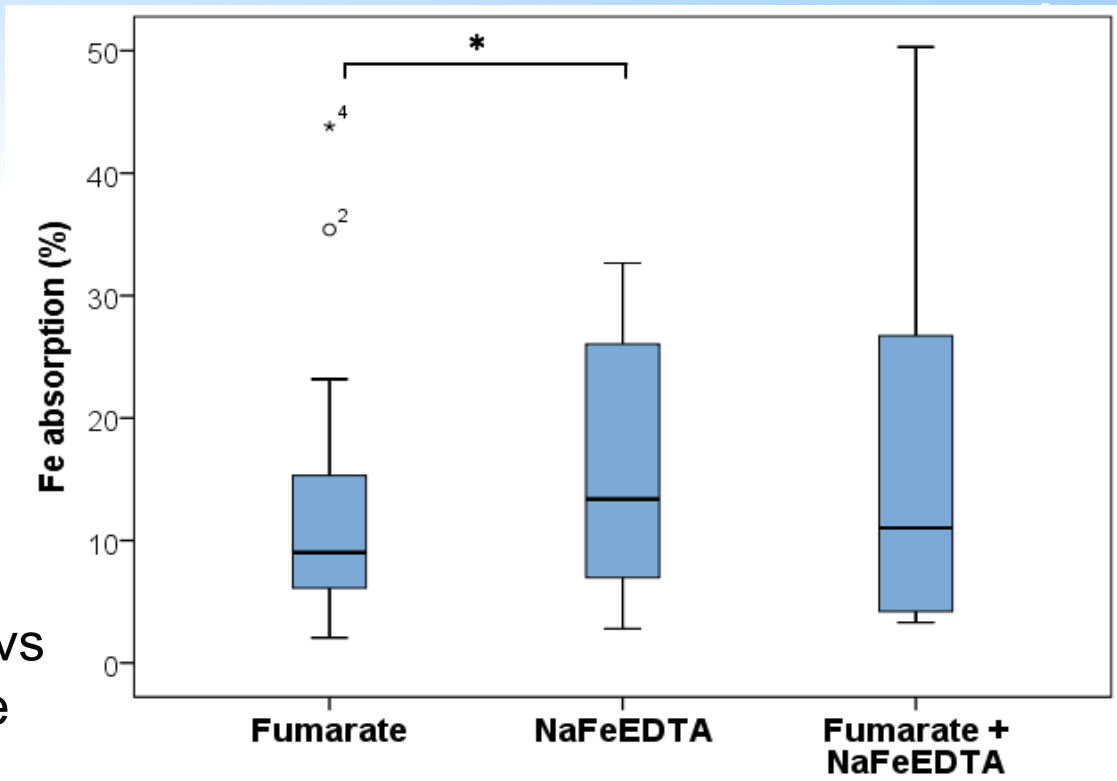
WHA targets 2025

Increase the rate of exclusive breastfeeding in the first 6 months up to at least 50%.

Haiti – Informing wheat flour fortification

Fe absorption in Haitian women is 41% higher from NaFeEDTA than from FeFumarate.

Recommendation to use FeFumarate at 60mg/kg flour (vs 40mg/kg NaFeEDTA), because of lower cost.



	Fe fumarate	NaFeEDTA	Fe fum + NaFeEDTA
Mothers	n=22	n=22	n=20
Fe absorption (%)	9.24 (6.35, 13.44) [a]	13.06 (9.23, 19.10) [b]	11.09 (7.45, 17.34) [a,b]
Fe absorbed (mg)	0.36 (0.26, 0.50) [a]	0.51 (0.35, 0.72) [a]	0.44 (0.30, 0.66) [a]

Values are geometric means (95% CI). Values not sharing a common superscript letter differ significantly from each other (repeated measures ANOVA with post hoc bonferroni correction for the mothers, $p<0.05$)

HERTER-AEBERLI I et al, BJN 118 (2017) 273-279

Fortified extruded rice improved vitamin A status of school children in Thailand

IAEA

Children's vitamin A reserves doubled, with no change in serum concentrations

	Intervention	Control
Serum retinol, *µmol/L*		
Baseline	1.21 ± 0.19	1.18 ± 0.26
Endline	1.28 ± 0.27	1.15 ± 0.23
Total body reserves of VA, *µmol retinol*		
Baseline	153 ± 66	108 ± 67
Endline	269 ± 148*,**	124 ± 89

*Different from control group, $p<0.05$, **Different from baseline, $p<0.05$

PINKAEW S et al, J Nutr 144 (2014) 519-524

Validity of 24-h recalls in (pre-)school aged children: Comparison of energy intakes with energy expenditure

- Little is known about the validity of repeated 24-h dietary recalls as a measure of total energy intake (**EI**) in young children
- Evaluate the validity of proxyreported **EI** by comparison with total energy expenditure (**TEE**) measured by the *doubly labeled water (DLW) technique*

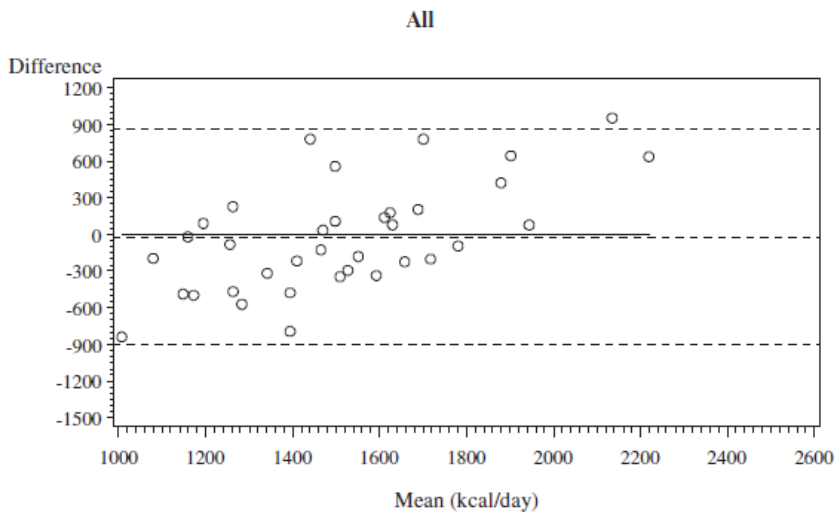


Fig. 2. Bland–Altman plot agreement between measured energy expenditure (TEE; kcal/day) and reported energy intake (EI; kcal/day). The mean of EI and TEE is plotted on the *x*-axis, the difference of both values (bias) on the *y*-axis accordingly. The solid line indicates the line of total agreement (zero differences between EI and TEE). Mean difference and upper/lower limits of agreement (mean difference ± 2 SD) are superimposed by broken line.

C. Börnhorst et al. / Clinical Nutrition 33 (2014) 79–84

Joint IAEA/WHO/UNICEF Symposium

Purpose and objectives

- To strengthen understanding of how to tackle the DBM and address key gaps identified at the 2017 joint workshop.
- To highlight the role of stable isotopes in addressing gaps both in the measurement of malnutrition and in assessing the impact of interventions.
- To identify double-duty actions, new assessment tools, considerations for policies and action plans with an overall aim to support Member States in achieving their defined nutrition commitments within the Nutrition Decade.

Joint IAEA/WHO/UNICEF Symposium

Thematic areas:

- **Epidemiology**
  - Prevalence, causes and consequences of the DBM.
- **Biology**
  - Biological mechanisms contributing to the DBM.
- **Assessment**
  - How to assess the DBM in individuals and populations.
- **Interventions**
  - From biology to interventions targeting the DBM.
- **Policy implications**
  - From biology to policies addressing the DBM.

Audience:

- The symposium aims to bring together a broad range of stakeholders including UN organisations, policy makers, researchers, health professionals, NGOs and civil society.

Fee-free registration and abstract submission until 23 April 2018!

https://www.iaea.org/events/understanding-the-double-burden-of-malnutrition-symposium-2018

AFRA Regional Designated Centres

Regional Designated Centres in the field of deuterium dilution techniques in human nutrition:

Botswana – National Food Technology Research Centre

Morocco – Joint Unit for Nutrition and Food Research at the National Centre for Nuclear Energy, Sciences and Technology (CNESTEN)

Regional Centres In Africa For Vitamin A Status Assessment

The IAEA is establishing capacity to measure vitamin A body pools using deuterated-retinol-dilution technique:

Cameroon – Centre for Food and Nutrition Research

Zambia - Tropical Diseases Research Centre at Ndola Central Hospital

Morocco – Joint Unit for Nutrition and Food Research at the National Centre for Nuclear Energy, Sciences and Technology (CNESTEN)

Regional Centres In Latin America

Regional Centres of excellence in assessment of body composition and energy expenditure:

Chile – Institute of Nutrition and Food Technology (INTA), University of Chile

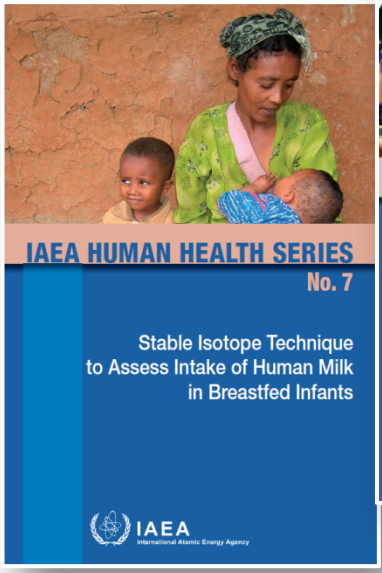
Guatemala – Institute of Nutrition for Central America and Panama (INCAP)

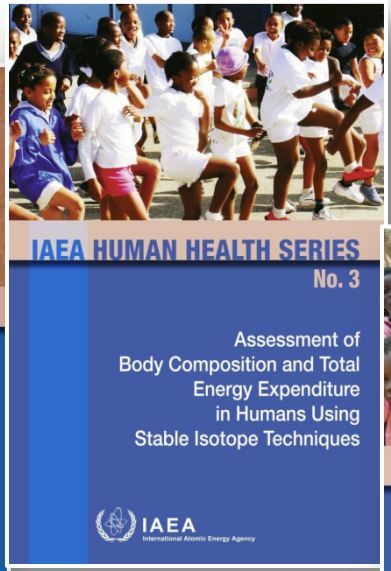
Mexico – Centre for Food Research and Development (CIAD) & University of Sonora

IAEA Collaborating Centre for Nutrition

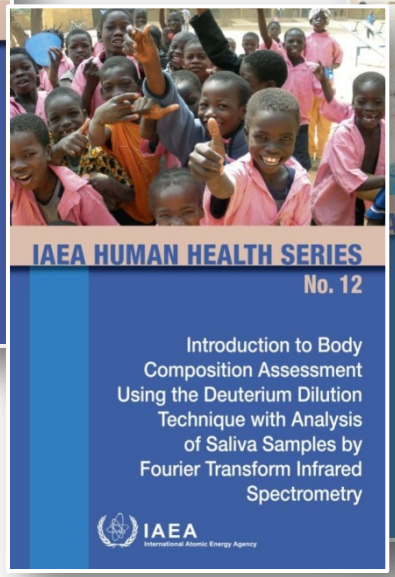
In 2010, St John's Research Institute, Bangalore, India was designated the first IAEA Collaborating Centre for Nutrition.

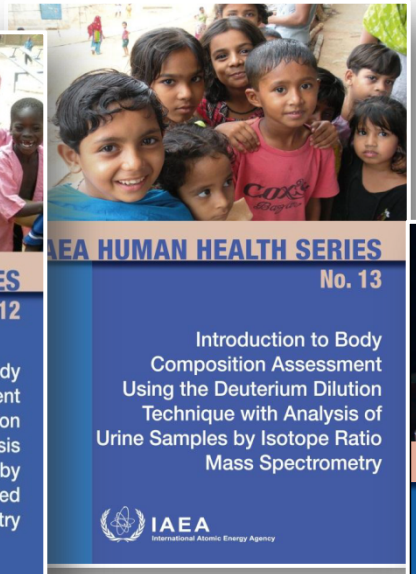
IAEA Human Health Series





Also available in Spanish and French!





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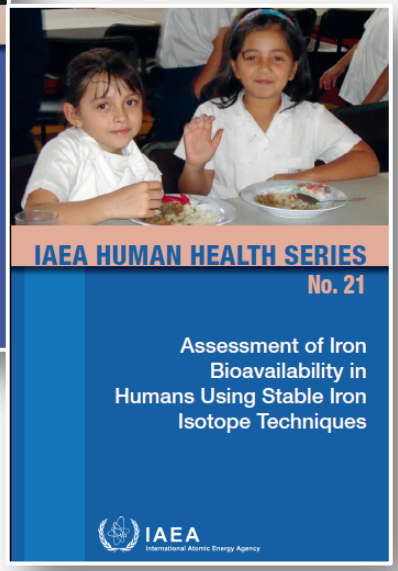
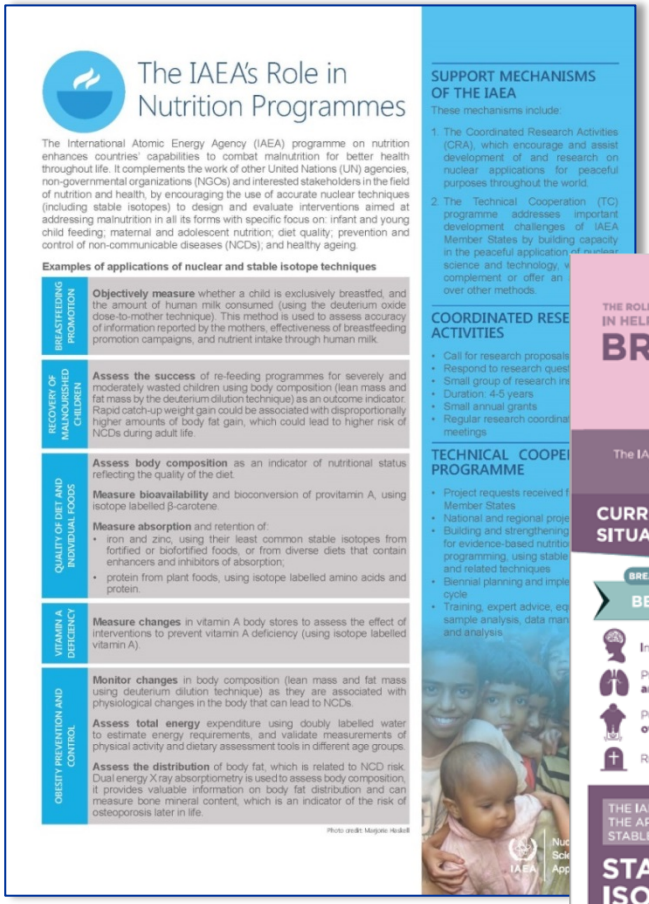


IAEA e-learning Modules

Factsheets and Brochures



The IAEA's Role in Nutrition Programmes

The International Atomic Energy Agency (IAEA) programme on nutrition enhances countries' capabilities to combat malnutrition for better health throughout life. It complements the work of other United Nations (UN) agencies, non-governmental organizations (NGOs) and interested stakeholders in the field of nutrition and health, by encouraging the use of accurate nuclear techniques (including stable isotopes) to design and evaluate interventions aimed at addressing malnutrition in all its forms with specific focus on: infant and young child feeding; maternal and adolescent nutrition; diet quality; prevention and control of non-communicable diseases (NCDs); and healthy ageing.

Examples of applications of nuclear and stable isotope techniques

BREASTFEEDING PROMOTION — **Objectively measure** whether a child is exclusively breastfed, and the amount of human milk consumed (using the deuterium oxide dose-to-mother technique). This method is used to assess accuracy of information reported by the mothers, effectiveness of breastfeeding promotion campaigns, and nutrient intake through human milk.

RECOVERY OF MALNOURISHED CHILDREN — **Assess the success** of re-feeding programmes for severely and moderately wasted children using body composition (lean mass and fat mass by the deuterium dilution technique) as an outcome indicator. Rapid catch-up weight gain could be associated with disproportionally higher amounts of body fat gain, which could lead to higher risk of NCDs during adult life.

QUALITY OF DIET AND INDIVIDUAL FOODS — **Assess body composition** as an indicator of nutritional status reflecting the quality of the diet.

Measure bioavailability and bioconversion of provitamin A, using isotope labelled β-carotene.

Measure absorption and retention of:

- iron and zinc, using their least common stable isotopes from fortified or biofortified foods, or from diverse diets that contain enhancers and inhibitors of absorption;
- protein from plant foods, using isotope labelled amino acids and protein.

VITAMIN A DEFICIENCY — **Measure changes** in vitamin A body stores to assess the effect of interventions to prevent vitamin A deficiency (using isotope labelled vitamin A).

OBESITY PREVENTION AND CONTROL — **Monitor changes** in body composition (lean mass and fat mass using deuterium dilution technique) as they are associated with physiological changes in the body that can lead to NCDs.

Assess total energy expenditure using doubly labelled water to estimate energy requirements, and validate measurements of physical activity and dietary assessment tools in different age groups.

Assess the distribution of body fat, which is related to NCD risk. Dual energy X ray absorptiometry is used to assess body composition, it provides valuable information on body fat distribution and can measure bone mineral content, which is an indicator of the risk of osteoporosis later in life.

Photo credit: Marjorie Hesdell

SUPPORT MECHANISMS OF THE IAEA

These mechanisms include:

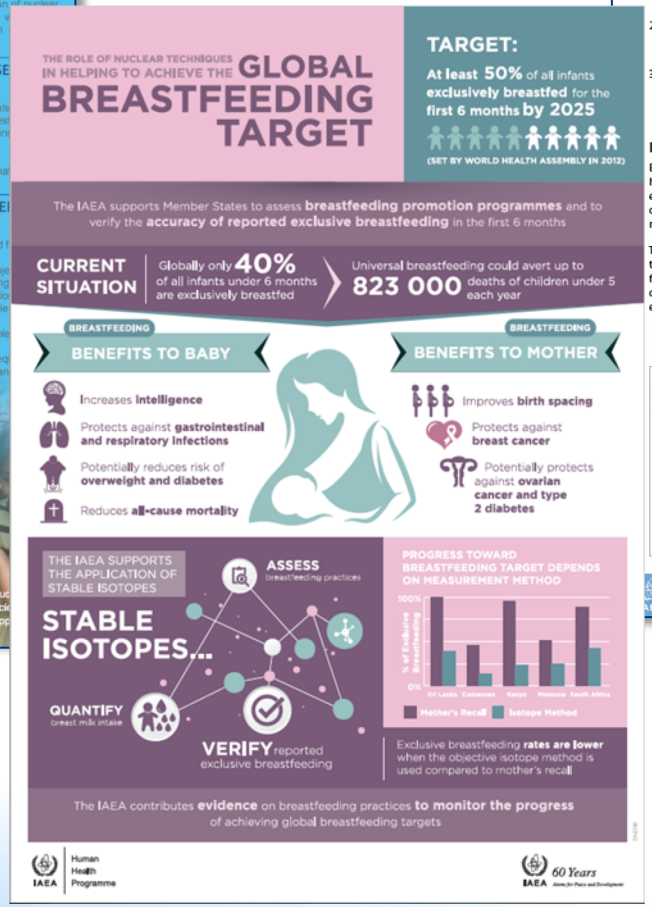
1. The Coordinated Research Activities (CRA), which encourage and assist development of and research on nuclear applications for peaceful purposes throughout the world.
2. The Technical Cooperation (TC) programme addresses important development challenges of IAEA Member States by building capacity in the peaceful application of nuclear science and technology, w complement or offer an over other methods.

COORDINATED RESE ACTIVITIES

- Call for research proposals
- Respond to research quest
- Small group of research in
- Duration: 4-5 years
- Small annual grants
- Regular research coordinat meetings

TECHNICAL COOPE PROGRAMME

- Project requests received f Member States
- National and regional proje
- Building and strengthening for evidence-based nutritio programming, using stable and related techniques
- Biennial planning and imple cycle
- Training, expert advice, eq sample analysis, data man and analysis



THE ROLE OF NUCLEAR TECHNIQUES IN HELPING TO ACHIEVE THE

GLOBAL BREASTFEEDING TARGET

TARGET: At least **50%** of all infants exclusively breastfed for the first 6 months by 2025

(SET BY WORLD HEALTH ASSEMBLY IN 2012)

The IAEA supports Member States to assess **breastfeeding promotion programmes** and to verify the **accuracy of reported exclusive breastfeeding** in the first 6 months

CURRENT SITUATION — Globally only **40%** of all infants under 6 months are exclusively breastfed. Universal breastfeeding could avert up to **823 000** deaths of children under 5 each year

BREASTFEEDING — **BENEFITS TO BABY**

- Increases **intelligence**
- Protects against **gastrointestinal and respiratory infections**
- Potentially reduces risk of **overweight and diabetes**
- Reduces **all-cause mortality**

BREASTFEEDING — **BENEFITS TO MOTHER**

- Improves **birth spacing**
- Protects against **breast cancer**
- Potentially protects against **ovarian cancer and type 2 diabetes**

THE IAEA SUPPORTS THE APPLICATION OF STABLE ISOTOPES

STABLE ISOTOPES...

- **ASSESS** breastfeeding practices
- **QUANTIFY** breast milk intake
- **VERIFY** reported exclusive breastfeeding

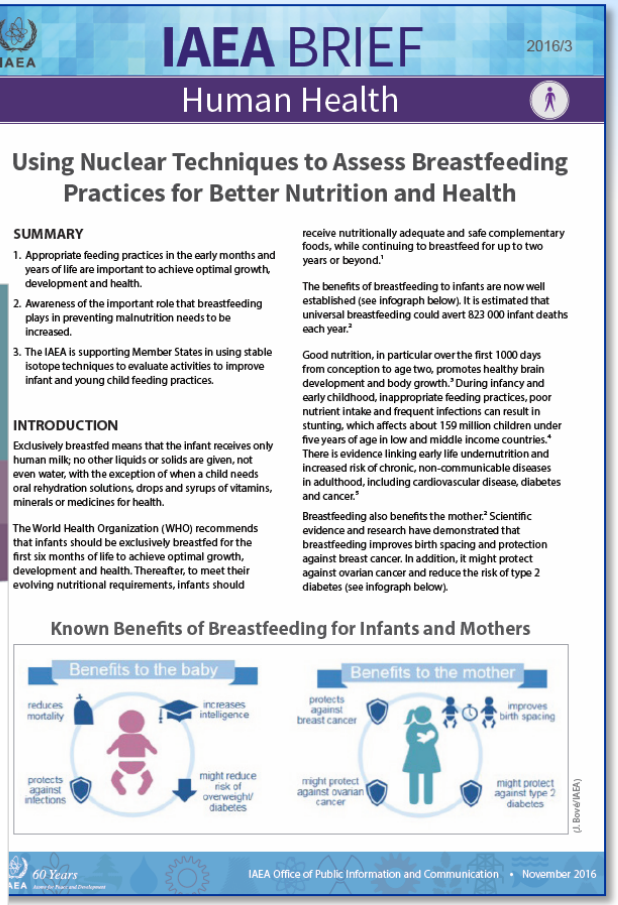
PROGRESS TOWARD BREASTFEEDING TARGET DEPENDS ON MEASUREMENT METHOD

100% — 0% — % of Exclusive Breastfeeding — Sri Lanka, Cameroon, Kenya, Morocco, South Africa — Mother's Recall, Isotope Method

Exclusive breastfeeding **rates are lower** when the objective isotope method is used compared to mother's recall

The IAEA contributes **evidence** on breastfeeding practices **to monitor the progress** of achieving global breastfeeding targets

IAEA Human Health Programme — 60 Years



IAEA BRIEF 2016/3

Human Health

Using Nuclear Techniques to Assess Breastfeeding Practices for Better Nutrition and Health

SUMMARY

1. Appropriate feeding practices in the early months and years of life are important to achieve optimal growth, development and health.
2. Awareness of the important role that breastfeeding plays in preventing malnutrition needs to be increased.
3. The IAEA is supporting Member States in using stable isotope techniques to evaluate activities to improve infant and young child feeding practices.

INTRODUCTION

Exclusively breastfed means that the infant receives only human milk; no other liquids or solids are given, not even water, with the exception of when a child needs oral rehydration solutions, drops and syrups of vitamins, minerals or medicines for health.

The World Health Organization (WHO) recommends that infants should be exclusively breastfed for the first six months of life to achieve optimal growth, development and health. Thereafter, to meet their evolving nutritional requirements, infants should receive nutritionally adequate and safe complementary foods, while continuing to breastfeed for up to two years or beyond.[1]

The benefits of breastfeeding to infants are now well established (see infograph below). It is estimated that universal breastfeeding could avert 823 000 infant deaths each year.[2]

Good nutrition, in particular over the first 1000 days from conception to age two, promotes healthy brain development and body growth.[3] During infancy and early childhood, inappropriate feeding practices, poor nutrient intake and frequent infections can result in stunting, which affects about 159 million children under five years of age in low and middle income countries.[4] There is evidence linking early life undernutrition and increased risk of chronic, non-communicable diseases in adulthood, including cardiovascular disease, diabetes and cancer.[5]

Breastfeeding also benefits the mother.[2] Scientific evidence and research have demonstrated that breastfeeding improves birth spacing and protection against breast cancer. In addition, it might protect against ovarian cancer and reduce the risk of type 2 diabetes (see infograph below).

Known Benefits of Breastfeeding for Infants and Mothers

Benefits to the baby: reduces mortality; increases intelligence; protects against infections; might reduce risk of overweight/diabetes

Benefits to the mother: protects against breast cancer; improves birth spacing; might protect against ovarian cancer; might protect against type 2 diabetes

(J. Bovd/IAEA)

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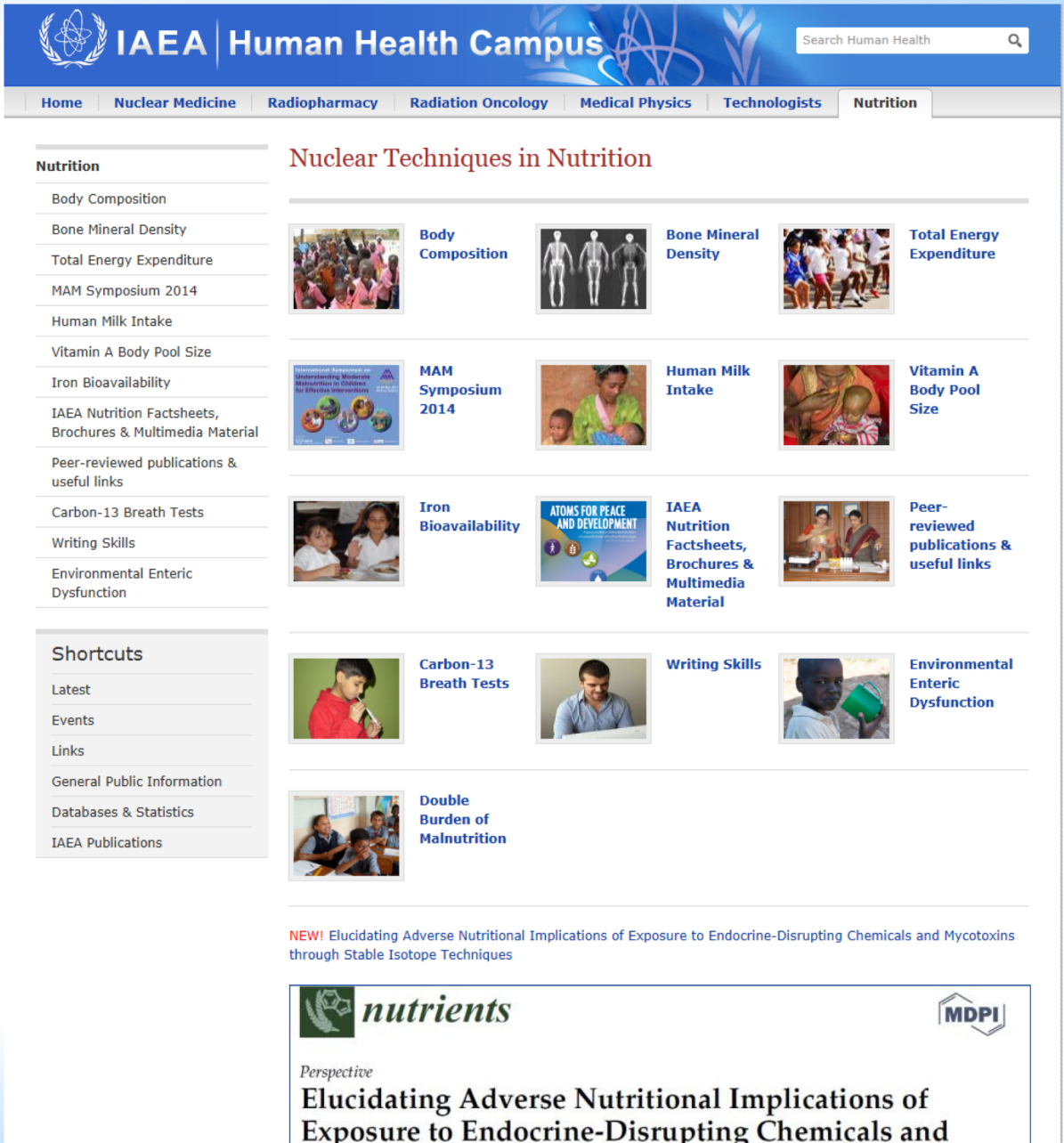
More information: Human Health Campus



https://humanhealth.iaea.org/HHW/Nutrition/index.html

IAEA 60 Years
Atoms for Peace and Development

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Thank you!

Deuterium dose-to-mother technique – measurement points?

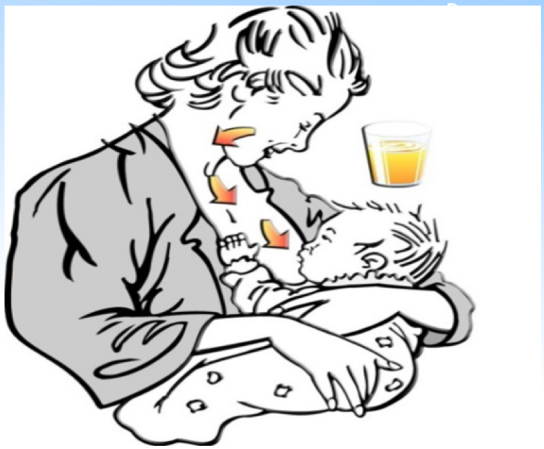
Sampling points:

Days 0, 1, 2, 3, 4, 13, 14 (**7** samples x 2)

Shorter protocol under validation:

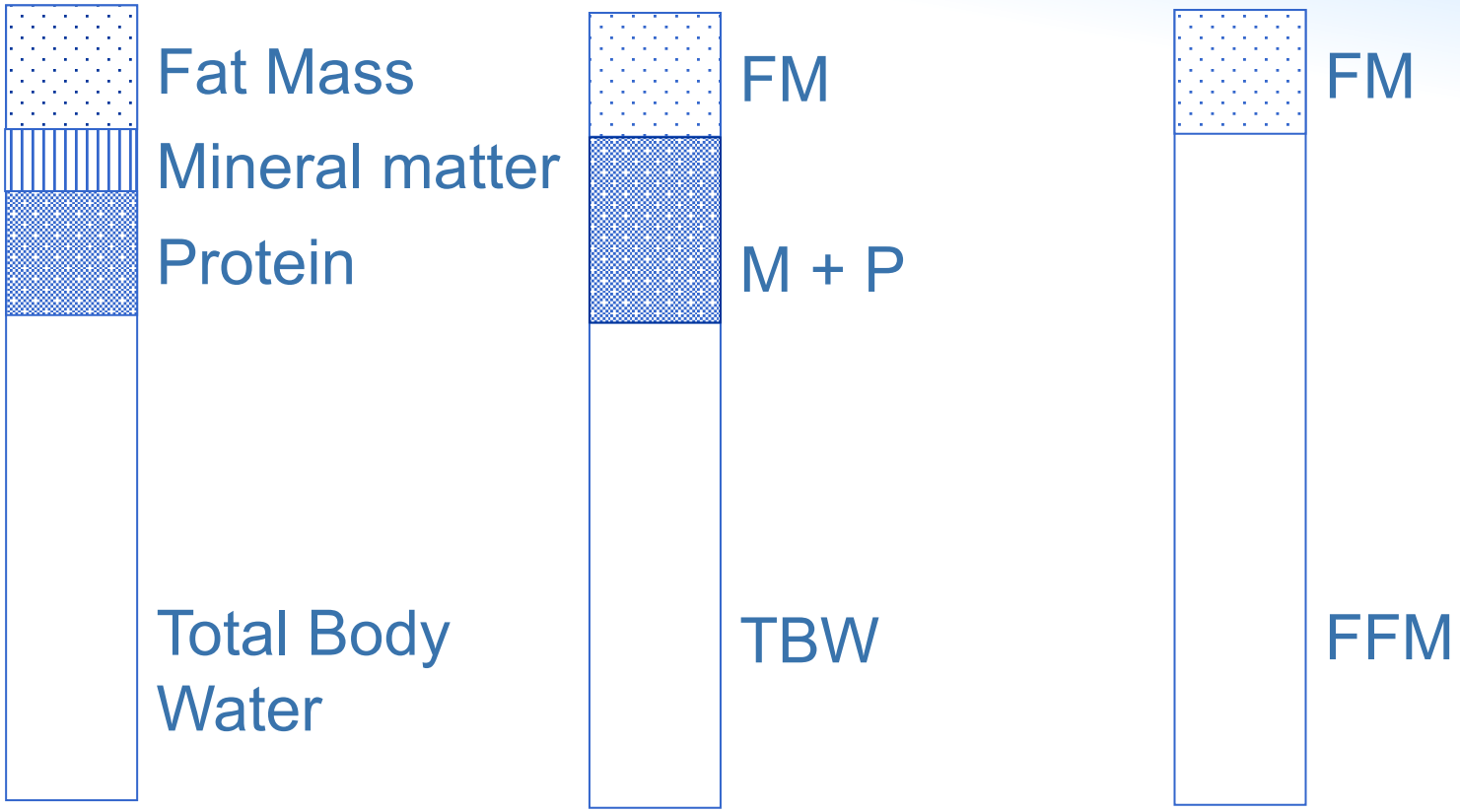
Days 0, 2, 7, 13 or 0, 2, 7, 14 (**4** samples x 2)

Deuterium dose-to-mother technique – costs?



Activity	Cost ($) per mother/baby pair
Inputs (consumables, deuterium)	15
Sample analysis	200
Training	?
Field logistics	?

Deuterium Dilution Technique For Body Composition Is Based On the Two-compartment Model



Four-compartment model Three-compartment model Two-compartment model