NUTRITIONAL STATUS AND GROWTH OF CHILDREN

ON MACROBIOTIC DIETS:

A POPULATION-BASED STUDY

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P.C. Dagnelie

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PROEFSCHRIFT
ter verkrijging van de graad van
doctor in de landbouwwetenschappen,
op gezag van de rector magnificus,
dr H.C. van der Plas,
in het openbaar te verdedigen
op woensdag 23 november 1988
des namiddags te vier uur in de aula
van de Landbouwuniversiteit te Wageningen

In dank aan mijn ouders en Gabriele

Dit onderzoek werd financieel ondersteund door het Praeventiefonds.

1. De gevallen van macrobiotisch gevoede kinderen die met voedingstekorten in een ziekenhuis zijn opgenomen, vormen geen incidentele uitzonderingen, doch zijn het topje van de ijsberg van onderliggende tekorten bij een groot deel van de macrobiotische populatie.
(dit proefschrift)

2. Het niet vinden van voedingstekorten ten gevolge van vegetarisch gerichte voedingswijzen in sommige onderzoeken moet in de eerste plaats worden toegeschreven aan zwakke punten in de onderzoeksmethodiek.

3. Calciumtekort kan een onafhankelijke oorzaak zijn bij het ontstaan van rachitis.
(dit proefschrift)

4. Het bestaan van overgevoeligheid voor koemelkprodukten bij sommige kinderen vormt geen aanleiding om deze produkten voor iedereen uit te sluiten. Veeleer moet in voorkomende gevallen van overgevoeligheid ernaar gestreefd worden, deze te verhelpen.

5. Het advies om minder vet in de voeding te gebruiken is voor volwassenen met een westers voedingspatroon gerechtvaardigd, maar voor jonge kinderen funest.

6. De klassieke mening, dat zonder de consumptie van dierlijke produkten een natuurlijke voeding niet in de vitamine B12 behoefte kan voorzien, is juist. Tot dusverre is geen betrouwbare plantaardige bron van vitamine B12 aangetoond.
(dit proefschrift)

7. Een bloedcel-volume (MCV) binnen de normaalwaarden van een populatie sluit het bestaan van een vitamine B12-tekort bij individuen met een vegetarische voeding niet uit.
(dit proefschrift)

8. Het systematisch weren van bepaalde natuurlijke produkten uit de voeding kan in geval van ziekte tijdelijk noodzakelijk zijn, maar schaadt op den duur het lichaam. De mens maakt zich hierdoor tot een kasplant die tegen de natuurlijke weersinvloeden niet bestand is.

9. Teneinde de concentratie van gifstoffen in moedermelk te verlagen is niet-roken en een matig gebruik van dierlijke produkten aan te raden.

10. Eventuele goede elementen in de macrobiotische voeding zullen geen erkenning vinden zolang nog ondervoeding bij macrobiotisch gevoede kinderen voorkomt.

11. Het is nog beter in het geheel niet bij de voeding stil te staan, dan er een dogma van te maken.

12. Critici van alternatieve geneeswijzen blinken doorgaans niet uit door een grote deskundigheid ten aanzien van hetgeen waarover zij oordelen.

13. De vermelding in personeelsadvertenties dat "bij gelijkwaardige kandidaten vrouwen de voorkeur verdienen", vormt een achterstelling van de man.

14. De opvatting dat de kans op een ernstig ongeluk bij kerncentrales of booreilanden "verwaarloosbaar klein" is, berust op een verkeerd gebruik van de statistiek, zoals de rampzalige gebeurtenissen van de afgelopen jaren leren.

15. Door het instellen van een avondklok tussen 23.00 en 6.00 uur in de vorm van een alarminstallatie draagt de Landbouwuniversiteit in belangrijke mate bij aan de gezondheid van haar promovendi.

16. Het invloedrijkste deel van een wetenschappelijk proefschrift wordt gevormd door wetenschappelijk niet bewezen stellingen.

17. In het kader van antropometrisch onderzoek is spanwijdte een rekbaar begrip.

Stellingen behorende bij het proefschrift van P.C. Dagnelie
Nutritional status and growth of children on macrobiotic diets: a population-based study

Wageningen, 23 november 1988

Der Endzweck der Wissenschaften ist Wahrheit. Wahrheit ist der Seele notwendig.

Gotthold Ephraim Lessing

NUTRITIONAL STATUS AND GROWTH OF CHILDREN ON MACROBIOTIC DIETS: A POPULATION-BASED STUDY

THESIS, DEPARTMENT OF HUMAN NUTRITION, AGRICULTURAL UNIVERSITY, WAGENINGEN, THE NETHERLANDS, 23 NOVEMBER 1988.

P.C. Dagnelie

Abstract

This thesis reports on the relationship between diet, growth, blood chemistry, psychomotor development, and clinical findings in the Dutch population of children on macrobiotic diets. The macrobiotic diet mainly consisted of cereals, pulses and vegetables with small additions of seaweeds, fermented foods, nuts and seeds. Meat and dairy products were avoided, whereas fish was occasionally being eaten but not by young children. The total Dutch macrobiotic population was invited to join the study; the refusal rate was below 5 per cent. A cross-sectional anthropometric study in macrobiotic children between birth and 8 years of age (n = 243) revealed that the age curves declined from the P50 of the Dutch standard mainly between 6 and 18 months of age. A partial return towards the P50 was observed after 2 years of age for weight and arm circumference, but not for height. A subsequent mixed-longitudinal study in macrobiotic infants aged 4 - 18 months and a matched omnivorous control group showed that growth of the macrobiotic infants was slowest between 8 and 14 months. This was attributed to a lack of both energy and protein in the macrobiotic weaning diet. The observed growth retardation was associated with retardation in gross motor and language development. For calcium, vitamin D, vitamin B12 and riboflavin, a low intake in combination with biochemical evidence of deficiency was found. Rickets was present in 28 per cent of macrobiotic infants in summer and 55 per cent in winter. As a favourable aspect, lower levels of contaminants were found in the breast-milk of macrobiotic mothers. It is concluded that nutritional deficiencies are present in a high proportion of macrobiotic infants. Continued marginal deficiencies in older macrobiotic children seem to prevent catch-up growth in height. It is advised to adapt the macrobiotic diet as to include fatty fish (100 - 150 g/week), oil (20 - 25 g/day) and dairy products (one serving per day).

Contents

Voorwoord

Voor de wetenschappelijke lezer

Bij de werkcolleges die ik indertijd op het gebied van de voorlichtingskunde mocht volgen, leerde ik dat er twee vormen van wetenschappelijk onderzoek te onderscheiden zijn: **conclusiegericht** en **decisiegericht** onderzoek.

Conclusiegericht onderzoek heeft als doel het vermeerderen van wetenschappelijke kennis. Echter, kennis heeft alleen zin wanneer deze ook wordt toegepast. De bedoeling van decisiegericht onderzoek is tot praktische toepassing van de gevonden resultaten bij te dragen. Deze vorm van onderzoek is vooral van belang als het onderzoek praktische consequenties voor het menselijk gedrag heeft, zoals in de voedings- en gezondheidswetenschappen vaak het geval is.

Het onderwerp van dit proefschrift, de voedingstoestand van macrobiotisch gevoede kinderen, heeft bij uitstek zulke praktische gevolgen. Bij de opzet van dit onderzoek moest dan ook bij voorbaat met een eventuele toepassing van de resultaten rekening worden gehouden. Om deze reden is bijvoorbeeld in een vroegtijdig stadium contact gezocht met leidinggevende personen in de macrobiotische wereld.

In deze dissertatie komt hoofdzakelijk het conclusiegerichte aspect, of in goed Nederlands: de "harde cijfers", naar voren. Echter, het is juist de combinatie van conclusie- en decisiegerichte aspecten in hetzelfde onderzoek geweest, die tot de opmerkelijk goede medewerking van macrobiotische zijde heeft geleid en daarmee tevens het trekken van duidelijke conclusies uit dit onderzoek heeft mogelijk gemaakt.

Voor de macrobiotisch geïnteresseerde lezer

Zoals hierboven is aangegeven, kon dit onderzoek alleen tot een goed einde worden gebracht dankzij de voortreffelijke medewerking van velen binnen de macrobiotische beweging, in de allereerste plaats de gezinnen die aan het onderzoek deelnamen. Voor vele ouders moet het een gevoel van teleurstelling zijn geweest, toen de eerste onderzoeksresultaten bekend werden. Ik ben mij hiervan terdege bewust. Gelukkig leert een macrobiotische grondbeginsel, dat iedereen "student" is: we zijn er om van onze fouten te leren. Op ons als onderzoekers rustte de verantwoordelijkheid, hieraan naar beste kunnen een bijdrage te leveren.

Om deze reden zijn de voorlopige resultaten al in het voorjaar van 1987 besproken met macrobiotische leraren tot op het hoogste niveau. Hiernaast hebben wij door middel van een nieuwsbrief de ouders regelmatig van nieuwe resultaten op de hoogte gehouden. Dit alles heeft een proces van verandering in de macrobiotische beweging ten gevolge gehad, waarvan het einde nog niet in zicht lijkt.

Zoals altijd, waren er ook hier bepaalde hindernissen die het doorvoeren van veranderingen in de weg stonden, en gedeeltelijk nog staan. Gezien het feit dat uitgangspunten die jarenlang als vaste waarheid hebben gegolden, nu plotseling ter discussie worden gesteld, is dit begrijpelijk. Het zou echter niet juist zijn om vanwege dergelijke redenen nieuwe informatie terzijde te schuiven.

Ohsawa heeft ooit gezegd, dat arrogantie de ergste ziekte is. Wie werkelijk flexibel is, zoals het ideaal van de macrobiotiek is, zal na het kennisnemen van de onderzoeksresultaten deze niet op anderen afschuiven maar zijn eigen handelen toetsen en corrigeren.

In concreto betekent dit dat naast de noodzaak van het gebruik van vette vis en naar verhouding veel meer vet in de macrobiotische kindervoeding, ook openheid voor het gebruik van zuivelprodukten een absolute noodzaak is.

Als dit onderzoek tot **deze** openheid een steentje heeft bijgedragen, is de inzet van de deelnemers niet voor niets geweest.

Dankwoord

Zoals elk proefschrift, was ook dit het resultaat van noeste arbeid van velen. Aan hen allen wil ik hierbij mijn dank uitspreken.

Enkele personen wil ik graag in het bijzonder noemen. Allereerst mijn promotoren, prof. dr J.G.A.J. Hautvast en prof. dr W.A. van Staveren, die mij de gelegenheid gaven om onder hun vleugels dit interessante en leerzame onderzoek uit te voeren. Naast kritisch commentaar op manuscripten waren zij beiden in alle fasen van het onderzoek, met name bij het formuleren van praktische adviezen, een belangrijke steun. De Landbouwuniversiteit en het Praeventiefonds wil ik danken voor de financiële steun aan dit onderzoeksproject. Van de wetenschappelijke begeleidingscommissie ben ik in het bijzonder prof. dr E.D.A.M. Schretlen zeer erkentelijk voor zijn waardevolle adviezen, gegeven vanuit zijn grote ervaring als kinderarts en als mens.

Alle ouders die aan dit onderzoek medewerking verleenden, zowel de macrobiotische ouders als de ouders van de gangbaar gevoede groep, wil ik hiervoor danken. Bij het werven van de marobiotische deelnemers speelden het Kushi Instituut en de regionale Oost-West Centra een belangrijke rol. Ik ben de heer en mevrouw Nelissen erkentelijk voor hun coördinerende rol hierbij. Ook wil ik de heer en mevrouw Faber danken, die speciaal naar Wageningen kwamen om voor ons een aantal kindermaaltijden te koken. De heer en mevrouw de Graaf, de heer en mevrouw Heijnen en heel in het bijzonder mevrouw J. Schalkwijk wil ik danken voor hun constructieve bijdrage in het overleg met macrobiotische leraren. Ook de gesprekken met mevrouw N. Goud vormden een belangrijke bijdrage; ik ben haar erkentelijk voor het initiatief, de grote lijn van deze onderzoeksresultaten in het nawoord van de derde druk van "Koken voor je leven" te verwerken. Haar en de uitgever, Zomer en Keuning, dank ik voor de toestemming om de tekst van het nawoord als los manuscript onder de deelnemers van het onderzoek te mogen verspreiden.

Zonder medewerking van de gangbaar gevoede gezinnen was een belangrijk deel van de conclusies van dit proefschrift niet mogelijk geweest. Het is binnen de structuur van de Nederlandse gezondheidszorg helaas lang niet overal mogelijk langs officiële weg op korte termijn medewerking te krijgen voor het werven van deelnemers voor een onderzoek als dit. Voor de werving van deelnemers was ik dan ook aangewezen op enkele consultatiebureau-artsen en -wijkverpleegkundigen die zich hiervoor bijzonder hebben ingezet. In verband hiermee wil ik mijn grote erkentelijkheid uitspreken aan dr H.G.J. Nijhuis, dr M.J. Roede, de stichting Het Groene Kruis in Den Haag, met name zr L. van Zorge, zr A. v.d. Burcht, zr van Bekkum, zr A. Kiela; de Provinciale Kruisvereniging Friesland, en de volgende CB-artsen en wijkverpleegkundigen: mw E.H. Wouters-v.d. Weijden, mw M.E. Fogteloo-Broecker, zr C. van Rossum, mw C.M. van de Werd-Molman, mw H.M.A. Uytdewilligen, zr A. Struik, mw Zijlstra-van Mierlo en mw A.M. van den Berg-Rookus, evenals alle andere artsen en wijkverpleegkundigen die hiertoe hebben bijgedragen.

Bij de verzameling en verwerking van de gegevens speelden velen een rol. mw S.A.J.M. Verschuren was in alle fasen van het onderzoek een belangrijke en energieke steun. Als kinderarts verzamelde en beoordeelde de heer F.J. Vergote op uiterst zorgvuldige en objectieve wijze de medische gegevens. Aan zijn vakbekwaamheid is het te danken, dat het bij vrijwel alle kinderen direct lukte om met behulp van een handprik bloed af te nemen. ir J.D. van Klaveren nam de organisatie van de computerverwerking en alle voorbewerkingen van de gegevens voor zijn rekening.

De laboratoriumbepalingen werden zeer welwillend verricht door medewerkers van het Ziekenhuis Gelderse Vallei te Wageningen, het Centraal Instituut voor Voedingsonderzoek TNO te Zeist en het Coronel Laboratorium te Amsterdam. Hiervoor wil ik dank zeggen aan de heren dr P.G. Dingjan, R.

Mulder en H. Leever, evenals dr H. van den Berg, mw J. van Rooyen-van Beek en dr A.A.E. Wibowo.

Niet minder dan 26 doctoraalstudenten vormden een onmisbare hulp bij de voorbereiding, praktische uitvoering en verwerking van een deel van de onderzoeksgegevens en ik ben hen erkentelijk voor het vele, vaak zeer gedegen werk dat zij hebben verricht.

Toen het onderzoek begon, beschikten wij niet over goede gegevens over de samenstelling van een aantal voedingsmiddelen die in de macrobiotische voeding veel worden gebruikt. Het Ministerie van Landbouw en Visserij verstrekte een aanvullende subsidie die het mogelijk maakte 50 voedingsmiddelen en 30 moedermelkmonsters te analyseren. Naast de medewerkers van de vakgroep en het Rijks- Kwaliteits Instituut (RIKILT) te Wageningen en de studenten die hiertoe bijdroegen, wil ik speciaal mw M.A.W. Willems danken, die de haar taak als coördinatrice van dit omvangrijke project zeer consciëntieus vervulde. Voor de analyse van contaminanten in moedermelk ben ik de directie en medewerkers van het RIKILT erkentelijk.

Bij verschillende delen van het onderzoek speelden adviseurs binnen en buiten de vakgroep een belangrijke rol. Ik noem hier speciaal prof. dr J.C. van Wieringen, die in alle fasen van het onderzoek waardevolle adviezen over het antropometrische gedeelte van het onderzoek gaf. Mw dr E.A. Schlesinger-Was en dr R. Kleber adviseerden bij het psychomotorische deel van het onderzoek. Voor het oplossen van statistische problemen stond drs J. Burema steeds klaar, in de flank gesteund door de expertise van dr M.A. van 't Hof, die naast de inbreng van zijn deskundigheid er niet voor terugschrok om enkele malen persoonlijk achter de terminal plaats te nemen, wanneer de moeilijkheidsgraad van de vereiste bewerkingen onze eigen computervaardigheid te boven dreigde te gaan. Voor praktische steun op computergebied aan het thuisfront wil ik mw H. van Oosten en dhr B. Scholte van harte danken.

Een aanzienlijk aantal medewerkers van de vakgroep en de diverse diensten van het Biotechnion zorgde voor de praktische ondersteuning. Ik denk hierbij vooral aan de hulp van alle medewerkers van het vakgroepssecretariaat bij het afdrukken van een schier onafzienbare reeks van voor-, tussen- en eind-concepten op de laserprinter; de technische dienst voor het vervaardigen van meetapparatuur; en de teken- en fotografieafdeling die de figuren steeds snel en uitstekend verzorgden. Voor het corrigeren van de Engelse concepten ben ik de heer J. Hudson en in het bijzonder mevrouw H. West zeer erkentelijk.

Tenslotte dank ik mijn ouders, die het mij niet alleen mogelijk maakten deze opleiding te volgen maar ook tijdens en na mijn studie het wel en wee op de voet volgden; en, last but not least, mijn vrouw. Zij werkte vrijwillig een jaar lang mee bij het afleggen van de huisbezoeken, hielp bij het regelmatig versturen van ruim 200 nieuwsbrieven, een taak die ik alleen onmogelijk had kunnen volbrengen, en was bij het overleg over de toepassing van de onderzoeksresultaten een onmisbare morele en feitelijke steun.

To the English reader

For their essential role in discussing the study findings and their support in implementing them, I am greatly indebted to the following persons:

Dr J.T. Dwyer, Frances Stern Nutrition Center, Boston, USA
Dr B. Specker, Dept of Pediatrics, University of Cincinnati, Ohio, USA
Mr and Mrs Coème, London, England
Mr and Mrs Acuff, Ulricehamn, Sweden
Dr Lawrence H. Kushi, Seattle, Washington, USA
Mrs G. Bruce, East-West Journal, Boston, USA.

I am also indebted to Mr Michio Kushi for his ready promise to adapt the macrobiotic diet according to our advice.

P.C. Dagnelie

1 Introduction

In the last two decades, alternative dietary lifestyles have become increasingly popular in Western countries. Most such lifestyles are characterized by some degree of avoidance of foods of animal origin. Lacto-vegetarian diets are diets which do not contain meat or fish, whereas strict vegetarians (vegans) avoid any food of animal origin.

Concern has been expressed about the risks of nutritional deficiencies, especially in children on diets containing little animal food. Since 1966 a number of reports have been made in the United States especially by the American Academy of Pediatrics, the National Research Council, the American Medical Association and other organizations.[1-7] According to these reports, the major groups at risk are children on strictly vegetarian diets. Nutritional deficiencies most likely to occur would be protein-energy malnutrition and shortage of calcium, iron, riboflavin, vitamin B12 and vitamin D.[3] Reference is also made to potential deficiencies in zinc,[7] folate[6,8] and vitamin C.[2,8] One of the diets mentioned frequently as potentially deficient is the macrobiotic diet,[1-6,8-11] a diet restricted in animal food which was described by Ohsawa (1965)[12] and more recently Kushi (1977, revised 1987).[13]

The concern expressed in these reports is based mainly on incidental information on hospital admissions[9-11,14-22] or deaths of severely malnourished children on alternative diets. Although cases of death are mentioned to have occurred,[2,5] they have rarely or never been thoroughly described in the medical press, probably because they were not well documented.

The question remains, however, whether such cases of malnutrition are incidental, or represent ubiquitous nutritional deficiencies in children on alternative diets. Below, we shall discuss in how far the available literature provides an answer to this question.

Relevance of the literature

Individual case studies as such do not permit conclusions to be drawn on the nutritional status of a population. On the one hand, they may represent the "top of the iceberg". For instance, the case studies refferred to may represent a much larger number of malnourished children who for some reason are never admitted to hospital. On the other hand, they may be only incidental cases caused by confounding factors. For instance, malnutrition may have been caused by faulty practices of parents who have not properly applied the basic principles of the alternative food system. Other confounding factors in the case history may be the previous food habits of the parents, drug abuse, or social and psychological problems.[10,24,25]

In order to assess the nutritional status of a community population-based studies need to be carried out. In the last 15 years, a number of studies have been done in groups of children on alternative diets, of which certainly the most important ones are the studies by Dwyer and coworkers in children on macrobiotic diets in Boston, USA.[26-31] While considerable insight has been gained from many of these studies, their potential impact has been reduced for a numberof reasons:

- Most studies are based on a small number of children;
- Little information is given on the food habits of the study sample and selection criteria for the participants are often not clearly defined. In many studies, participants have been selected on the basis of their own statement about their food habits. This is not a valid criteria. For instance, in the pilot study for this research project, some repondents declared themselves to be "vegetarian", even though, in fact, they consumed meat twice per week.
- Very often no information is available on the representativeness of the sample of the concerned population.
- No study includes a comparable control group of children on omnivorous diets.
- Virtually all studies use a cross-sectional design. However, it is well established that the nutritional status of children is better indicated by longitudinal information on growth velocity than by cross-sectional anthropometric information.[32]
- Most studies are restricted to anthropometric and dietary data. Very little information is available on blood chemistry in children on alternative diets.[30]
- The diet of young children changes greatly during the first two years of life, but these changes are not taken into account in most studies. For instance, no study has concentrated on the age of weaning, that is the period between 6 and 18 months of age, yet nutritional deficiencies are most likely to affect growth and development during this age period.[26,33] No study has assessed the quantitative intake of breast-milk.
- The nutritional composition of foods consumed in some dietary systems, the

macrobiotic food system especially, is not accurately known.[9]

It may be concluded that insufficient data is available in the literature on which to base a conclusion as to whether vegetarian diets are either harmful or favourable to children. The present research project, therefore, aims to collect information which would provide the foundation for conclusions on the nutritional status of children on one specific alternative diet.

Research project

A cross-sectional pilot study was performed in children aged 1 to 3 years on lacto-vegetarian and macrobiotic diets, respectively, and a control group on omnivorous diets. The macrobiotic diet consists of cereals (mainly unpolished rice), pulses and vegetables with small additions of seaweeds, fermented foods, nuts and seeds. Meat, dairy products and fruits are avoided. Lean (white) fish may be taken occasionally if desired, but is rarely given to young children.

The results of this pilot study, which have been reported elsewhere,[34] showed that anthropometric parameters and the intake of energy and nutrients by macrobiotic children deviated most from current norms. For this reason, it was decided to investigate the nutritional status, growth and development of the population of children on macrobiotic diets. The following specific questions were formulated:

1. **Do growth pattern and growth velocity differ in children on macrobiotic and omnivorous diets?**
2. **Does the concentration of blood nutrients differ in children on macrobiotic and omnivorous diets?**
3. **What are the health consequences of any deviations found?**
4. **Is there a nutritional explanation for these differences?**
5. **On the basis of these findings, can practical guidelines be formulated to overcome these deficiencies within the scope of the current macrobiotic food system?**

Below, the major parts of this research project are briefly described.

Parts of research project

The research project consisted of several related studies, of which the following are reported in this thesis:

1. **A literature review,** which is reported in Chapter 2 in the Dutch language.

2. A population-based **cross-sectional study** in 246 children on macrobiotic diets aged 0 - 8 years. The purpose of this study was to ascertain the age at which growth in macrobiotic children would slow down, and whether there is a return to anthropometric standards later in childhood. This study is described in Chapter 3.
3. A population-based **mixed-longitudinal study** in 53 infants aged 4 - 18 months on macrobiotic diets and a matched control group on omnivorous diets. The objective of this study was to check whether the findings of the cross-sectional study would be confirmed by longitudinal data on growth, and whether there is a relationship between growth, clinical findings, psychomotor development, biochemical parameters and intake of energy and nutrients. The study design included regular anthropometric measurements and psychomotor evaluation, collection of dietary information at different ages, and a medical examination with blood sampling in summer and winter. This study is reported as follows:
   - study design and intake of energy and nutrients: Chapter 4;
   - biochemistry related to the iron and vitamin B12 status: Chapter 5;
   - biochemical and clinical findings on the vitamin D and calcium status: Chapter 6;
   - growth, psychomotor development and clinical findings: Chapter 7.
4. Analysis of **contaminants in breast-milk** of mothers on macrobiotic diets and a control group on omnivorous diets: Chapter 8.

During the period of the present research project a number of closely related studies were carried out, which will not be reported in this dissertation. For the interested reader, they are mentioned below:
- An intervention study in participants of the mixed-longitudinal study and a follow-up study when they were two years of age;
- Analysis of nutrient content of macrobiotic foods,[36] macrobiotic weaning dishes,[37] and breast-milk of mothers on macrobiotic and omnivorous diets;[38]
- A study of the mental development in macrobiotic children aged 4 - 6 years.[39]

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2 Literature review: De gezondheid en voedingstoestand van 'alternatief' gevoede zuigelingen en peuters, feiten en onzekerheden

I. DEFINITIES EN ALGEMENE GEZONDHEIDSINDICATOREN

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SAMENVATTING

Er is de laatste jaren een sterk toegenomen belangstelling voor alternatieve zuigelingen- en peutervoeding en – hiermee samengaand – in de gezondheidsconsequenties hiervan. In dit artikel, het eerste van een serie van twee, wordt een actueel overzicht van dit gebied gegeven. Het artikel geeft eerst een globale begripsomschrijving van de richtlijnen voor zuigelingen- en peutervoeding binnen enkele alternatieve voedingsrichtingen in Nederland en behandelt vervolgens enkele problemen waarmee men bij de interpretatie van de wetenschappelijke literatuur over dit onderwerp wordt geconfronteerd. Tenslotte worden literatuurgegevens betreffende algemene gezondheidsindicatoren zoals het zwangerschapsverloop van de zich alternatief voedende moeder en de groei en ontwikkeling van het kind besproken. Alternatief gevoede peuters van ongeveer 1/2 tot 3 jaar blijken kleiner en lichter voor hun leeftijd dan gangbaar gevoede leeftijdgenootjes, terwijl er aanwijzingen bestaan voor een versnelde groei vanaf 2 jaar. De betekenis van deze gegevens wordt besproken.

SUMMARY

In this first article out of a series of two articles, a critical review of available scientific information on the nutritional consequences of alternative and especially vegan-type food habits in infants and preschool children is presented. This article involves definitions and information on general health indicators, such as the health of mothers during pregnancy and the growth and development of children. Some difficulties in interpreting available literature are also discussed. Many of the available case studies do not seem to be representative for population groups of infants and children fed alternative diets. Population studies mostly lack a control group and do not provide information on whether the sample is representative or not. Because of changing alternative food habits, some studies may be outdated. Alternatively fed toddlers six months to three years old, especially macrobiotics and veganists, seem to be somewhat smaller than their counterparts eating mixed diets, whereas there is some evidence of increased growth after the age of two years. The significance of these differences is not completely clear.

INLEIDING

In de wetenschappelijke literatuur van de laatste 20 jaar zijn herhaaldelijk berichten verschenen over risico's van ondervoeding bij zuigelingen en peuters die volgens een zogenaamde 'alternatieve' wijze worden gevoed. Vooral in de Verenigde Staten zijn hierover sinds 1966 regelmatig officiële uitspraken van medische colleges, zoals de American Academy of Pediatrics, de National Research Council en de American Medical Association verschenen.[1-6] Als risicogroep worden in het bijzonder streng-vegetarisch (veganistisch) gevoede kinderen genoemd, als risiconutriënten voor deze groep noemt men calcium, ijzer en de vitamines B_2, B_{12} en D. In Nederland is de laatste 15 jaar eveneens sprake van een sterke toename van alternatieve zuigelingen- en kindervoeding. Deze groep wordt herhaaldelijk als risicogroep genoemd.[7-13] Op grond hiervan stelden diverse instanties reeds richtlijnen voor alternatieve zuigelingen- en peutervoeding op.[7, 14-19] Over de feitelijke voedingstoestand van alternatief gevoede kinderen is in Nederland echter weinig bekend. Ook een gedocumenteerd overzicht van internationale literatuur op dit gebied bestaat tot dusverre in Nederland niet. Door middel van een serie van twee artikelen willen wij in deze leemte voorzien. In dit eerste artikel zullen wij drie vragen behandelen:

I. Wat verstaan wij onder alternatieve voeding en welke hoofdrichtingen zijn te onderscheiden?

II. Welke moeilijkheden ondervindt men bij de interpretatie van literatuurgegevens over de gezondheid van alternatief gevoede zuigelingen?

III. Zijn er aantoonbare verschillen in het zwangerschapsverloop van de moeder en de groei en de ontwikkeling van zuigelingen op een alternatieve voeding in vergelijking tot de gangbare voeding en wat is de betekenis hiervan?

Vakgroep Humane Voeding, De Dreijen 12, 6703 BC Wageningen.

In het tweede artikel zal op het eventuele vóórkomen van specifieke voedingsdeficiënties ten gevolge van alternatieve voedingswijzen worden ingegaan.

1. WAT VERSTAAN WIJ ONDER ALTERNATIEVE VOEDING EN WELKE HOOFDRICHTLIJNEN ZIJN TE ONDERSCHEIDEN?

Volgens Van Dale is 'alternatief' onder andere 'de andere van twee mogelijkheden betreffend, thans in 't bijzonder voor: gevestigd op geheel nieuwe beginselen, gericht op een geheel andere dan de heersende maatschappelijke orde'. Voor de voeding betekent dit gewoonlijk het afwijzen van 'gangbare', dat wil zeggen elders in de samenleving gebruikelijke produktie- en verwerkingsmethoden en het gebruik van overwegend onbewerkte voedingsmiddelen zoals deze in zogenaamde biologische winkels en deels ook in reformhuizen worden verkocht. Geïsoleerde stoffen, zoals suiker, witmeel, voedings- en vitaminepreparaten worden gemeden. Op de motivatie en achtergronden van de alternatieve voedingsbeweging zal hier niet verder worden ingegaan. Wel willen we opmerken, dat met 'alternatieve voeding' in dit verband geen modegril, zoals bijvoorbeeld een rage van veelal dure voedingspreparaten zoals zemelen, wordt bedoeld. Het gaat om een groep mensen met een consistent, gezondheidsbewust en veelal sober voedingspatroon met een doorgaans ideële of levensbeschouwelijke grondslag. Binnen de alternatieve voedingswereld bestaan tussen de mensen onderling aanzienlijke verschillen in de voeding. Het is dan ook niet verwonderlijk, dat er wat betreft de nomenclatuur bij binnen- en buitenstaanders een welhaast babylonische spraakverwarring heerst. Hieronder zullen wij pogen om – voor zover in kort bestek mogelijk – hierin enige duidelijkheid te scheppen.

Allereerst de term 'vegetarisme'. Dit woord heeft betrekking op het bewust uitsluiten van een aantal dierlijke produkten uit de voeding en betreft dus het concrete gedrag, zonder iets over de achterliggende motieven te zeggen. Veelal wordt hierbij nader onderscheid gemaakt tussen enerzijds lacto-(ovo-)vegetariërs, die vlees en vis mijden maar wel melk resp. eieren gebruiken, en anderzijds veganisten, die alle dierlijke produkten afwijzen. Wij zullen verderop zien, dat deze veel gebruikte verzamelbegrippen in de praktijk soms verwarring geven.

Naast deze indeling naar voedingsgedrag kan men een nadere opsplitsing maken naar de achterliggende denkwijze of het denksysteem, zoals bijvoorbeeld de antroposofie of de macrobiotiek. Hieronder volgen enkele kenmerken van drie alternatieve voedingsstromingen (-systemen) in Nederland waarbinnen bepaalde richtlijnen voor zuigelingenvoeding bestaan:

1. Bij de ecologische voedingswijze staan rationele motieven zoals het goede beheer van de beperkte aardse hulpbronnen centraal. Onder meer vanwege het lagere energie- en eiwitrendement* bij dierlijke ten opzichte van plantaardige produktie en vanwege de samenhang van diverse welvaartsziekten met een voeding rijk aan dierlijk vet en cholesterol geeft men de voorkeur aan een overwegend plantaardige voeding (o.a. volle granen en peulvruchten) met als aanvulling zuivelprodukten en eieren. De richtlijnen voor de ecologische zuigelingenvoeding zijn geënt op de gangbare voedingschema's. Aan borstvoeding kent men een hoge prioriteit toe; bij ontbreken hiervan geeft men in het algemeen de voorkeur aan koemelkwatermengsels boven gehumaniseerde voeding. Bijvoeding begint vanaf ongeveer 5 maanden. Granen worden langzaam geïntroduceerd en de soort en bereidingswijze worden aangepast aan de leeftijd van het kind (eerst afkooksels, geen gluten vóór 6 maanden). Met betrekking tot vitamine D-profylaxe neemt men een tussenpositie in: de nadruk wordt gelegd op dagelijkse blootstelling aan de zon, met in twijfelgevallen c.q. bij risicogroepen (flessekinderen, donkere huid) een vitamine D-preparaat.

2. De antroposofische voedingswijze is gebaseerd op het mensbeeld van Rudolf Steiner, waarin een relatie tussen lichaam en geest, aarde en kosmos wordt gelegd als basis voor het handelen. Men kent een eigen landbouwmetho-

* De begrippen energie- en eiwitrendement hebben betrekking op de hoeveelheid voor de mens beschikbare energie resp. eiwit die op een bepaald landbouwareaal geproduceerd kan worden. Granen kunnen hetzij direct door de mens gegeten worden, hetzij via het vee als voeding voor de mens dienen. In dit laatste geval gaat een aanzienlijk deel van de energie resp. het eiwit verloren.

de, de biologisch-dynamische landbouw, waarin met deze kosmische krachten rekening wordt gehouden. In de kindervoeding beschouwt men de individuele ontwikkeling als maatgevend, niet vaste voorschriften. Gewoonlijk begint na 3-4 maanden van uitsluitend borstvoeding de bijvoeding met groente- of vruchtesap, ook gebruikt men veelal koemelk-watermengsels met graanafkooksels of meelprodukten. Vlees, eieren en peulvruchten worden niet aanbevolen, terwijl een matig zoeten met natuurlijke zoetmiddelen (ook voor zuigelingen) niet wordt afgewezen. In plaats van de gangbare vitamine D-profylaxe gebruikt men ten behoeve van de botontwikkeling kalkvoedingszouten en homeopatische preparaten.

3. In de macrobiotische voedingswijze streeft men via de voeding naar een evenwicht tussen twee complementaire krachten, yin en yang genoemd. Deze begrippen stemmen overeen met de natuurwetenschappelijk bekende termen 'positief' en 'negatief' (elektriciteit), manlijk en vrouwelijk, sympathicus en parasympathicus. De toepassing van deze polariteit op de voeding wordt overigens in diverse niet-westerse culturen gevonden (heet-koud). De macrobiotische voeding bestaat uit volle granen en groenten, aangevuld met peulvruchten en fermentatieprodukten daarvan, zaden en zeevruchten (zeewier, vis). Vlees en zuivelprodukten worden in principe afgewezen. Voor de zuigeling staat ook hier borstvoeding centraal. Bij onverhoopt ontbreken hiervan werd in de jaren zestig het plantaardige instantprodukt kokoh met water aangelengd, gebruikt. Op grond van de praktijkervaring in die jaren dat kinderen hierop niet goed bleken te gedijen, bevelen thans de macrobiotische organisaties in plaats van kokoh een zelfgemaakt afkooksel van o.a. volle rijst, sesamzaad en peulvruchten aan, met een aanvulling van koemelk tijdens de eerste maanden indien een kind hierop niet blijkt te groeien. In Nederland zijn hiernaast enkele groepen die melkgebruik voor kinderen algemeen aanvaardbaar achten. Borstvoeding wordt zeer lang voortgezet, gewoonlijk tot 1 à $1^1/_2$ jaar; bijvoeding begint na ongeveer 5 à 6 maanden met de langzame introductie van granen, groenten en peulvruchten. Als zoetmiddel worden kleine hoeveelheden gerste- en rijstemout gebruikt, terwijl zout in het eerste levensjaar wordt afgeraden. Fruit wordt weinig gebruikt en het profylactisch gebruik van vitamine D-preparaten wordt afgewezen.

Bij de hierboven gegeven indeling van voedingssystemen willen wij enkele kanttekeningen maken.

Elk der drie besproken voedingssystemen beveelt een beperking of het vermijden van bepaalde dierlijke produkten aan. Toch passen zij niet zonder meer in de eerder genoemde categorieën 'lactovegetariërs' of 'veganisten', aangezien veel antroposofen wel eens vlees eten en de meeste macrobioten af en toe vis en sommigen ook melkprodukten gebruiken. Wel zullen de gebruikte hoeveelheden van deze produkten gewoonlijk klein zijn in verhouding tot de gangbare voeding. De begrippen 'macrobiotisch' en 'antroposofisch c.q. biologisch-dynamisch' worden in de praktijk zeer vaak ten onrechte als verwant of zelfs synoniem gebezigd. In feite hebben deze begrippen betrekking op twee uiteenlopende richtingen die elkaar wederzijds qua denkwijze en voedingsgedrag vrijwel uitsluiten. Een recente discussie[20] is onder meer hierop terug te voeren. Aangezien er binnen elk voedingssysteem grote individuele verschillen in concreet voedingsgedrag bestaan, kan men niet van 'de' antroposofische of 'de' macrobiotische voeding spreken, evenmin als men kan spreken van 'de' gangbare Nederlandse voeding. Niet zelden is sprake van aanmerkelijke verschillen binnen één en dezelfde richting. Daarnaast is in beide genoemde richtingen het streven de voeding aan te passen aan de individuele ontwikkeling en behoeften van het kind, met het gevolg dat het inzicht en de ervaring van de individuele moeder de mate van succes binnen het betreffende voedingssysteem in belangrijke mate zullen bepalen.

II. WELKE MOEILIJKHEDEN ONDERVINDT MEN BIJ DE INTERPRETATIE VAN LITERATUURGEGEVENS OVER DE GEZONDHEID VAN ALTERNATIEF GEVOEDE KINDEREN?

Alvorens tot het bespreken van de literatuur over te gaan, willen wij van enkele moeilijkheden bij de interpretatie van deze literatuurgegevens gewag maken.

Veel berichten in de literatuur beperken zich tot enkele gevallen (casestudies). Zulke extreme gevallen kunnen enerzijds het topje van de 'ijsberg' vormen, terwijl anderzijds in de anamnese van zulke kinderen zeer vaak relevante factoren die los staan van het desbetreffende voedingssysteem blijken voor te komen, zoals de voormalige voedingstoestand van de ouders, psychische en sociale probleemsituaties of voormalig druggebruik.[21-23]

Onderzoeken bij groepen kinderen zijn aanmerkelijk dunner gezaaid. Veelal betreft het kleine aantallen kinderen[24] of heeft de groep een grote leeftijdspreiding.[25] Ook ontbreekt vaak een gangbaar gevoede controlegroep.[25-30] Gegevens over de representativiteit van de onderzochte groep voor de betreffende populatie ontbreken vrijwel steeds. Dit is een belangrijke tekortkoming aangezien het indelen van individuen met hun pluriformiteit naar enkele standaardrichtingen toch al een moeilijke zaak is. Diverse onderzoekers hanteren voor zo'n indeling verschillende criteria, terwijl veelal deze indelingscriteria ook niet duidelijk worden vermeld.[31] Sommige onderzoekers gaan uit van de richting waartoe de respondenten zichzelf rekenen.[32] Dit is geen goede maatstaf, als men bedenkt dat in een Nederlands onderzoek[33] sommige mensen zich 'vegetariër' noemden die tweemaal per week vlees aten. Deze begripsverwarring leidt zoals gezegd ook in de wetenschappelijke literatuur soms tot storende vergissingen, bijvoorbeeld waar in een referaatartikel wordt gesproken over deficiënties bij macrobiotisch gevoede kinderen,[34,35] terwijl in de geciteerde oorspronkelijke literatuur kennelijk van een geheel andere voedingswijze sprake was.[9,36] Informatie over de vraag, hoe lang de families van de onderzochte kinderen reeds alternatief aten – van belang in verband met de ervaring van de moeder in het betreffende denksysteem – ontbreekt vrijwel steeds.

Aangezien in Nederland nauwelijks onderzoek naar alternatieve zuigelingen- en peutervoeding is verricht, grijpen wij terug op internationale literatuur. Er zijn echter ook per richting vaak verschillen van land tot land, zelfs van streek tot streek, zoals bijvoorbeeld met betrekking tot het melkgebruik bij macrobioten. Bovendien zijn er in de loop van de laatste 10 tot 20 jaar duidelijke veranderingen in een aantal alternatieve praktijken opgetreden in de richting van een meer genuanceerde benadering zodat een artikel uit de jaren zeventig veelal niet meer actueel is. Een voorbeeld hiervan vormt de nog steeds regelmatig geciteerde indeling in 10 'dieettrappen' binnen de macrobiotiek,[35,37-39] die in feite door de macrobiotische organisaties reeds sinds het eind van de jaren zestig niet meer wordt gebruikt.

III. ZIJN ER AANTOONBARE VERSCHILLEN IN HET ZWANGERSCHAPSVERLOOP VAN DE MOEDER EN DE GROEI EN DE ONTWIKKELING VAN ZUIGELINGEN OP EEN ALTERNATIEVE VOEDING IN VERGELIJKING TOT DE GANGBARE VOEDING?

Aangezien de veganistische en macrobiotische kindervoeding door het uitsluiten van koemelkprodukten het sterkst van het gangbare patroon afwijkt, richt de bespreking van bovengestelde vraag zich vooral op deze groepen.

Zwangerschapsverloop en geboortegewicht

Kindervoeding begint tijdens de zwangerschap. Het is dus van belang na te gaan, in hoeverre het verloop van zwangerschap en geboorte bij alternatief gevoede moeders van het normale verloop afwijkt. Het enige systematische onderzoek op dit gebied is van Thomas en Ellis[40] (Department of Pathology, Kingston Hospital, England) die het zwangerschapsverloop bij 14 veganisten (28 zwangerschappen) en 18 controlepersonen (41 zwangerschappen) vergeleken. Zij vonden geen significante verschillen in het verloop van zwangerschap en bevalling en evenmin in het geboortegewicht bij beide groepen. In de Verenigde Staten heeft de groep van Dwyer e.a.[25,27,31,32] verschillende onderzoeken bij deels overlappende groepen alternatief gevoede kinderen uitgevoerd, waarin zij naast andere informatie ook naar het (gerapporteerde) geboortegewicht vroegen. De moeders van deze kinderen voedden zich gedurende de zwangerschap reeds alternatief. In twee onderzoeken bleek geen verschil aantoonbaar,[27,32] terwijl eveneens tweemaal [25,31] verschillen tussen macrobiotische en lacto-vegetarische meisjes werd gerapporteerd (3,0 vs 3,5 kg[25]). Dit zijn dus verschillen in geboortegewicht bij kinderen van moeders met een macrobiotische voeding, die absoluut geen melk gebruiken en van moeders die een andere alternatieve voeding gebruiken, waarin wel melk voorkomt. Van een gerapporteerd geboortegewicht van minder dan 2,5 kg was slechts in enkele gevallen sprake. Concluderend moet gesteld worden, dat uit deze beperkte informatie geen systematische verschillen blijken.

Antropometrie.
Eén van de meest gehanteerde parameters voor de ontwikkeling van zuigelingen bestaat in antropometrische gegevens, in het bijzonder lengte en gewicht en daarnaast (onder andere) hoofd- en armomtrek. De vraag ligt dan ook voor de hand of alternatief gevoede kinderen kleiner zijn en langzamer groeien dan gangbaar gevoede kinderen en zo ja, wat de betekenis hiervan is. Er bestaat – anders dan over het vorige onderwerp – een aanzienlijke hoeveelheid literatuur op dit gebied. Bij de bespreking hiervan maken we onderscheid tussen transversale gegevens (gewicht enz. op één bepaalde leeftijd) en longitudinale gegevens (groei).

Transversale gegevens
In Nederland werd recentelijk vanuit de Vakgroep Humane Voeding van de Landbouwhogeschool een onderzoek verricht naar o.a. lengte en gewicht bij peuters van 1 tot 3 jaar van verschillende alternatieve voedingsrichtingen.[33] De ouders werden geworven via advertenties, vlugschriften bij alternatieve verkooppunten en via contactpersonen. Op grond van duidelijk omschreven criteria werden de kinderen ingedeeld in drie groepen, namelijk lacto-vegetarisch (zonder bepaalde richting), antroposofisch en macrobiotisch. Elke groep telde ongeveer 30 kinderen. Als controlegroep diende een aselecte steekproef van 50 kinderen van één consultatiebureau. De cijfers werden vergeleken met de recente Nederlandse standaarden van Roede en Van Wieringen.[41] Het bleek dat de referentiegroep goed overeenkwam met de standaard; de lacto-vegetarische en antroposofische kinderen waren iets lichter en kleiner voor hun leeftijd, terwijl de macrobiotische kinderen aanmerkelijk lichter en kleiner waren (tabel 1). Opmerkelijk is het feit, dat het gewicht naar lengte tussen de groepen niet significant verschilde. Engelse en Amerikaanse literatuur wijst in dezelfde richting: in het algemeen zijn de alternatief gevoede kinderen vanaf 6 maanden iets lichter en kleiner, in het bijzonder veganistisch en macrobiotisch gevoede kinderen, terwijl het gewicht naar lengte meestal weinig van de standaard afwijkt.[28, 29, 30, 32] De schaarse cijfers over huidplooien (triceps, subscapula) geven voor alternatief gevoede kinderen vanaf 6 à 12 maanden vaak iets kleinere waarden, die echter binnen de normale spreiding vallen.[28, 29, 32]

Longitudinale gegevens (groeisnelheid)
Volgens Tanner[42] is de groeisnelheid een veel gevoeliger indicator voor de voedingstoestand dan de totale lengte resp. het gewicht. Zulk longitudinaal onderzoek is echter veel moeilijker uitvoerbaar. Wij vonden dan ook slechts één dergelijk onderzoek, namelijk van Shull e.a.[31]

Tabel 1: Percentage kinderen (12-36 maanden) van verschillende voedingswijzen[33] met een gewicht respectievelijk lengte beneden de tiende percentiel (P10) van de Nederlandse standaarden 1980[41]

	Voedingswijze			
	gangbaar (n=50)	lacto-vegetarisch (n=33)	antroposofisch (n=26)	macrobiotisch (n=33)
Leeftijd (gem. ± standaardafw. in maanden)	23,2±5,0	22,6±7,1	19,6±5,8	25,3±7,2
	Percentages			
Gewicht naar leeftijd <P10*	8	22	4	42
Lengte naar leeftijd <P10*	8	17	4	51
Gewicht naar lengte <P10	10	16	12	9

* Verschillen significant bij p≤0,05.

Deze auteurs voerden een semi-longitudinaal onderzoek uit bij 38 lacto-vegetarisch en 34 macrobiotisch gevoede kinderen van 0 tot 5 jaar met een gangbaar gevoede controlegroep. Het aantal waarnemingspunten was klein (gemiddeld 2-3) en de waarnemingsperiode wordt helaas niet vermeld. Het begingewicht en de beginlengte lagen bij beide alternatieve groepen iets beneden de controlegroep en Harvard standaard. De groeisnelheid van de lacto-vegetarische en in het bijzonder de macrobiotische kinderen was voor gewicht en lengte beneden 2-jarige leeftijd geringer dan de standaard (mediaan). Vanaf 2 jaar vond een iets versnelde gewichtstoename plaats, waarbij de macrobiotische jongetjes significant sneller groeiden dan de lacto-vegetarische jongens. Op basis van deze semi-longitudinale gegevens construeerden Dwyer e.a.[43] theoretische lengte- en gewichtsgroeicurves voor lacto-vegetarische en macrobiotische kinderen in vergelijking tot de Harvard groeistandaard. De mediaan van de gevonden curves voor deze beide groepen verliepen beneden de mediaan (P50) van de Harvard standard. Bij het lichaamsgewicht was het verschil tussen standaard en berekende mediaan afhankelijk van de leeftijd 0,5-1 kg. Bij de lengte was dit verschil 1-2 cm.

Interpretatie

Men kan de vraag opwerpen of in de geciteerde onderzoeken naast de voeding ook andere factoren voor de gevonden verschillen in gewicht en lengte verantwoordelijk kunnen zijn. Te denken valt aan erfelijke factoren (lengte van de ouders, geboortegewicht) of aan omgevingsfactoren zoals de sociaal-economische klasse, die beide immers positief verband met deze lichaamsmaten hebben. Noch voor erfelijke factoren,[32] noch voor sociaal-economische invloeden[27,33] vonden wij hiervoor aanwijzingen. Het feit dat gewoonlijk pas vanaf 6 maanden lagere waarden voor alternatief gevoede kinderen worden gevonden, pleit voor een omgevingsresp. voedingsinvloed.[32] Niet uit te sluiten valt echter de invloed van de relatief lange lactatieperiode die in diverse onderzoeken bij alternatieve groepen en in het bijzonder macrobioten werd gevonden.[31,33] Zo blijkt uit de gegevens van Shull e.a.[31] dat aan de borst gevoede kinderen langzamer groeiden dan kinderen zonder borstvoeding. In Nutrition Reviews[44] wordt dan ook geconcludeerd, dat uit dit onderzoek geen oorzakelijk verband tussen vegetarische voeding en langzamer groei kan worden afgeleid. Afgezien hiervan is de betekenis van het afwijkende groeipatroon voor de gezondheid niet geheel duidelijk. In het algemeen lijken de afwijkingen betrekkelijk klein[43] in vergelijking tot die, welke bij ondervoeding in ontwikkelingslanden worden gevonden.[45,46] Van Wieringen[47] merkt op, dat per definitie een groeistandaard is afgeleid van een aantal waarnemingen en daarom niet als strikt maatgevend kan worden beschouwd. Aangezien in de praktijk vaak een vertraagde groei met toename in morbiditeit en mortaliteit gepaard bleek te gaan, werd de groeisnelheid gewoonlijk gezien als een positieve gezondheidsindicator. Het is niet duidelijk, of deze interpretatie ook bij het huidige hoge groeiniveau bij zuigelingen nog van toepassing is. Als illustratie hiervoor kan het feit dienen, dat de gemiddelde lengte- en gewichtscijfers van Nederlandse zuigelingen in 1980 iets lager liggen dan die van 1965. Het lijkt dan ook belangrijk om naast de antropometrische gegevens ook andere indicatoren voor de gezondheidstoestand en ontwikkeling te gebruiken.

Mentale ontwikkeling

Aangezien bekend is dat ondervoeding kan leiden tot een gestoorde mentale ontwikkeling[27] doet zich de vraag voor, of wellicht de kleinere lichaamsmaten bij alternatief gevoede kinderen samengaan met een vertraagde mentale ontwikkeling. Dwyer e.a.[27] onderzochten daarom – als enigen tot dusverre – de mentale ontwikkeling en intelligentie bij een groep van 28 vegetarische kinderen waarvan 17 macrobioten met leeftijden van 2 tot 8 jaar. De ouders waren vrijwilligers uit eerdere groeistudies. Tot verrassing van de onderzoekers scoorden de kinderen een intelligentiequotiënt van gemiddeld 115,8 hetgeen overeenkomt met de 85e percentiel van een Amerikaanse standaardpopulatie. De mentale leeftijd lag gemiddeld één jaar voor op de chronologische leeftijd. Slechts vijf kinderen hadden een IQ beneden de 100 en deze waren tegen de veronderstelling niet kleiner maar zelfs gemiddeld iets langer en zwaarder dan de andere geteste kinderen (niet statistisch getoetst). Ook scoorden veganistische en macrobiotische kinderen niet lager dan de overige kinderen. Kanttekeningen bij dit onderzoek zijn het hoge uitvalpercentage (79%) zodat selectie niet kan worden uitgesloten en het relatief hoge opleidings- en inkomenspeil van de ouders dat met het IQ van de kinderen geassocieerd bleek te zijn. Hoewel de betekenis van dit onderzoek dus niet geheel duidelijk is, geeft het althans geen aanwijzing voor een mentale achterstand bij alternatief gevoede kinderen en evenmin voor een associatie tussen vertraagde antropometrische groei en vertraagde mentale ontwikkeling bij deze groep.

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De gezondheid en voedingstoestand van 'alternatief' gevoede zuigelingen en peuters, feiten en onzekerheden

II. SPECIFIEKE VOEDINGSTEKORTEN, DISCUSSIE

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SAMENVATTING

Dit vervolgartikel uit een serie van twee artikelen behandelt het eventuele vóórkomen van klinische voedingsdeficiënties bij alternatief gevoede zuigelingen en peuters en gegevens uit klinisch-chemisch en voedselconsumptie-onderzoek met betrekking tot de nutriënten vitamine D, calcium, vitamine B12 en ijzer. Ook enkele gunstige aspecten van alternatieve zuigelingen- en peutervoeding komen kort ter sprake. Van de genoemde nutriënten met uitzondering van ijzer wordt door de meeste onderzoekers een lagere opname dan de aanbevolen hoeveelheden geconstateerd. De betekenis hiervan is echter minder duidelijk. Vrijwel alleen voor vitamine D en – bij zuigelingen gezoogd door veganistische moeders – vitamine B_{12} zijn gevallen van deficiëntie geconstateerd en de bewijsvoering hiervan is zelden zodanig, dat andere oorzaken kunnen worden uitgesloten. Risicogroepen zijn mogelijk vroeg gespeende zuigelingen en zuigelingen van primaparae. Op grond van de thans beschikbare informatie is het niet mogelijk om praktische adviezen ten behoeve van artsen, wijkverpleegkundigen en diëtisten te formuleren.

SUMMARY

This article, which is the second in a series of two articles, discusses available scientific information on the nutritional status of infants and preschool children on alternative diets with regard to calcium, iron, vitamin B_{12} and D. Some favourable aspects of alternative food habits in such children are also mentioned. Most studies report low intakes of vitamin D and in vegan and macrobiotic children also of calcium and vitamin B_{12}, but it cannot be excluded that some alternative sources of these nutrient may have been missed. Deficiencies have been described for vitamin D and B_{12} but the evidence is often unconvincing. For example, exposure to sunlight has not been measured in most of the studies on rickets. From the literature available, it would appear that there is a need for longitudinal research on the growth and development of alternatively fed infants and preschool children and for information on the nutrient composition of alternative foods.

INLEIDING

Nadat in het eerste artikel algemene indicatoren voor de voedingstoestand, zoals de groei van alternatief gevoede zuigelingen en peuters zijn besproken, zullen wij thans nader op het eventuele vóórkomen van specifieke voedingstekorten bij deze groep ingaan. Wij beperken ons hierbij tot die nutriënten en alternatieve richtingen, waarbij deficiënties in de literatuur zijn beschreven of de voorziening mogelijk te gering zou kunnen zijn. Dit betekent dat wij ons

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hoofdzakelijk richten op de groepen van wie het voedingspatroon het sterkst van het gangbare patroon afwijkt, te weten de veganistisch en macrobiotisch gevoede groepen. Bij de bespreking van de nutriënten vitamine D en ijzer worden echter ook de lacto-vegetarisch en antroposofisch gevoede kinderen betrokken. De Nederlandse informatie over de nutriëntenopname van alternatief gevoede peuters is afkomstig van een recent onderzoek van de Vakgroep Humane Voeding van de Landbouwhogeschool[33] en wordt samengevat in tabel II. De literatuurverwijzingen 1-47 zijn bij het eerste artikel vermeld.

ENERGIE EN EIWIT

In het verleden zijn enkele casuïstische mededelingen verschenen over extreme vermagering[21,22,48] of kwashiorkor[49] bij vroegtijdig gespeende kinderen, die vanaf zeer jonge leeftijd (enkele weken tot maanden) met uitsluitend het instantprodukt kokoh of een zelf bereide rauwkostvoeding waren gevoed. Wellicht op grond van deze gegevens wordt door sommige voorlichtingsinstanties gewaarschuwd voor eiwittekort bij het ontbreken van koemelk als dierlijke eiwitbron.[17] Robson[48] concludeert echter dat het eiwitgehalte van kokoh per energie-eenheid voldoende is maar dat door de sterke verdunning, nodig voor een drinkbare consistentie voor zuigelingen, vooral de energiebehoefte niet gedekt kan worden. Bovendien betreft het vroeg spenen bij alternatief gevoede kinderen een uitzonderingssituatie: in het Nederlandse onderzoek bleek dat 97% van de alternatief gevoede peuters als zuigeling aan de borst waren gevoed, met een gemiddelde duur van 7 maanden voor de lactor-vegetarische en antroposofische groepen, en zelfs 13 maanden voor de macrobiotische groep.[33] Bij peuters met een veganistische of macrobiotische voeding lijkt de energievoorziening voldoende en de eiwitvoorziening zelfs veeleer ruim (tabel II)[24,25,30,32,33] ook als met een iets lagere biologische waarde van het eiwit rekening wordt gehouden. Alleen in het uitzonderingsgeval van vroeg spenen lijkt dus de energie- en eventueel eiwitvoorziening bij alternatief gevoede zuigelingen nadere aandacht te verdienen.

VITAMINE D

Zowel in de Nederlandse[8-10,13,51-54] alsook in de Engelstalige[21,22,26,36,48,55-58] literatuur is een recente toename van rachitis beschreven, in het bijzonder bij immigrantenkinderen met een gepigmenteerde huid.[8,51,55,56,58] In Nederland is slechts één casuïstiek van rachitis bij een alternatief gevoed kind gepubliceerd, en wel door Schulpen;[9] het betrof een gespeend 9 maanden oud jongetje van zich antroposofisch noemende ouders. Daarnaast is door Nijhuis e.a.[51] epidemiologisch onderzoek verricht naar de rachitisincidentie in Den Haag over de periode 1970-1980. Er bleken 13 Nederlandse (kaukasische) en 53 buitenlandse kinderen met rachitis te zijn opgenomen. Terwijl het aantal buitenlandse patiëntjes gedurende deze periode was toegenomen (in 1971-1975: 8 gevallen, in 1976-1980: 45), nam het aantal Nederlandse rachitis-patiëntjes juist af (resp. 9 en 4 gevallen). Nadere informatie over de voeding van de Nederlandse patiëntjes ontbreekt*. Hiernaast bestaan enkele algemene mededelingen over rachitistoename bij vroeg gespeende zuigelingen van moeders die het gebruik van fabrieksmatige produkten afwijzen[53] en bij sociaal gedepriveerde groepen,[54] maar over de frequentie en de oorzaken hiervan bestaat geen duidelijkheid.

In het eerder genoemde onderzoek van de Vakgroep Humane Voeding bedroeg de vitamine D-opname uit de voeding bij verschillende groepen alternatief gevoede peuters gemiddeld 0,3-0,5 μg (12-20 IE) en bij de gangbare groep gemiddeld 1,0 μg (40 IE; tabel II). De meeste alternatief gevoede kinderen, in het bijzonder de antroposofische en macrobiotische groepen, bleken geen vitamine D-profylaxe in te nemen. Klinisch onderzoek werd niet verricht.

In de buitenlandse literatuur zijn enkele casuïstische mededelingen verschenen over rachitis bij reeds gespeende, alternatief gevoede kaukasische kinderen[21,22,36] waarvan slechts één geval als relevant kan worden beschouwd.[22]

* Volgens mondelinge informatie van de auteur vermeldde geen van de dossiers van deze kinderen in de anamnese een alternatieve voedingswijze, terwijl wel herhaaldelijk andere factoren zoals sociale of psychiatrische probleemsituaties in het gezin werden vermeld.

Tabel II: Gemiddelde en standaardafwijking van de dagelijkse opneming van energie en enkele voedingsstoffen door kinderen (12-36 maanden) met verschillende voedingswijzen[33] in vergelijking tot de Nederlandse aanbevolen hoeveelheden[104]

			Voedingswijze				Aanbevolen hoeveelheid (1981)
			gangbaar (n=50)	lacto-vegetarisch (n=33)	antroposofisch (n=26)	macrobiotisch (n=28)**	
Energie		kJ	4500 ± 678	4267 ± 755	4412 ± 863	4224 ± 898	–
		kcal	1076 ± 162	1020 ± 181	1054 ± 206	1010 ± 214	1200
Eiwit	– totaal*	g	39 ± 8	36 ± 9	34 ± 9	31 ± 7	35
	– energie	%	15 ± 3	14 ± 3	13 ± 2	13 ± 1	12
	– dierlijk*	g	29 ± 8	21 ± 11	18 ± 6	4 ± 3	18
Vet	– totaal	g	39 ± 10	34 ± 8	35 ± 10	22 ± 8	–
	– energie	%	32 ± 6	30 ± 5	30 ± 5	20 ± 5	30-35
	– meerv. onverzadigd*	g	5 ± 2	5 ± 3	4 ± 1	8 ± 4	10-12
Cholesterol*		mg	154 ± 51	122 ± 55	93 ± 34	33 ± 34	≤ 120
Koolhydraten	– totaal*	g	145 ± 27	144 ± 31	151 ± 35	171 ± 39	–
	– energie	%	54 ± 6	56 ± 5	57 ± 7	68 ± 5	55-60
	– oligosacchariden*	g	90 ± 22	76 ± 24	74 ± 19	97 ± 20	≤ 50
Voedingsvezel*		g	10,3 ± 2,3	16,0 ± 5,3	15,8 ± 5,0	24,9 ± 6,5	–
Calcium*		mg	785 ± 229	783 ± 284	723 ± 238	345 ± 97	800
IJzer*		mg	6,3 ± 4,1	7,1 ± 2,2	7,3 ± 2,4	10,8 ± 1,9	7
Vitamine B_2*		mg	1,2 ± 0,3	1,1 ± 0,4	1,0 ± 0,3	0,5 ± 0,1	0,8
Vitamine D		µg	1,0 ± 0,7	0,5 ± 0,5	0,3 ± 0,2	0,3 ± 0,7	10-15

* Verschillen significant bij $p \leq 0{,}05$

** Met uitsluiting van 5 kinderen die nog borstvoeding kregen

Soms wordt de huidskleur niet vermeld.[57] Epidemiologische informatie ontbreekt. Alleen Dwyer e.a.[26] verrichtten populatie-onderzoek naar het vóórkomen van rachitis bij 24 macrobiotische en 28 andere vegetarische kinderen van 1 tot 6 jaar. Van de macrobiotische kinderen had 88% een kleinere vitamine D-opname dan 2,5 µg (100 IE) per dag tegenover 18% van de overige vegetarische kinderen. Bij twee macrobiotische kinderen kon via reeds bestaande röntgenfoto's rachitis worden aangetoond. In een röntgenologisch vervolgonderzoek bij 20 macrobiotische kinderen met een anamnese suggestief voor rachitis kon tot verrassing van de auteurs geen rachitis worden vastgesteld.[26] In een recenter onderzoek[25] bij een overlappende groep was sprake van verhoogde serumwaarden voor alkalisch fosfatase en bij sommige kinderen van verlaagde serumcalciumwaarden, terwijl bij klinisch onderzoek door een kinderarts alle kinderen in goede gezondheid bleken te zijn. In een bespreking van hun bevindingen[26] merken de auteurs op dat het ontbreken van rachitis bij de meeste macrobiotische kinderen ondanks hun lage vitamine D-opname wijst op het mogelijk belang van andere factoren die het risico op de ontwikkeling van rachitis kunnen beïnvloeden. Helaas wordt in geen van de genoemde onderzoeksberichten[9,22,26] iets naders over dergelijke factoren medegedeeld, zoals de vitamine D-status van de moeder, de mate van blootstelling van moeder en kind aan de zon, de kleding, de behuizing en dergelijke. Dit bevreemdt in zoverre als toch algemeen bekend mag worden verondersteld dat rachitis door vitamine D-deficiëntie primair samenhangt met een gebrek aan voldoende bestraling van de huid door zonlicht, terwijl vitamine D uitsluitend als essentiële nutriënt wordt beschouwd voor zover deze bestraling te gering is.[55,57,59,60] Al met al is het van belang meer te weten over de rachitisfrequentie bij Nederlandse alternatief gevoede zuigelingen en peuters en de eventuele factoren die hierbij een rol spelen.

CALCIUM

De calciumopname ligt bij gespeende zuigelingen en peuters die geen melkprodukten gebruiken, te weten veganistisch en macrobiotisch gevoede groepen, in het algemeen aanzienlijk beneden de in Nederland aanbevolen hoeveelheden (tabel II).[28-30,33,61] Toch is hypocalciëmie bij deze categorieën slechts zelden beschreven en was zij bovendien gekoppeld met aanwijzingen voor vitamine D-deficiëntie,[12,25] zodat betwijfeld moet worden of calciumtekort de primaire oorzaak was.

In de literatuur worden enkele mogelijke oorzaken van deze discrepantie aangevoerd. Allereerst lijkt men bij het berekenen van de calciumopname geen rekening te hebben gehouden met de calciumvoorziening uit drinkwater, die in gebieden met hard water wellicht tot 250 mg per dag kan bedragen.[30] Daarnaast bestaat internationaal geen overeenstemming over de hoogte van de calciumaanbevelingen.[62,63] Reeds langere tijd is bekend, dat – ook bij kinderen – een sterke adaptatie aan lage calciumopnames mogelijk is.[64] Zo bleken veganistisch gevoede kinderen in India ook bij opname van gemiddeld slechts 200 mg calcium per dag een positieve calciumbalans te hebben.[65] Er was sprake van zowel een verhoogde calciumabsorptie als van een verlaagde uitscheiding met de urine hetgeen mogelijk verklaard kan worden door een geringere eiwit- of vetopname in vergelijking tot een omnivore voeding. Vet kan de calciumabsorptie belemmeren,[64] terwijl een toename van de eiwitconsumptie, wellicht in het bijzonder van dierlijk eiwit,[66] de calciumuitscheiding in de urine bij volwassen proefpersonen aanmerkelijk doet stijgen.[66-68] Gewoonlijk wordt deze stijging niet door een hogere absorptie gecompenseerd,[69-71] zodat de calciumbehoefte groter wordt.[72] Mogelijk geldt dit ook voor kinderen. Alleen balansonderzoek bij alternatief gevoede kinderen zal deze vragen kunnen beantwoorden.

VITAMINE B_{12}

Met betrekking tot vitamine B_{12}-status van alternatief gevoede zuigelingen en peuters in Nederland is geen informatie beschikbaar. In de recente internationale litaratuur zijn enkele casuïstische gevallen van megaloblastische anemie bij zuigelingen van een veganistische moeder beschreven.[73-76] Meestal bleek de moeder een lage moedermelk- of serumwaarde van dit vitamine te hebben, terwijl klinische symptomen bij haar ontbraken. Dwyer e.a. vonden in het eerder beschreven onderzoek[25] bij een groep van 27 macrobiotisch gevoede kinderen van 0,8-8,4 jaar normale serumwaarden van vitamine B_{12} ondanks een zeer lage berekende B_{12}-opname. Veganistisch gevoede peuters bleken vaak een vitamine B_{12}-supplement te krijgen.[29,30] De interpretatie van deze gegevens wordt door twee omstandigheden bemoeilijkt. Ten eerste is het uiterst moeilijk aan te tonen dat klinische symptomen van vitamine B_{12}-deficiëntie ook werkelijk door een voedingstekort worden veroorzaakt. Immerman[77] suggereert een aantal criteria waaraan deze bewijsvoering zou moeten voldoen, waaronder het verdwijnen van de symptomen door orale toediening van kleine B_{12}-doses. De meeste door hem besproken berichten over vitamine B_{12}-deficiëntie – waarvan enkele bij kinderen[75,78] – blijken niet aan deze criteria te voldoen. Zo is bijvoorbeeld in de door ons geciteerde casuïstische gevallen de moeder niet nader onderzocht, zodat onduidelijk is in hoeverre bij haar factoren buiten de voeding, zoals malabsorptie, een rol speelden. Ten tweede worden bij veganistisch gevoede volwassenen weliswaar lagere serum vitamine B_{12}-waarden gevonden dan bij omnivore personen, maar wordt klinische deficiëntie ondanks de geringe opname van dit vitamine slechts zelden aangetroffen. Op grond hiervan is wel geopperd dat bij veganisten de darmflora als vitamine B_{12}-bron zou kunnen dienen[84] of dat in gevallen van klinische deficiëntie sprake zou zijn van een begeleidende stoornis, die pas bij een minimale B_{12}-opname tot uiting zou komen.[85] Aangezien vitamine B_{12} uitsluitend door mikro-organismen wordt gevormd,[84] werd in het verleden algemeen aangenomen dat dit vitamine in het plantenrijk niet voorkomt.[35,86,87] Volgens recentere berichten wordt het echter ook aangetroffen in onder meer zeewieren[77,88,89] en gefermenteerde sojaprodukten,[90] die vooral in de macrobiotische kindervoeding regelmatig gebruikt worden.[1] Ook een contaminatie van groenten via de bodem is denkbaar, in het bijzonder bij wortelgroenten. Over de in Nederland verkrijgbare potentiële vitamine B_{12}-bronnen zijn geen betrouwbare analysegegevens beschikbaar. Met het oog op preventieve adviezen lijkt het van belang over zulke cijfers te beschikken.

IJZER

IJzerdeficiëntie wordt bij zuigelingen en peuters in de welvarende landen regelmatig waargenomen[91-94] en diverse auteurs beschouwen de ijzervoorziening bij gangbaar gevoede jonge kinderen als krap in verhouding tot de aanbevolen hoeveelheden.[92,95,96] Er zijn geen berichten van ijzerdeficiëntie bij zuigelingen die werden gezoogd door moeders met een alternatieve voeding. Wel is deze beschreven in enkele reeds gespeende kinderen bij een uitsluitende rauwkostvoeding[22,23] en bij enkele oudere kinderen (6 resp. 11 jaar) die – bij een overigens gangbare voeding – een afkeer van vlees hadden[97] (de auteur spreekt hier enigszins verwarrend van een 'lacto-ovo-vegetarische' voeding). Dwyer e.a.[25] vonden bij de reeds genoemde groep van 39 lacto-vegetarische en macrobiotische kinderen normale serumijzer- en -hemoglobinewaarden (transferrine en ferritine werden niet bepaald). In alle onderzoeken bij alternatief gevoede groepen voldeed de totale ijzeropname aan de Nederlandse aanbevolen hoeveelheden;[25,30,33] in het onderzoek van de Vakgroep Humane Voeding was de ijzeropname van de macrobiotisch gevoede groep hoger dan bij de andere alternatieve of gangbaar gevoede groepen (tabel II).[33]

Onzekerheid bestaat echter over de mate waarin plantaardig ijzer voor absorptie in de darm beschikbaar is. Onderzoek hiernaar is voornamelijk bij volwassenen uitgevoerd;[91] factoren van belang zijn onder meer de ijzerstatus van het lichaam en de verdere samenstelling van de maaltijd. Wij volstaan hier met enkele opmerkingen die voor de alternatieve voeding van belang zijn. Eén van de beste plantaardige bronnen van beschikbaar ijzer is soja.[96] De beschikbaarheid in granen wordt onder andere door de aanwezigheid van fytinezuur verminderd.[91] Uit recent onderzoek blijkt echter, dat dit fytinezuur grotendeels kan worden afgebroken door het graaneigen enzym fytase, en wel tijdens het inweken[98] en vooral tijdens het in alternatieve bakkerijen gebruikelijke langdurige rijsproces van gist- of (nog sterker) zuurdesembrood. Ook met betrekking tot de verdere samenstelling van de alternatieve voeding zijn enkele potentieel absorptiebevorderende factoren voorhanden zoals een lang voortgezette borstvoeding en een hoog vitamine C-gehalte, evenals de afwezigheid van enkele sterk absorptieremmende produkten zoals thee en (bij macrobioten en veganisten) koemelk.[91] Dwyer e.a.[25] schatten op grond van beschikbaarheidscijfers voor volwassenen de hoeveelheid beschikbaar ijzer voor de diverse alternatieve onderzoeksgroepen op 0,8-1,5 mg per dag, tegenover een geschatte behoefte van 1 mg per dag.[91]

Concluderend: alhoewel er geen concrete aanwijzingen zijn voor het bestaan van ijzerdeficiëntie bij alternatief gevoede kinderen, lijkt het van belang over nauwkeuriger informatie

[1] Deze informatie berust op inmiddels verouderde analysemethoden (zie hoofdstukken 5 en 9).

hieromtrent en in het bijzonder omtrent de mate van beschikbaarheid in zulke voedingen te beschikken.

OVERIGE VOEDINGSSTOFFEN

De voorziening met andere dan de besproken voedingsstoffen in alternatieve kindervoedingen is in het algemeen redelijk tot zeer ruim, terwijl geen deficiëntiegevallen beschreven zijn. Alleen de vitamine B_2-opname is bij macrobiotische[33] en veganistische kinderen wellicht aan de lage kant (tabel II); Dwyer[25] vond bij macrobiotische kinderen een opname beneden de Amerikaanse, maar boven de Nederlandse aanbevolen hoeveelheid.

De vitamine C-opname blijkt door het gebruik van vitamine C-rijke groenten gewoonlijk zeer ruim te zijn, zowel bij alternatief gevoede kinderen[25,29,61] als bij volwassenen.[24,61,81] Jonxis[53] merkt in dit verband op dat gezien het betrekkelijk hoge vitamine C-gehalte van vele groenten de waarde van vruchtensappen in de voeding van zuigelingen niet moet worden overschat. Verder stelt hij 'dat het vitamine C-gehalte van moedermelk zo ruim is dat toediening van extra vitamine C aan het borstkind doet denken aan water naar de zee dragen'. Alleen bij alternatief gevoede zuigelingen die geen borstvoeding krijgen, vraagt de vitamine C-voorziening de aandacht.

DISCUSSIE

In de medische en wetenschappelijke wereld wordt in verband met alternatieve zuigelingen- en kindervoeding meestal van gezondheidsrisico's gesproken. Vanuit de klinische situatie, waar men gewoonlijk met probleemsituaties geconfronteerd wordt, is dit begrijpelijk; opgemerkt moet echter worden, dat over de feitelijke Nederlandse situatie met betrekking tot voedingsdeficiënties ten gevolge van alternatieve voedingswijzen geen significante informatie beschikbaar is. In de buitenlandse literatuur zijn casuïstieken verschenen over onder meer vitamine D- en (bij zuigelingen gezoogd door een veganistische moeder) voor vitamine B_{12}-deficiënties. De relevantie hiervan voor de Nederlandse situatie is echter moeilijk te bepalen aangezien de bewijsvoering vaak niet aan strenge methodologische eisen voldoet en bovendien in de casuïstiek – voorzover beschreven – zeer vaak uitzonderlijke omstandigheden zoals vroeg spenen en sociaal-psychologische problemen blijken voor te komen. Hier komt bij, dat diverse richtingen zich in de laatste tien tot twintig jaar verder hebben ontwikkeld tot een meer genuanceerde benadering, waardoor de risico's lijken te zijn afgenomen. Al met al bestaat geen goede wetenschappelijke basis om van een verhoogd vóórkomen van voedingsdeficiënties bij alternatieve voedingswijzen in Nederland te kunnen spreken.

Het groeipatroon van alternatief gevoede zuigelingen en peuters, in het bijzonder bij veganisten en macrobioten, blijkt in Nederlands en buitenlands onderzoek van het gemiddelde patroon bij omnivore kinderen af te wijken: in het algemeen lijkt de groei bij de alternatieve groepen tot 2 jaar iets langzamer en daarna gelijk of zelfs iets sneller te zijn dan de standaard (d.w.z. de mediaan). Vrijwel steeds betreft het onderzoek echter een momentopname, terwijl slechts één longitudinale groeistudie is uitgevoerd. Ook een vergelijking van antropometrische gegevens met verschillen in klinische gezondheid en ontwikkeling voor de kinderen heeft nauwelijks plaatsgevonden, zodat de betekenis van de gevonden groeiverschillen vooralsnog onduidelijk is. De berekende opname van vitamine D uit de voeding en – bij veganistische en macrobiotische peuters – van calcium en vitamine B_{12} ligt aanmerkelijk beneden de aanbevolen hoeveelheden. Hieruit mag echter niet zonder meer worden geconcludeerd, dat deze kinderen een tekort aan deze voedingsstoffen zouden hebben. Onzekerheidsfactoren liggen in de berekening van de opname, namelijk door geen rekening te houden met potentiële bronnen zoals drinkwater (calcium) en gefermenteerde sojaprodukten (vitamine B_{12}), evenals in de eventuele mogelijkheid van adaptie aan een lage opname, zoals bij calcium. Ook een veranderd interactiepatroon tussen verschillende voedingsstoffen in een alternatieve voeding zou tot andere behoeften kunnen leiden, zodat de aanbevolen hoeveelheden voor deze groepen niet zonder meer van toepassing zijn. Met betrekking tot vitamine D leggen alle alternatieve richtingen de nadruk op voldoende blootstelling van zuigelingen en peuters aan zonlicht in plaats van een algemeen profylactisch gebruik van vitamine D-preparaten. Het is nog onduidelijk in hoeverre de voorziening met vitamine D hierdoor voldoende is.

De meeste geciteerde auteurs zijn van mening, dat bij een zorgvuldig samengestelde vegetarische of veganistische kindervoeding een goede voedingstoestand zeer wel mogelijk is. In een onderzoek van de Vakgroep Humane Voeding bleek zelfs dat de voeding van de onderzochte lacto-vegetarisch en antroposofisch gevoede peuters beter aan de aanbevelingen van de Voedingsraad voldeed dan die van een omnivore controlegroep. Gunstige aspecten waren bij alle alternatieve groepen het hoge percentage moeders dat borstvoeding gaf (97) en de geringe consumptie van geraffineerde koolhydraten, dierlijk eiwit, vet en cholesterol in vergelijking tot de omnivore kinderen.[33] Met betrekking tot de samenstelling van moedermelk bij een alternatieve voeding geeft buitenlands onderzoek aanwijzingen voor een gunstiger vetzuurspectrum in moedermelk van veganistische moeders[101] en voor een lagere belasting van moedermelk met een aantal moeilijke afbreekbare organochloorpesticiden bij moeders met een (lacto-)vegetarische voedingswijze[102,103] dan wel een reeds langdurig gebruik van onbespoten voedingsmiddelen.[103]

Op grond van de thans beschikbare informatie is het niet mogelijk praktische adviezen ten behoeve van artsen, wijkverpleegkundigen en diëtisten te formuleren. Voor de praktijk kan op dit moment uitsluitend worden gezegd, dat voorlopig bij alternatief gevoede zuigelingen en peuters – evenals uiteraard bij gangbaar gevoede leeftijdsgenootjes – oplettendheid op zijn plaats is. Wij denken bijvoorbeeld aan zuigelingen die geen vitamine D-profylaxe krijgen evenals aan zuigelingen die vroeg (voor 6 maanden) gespeend worden en in het geheel geen dierlijke produkten of adequate vervanging hiervan krijgen. Ook zuigelingen van primiparae die geen ervaring met een dergelijke voedingswijze hebben, verdienen extra aandacht. Al met al is onze kennis over de Nederlandse situatie zeer gebrekkig. Mede op grond van praktijkvragen menen wij dat er grote behoefte is aan een betere kennis van eventuele problemen die zich bij alternatieve kindervoeding kunnen voordoen en van mogelijke oplossingen hiervan, evenals mogelijke gunstige aspecten. Wij zien hierbij de volgende onderzoeksprioriteiten:

1. Registratie van de incidentie van voedingsdeficiënties bij kaukasische kinderen in een aantal poliklinieken over een zekere periode, waarbij per geval dient te worden nagegaan welke voedings- en andere factoren tot het ontstaan van deze deficiënties hebben bijgedragen. Hieruit moet blijken of alternatieve voedingswijzen werkelijk tot een verhoogd risico leiden en zo ja, welke groepen het meeste risico lopen.

2. Een longitudinaal populatie-onderzoek naar de voeding en voedingstoestand van zuigelingen en peuters van de alternatieve voedingsrichtingen die het sterkst van het gangbare voedingspatroon afwijken. Een zeer belangrijk element hierin zal een nauwkeurige beschrijving van de populatie dienen te zijn. Uit het oogpunt van preventie is de vraag van groot belang, waarom zich ook in gevallen van een schijnbaar te geringe nutriëntenopname bij bepaalde kinderen géén problemen voordoen. Ook de nutriëntensamenstelling en de beschikbaarheid van mineralen in alternatieve voedingsmiddelen vragen de aandacht.

DANKBETUIGING

Onze dank gaat uit naar het Praeventiefonds voor de financiële ondersteuning van een onderzoeksproject over alternatieve zuigelingen- en peutervoeding en naar de Vereniging van Kindergeneeskunde voor haar toegezegde medewerking hieraan. Verder danken wij Prof. Dr. E. D. A. M. Schretlen voor kritisch commentaar en mw. R. Janssen en mw. A. Zijlmans voor het tikken van het manuscript.

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3 Do children on macrobiotic diets show catch-up growth? A cross-sectional study in children between birth and 8 years of age

by P.C. Dagnelie, W.A. van Staveren, J.D. van Klaveren & J. Burema

SUMMARY

Children who are fed alternative and especially macrobiotic diets have been reported to be smaller and weigh less than their peers fed omnivorous diets. To answer the question, at what age growth in children on macrobiotic diets slows down, and if any return to standards occurs later in childhood, a cross-sectional anthropometric study was performed in the Dutch macrobiotic child population aged 0 to 8 years (n = 243). Addresses were obtained from macrobiotic organizations and from families already participating in the study. Food habits were checked by a structured food frequency questionnaire. Anthropometric measurements included weight, height, mid-upper arm circumference and triceps and subscapular skinfolds. For each sex, age curves were constructed in comparison to standards. For selected age intervals, standard deviation scores (SDS) were tested for differences with the reference after accounting for confounding variables in a multiple regression model. Reported birth weight was 150 g lower than the Dutch reference; birth weight was positively associated with the consumption frequency of dairy products and fish. During the first 6 - 8 months of life, SDS were not different from the standard except for arm circumference and skinfolds. From 6 - 8 months onwards, growth stagnation occurred in both sexes, which was most marked in girls. A minimum level of 1 to 1.5 SD below the P50 of the reference was reached by the age of 18 months. Between 2 and 4 years a partial return towards the P50 occurred for arm circumference and, in boys only, for weight and skinfolds, but not for height. SDS of weight, height and arm circumference were higher in children from families with regular consumption of dairy products than in children from families avoiding dairy products.

INTRODUCTION

It is wellknown that children who are fed alternative diets are smaller and weigh less than their peers fed omnivorous diets (Shull et al., 1977; Dwyer et al.,1980; Fulton, Hutton & Stitt, 1980; Sanders & Purves, 1981; Shinwell & Gorodischer, 1982, van Staveren et al., 1985; Hebert, 1985). This particularly applies to children on a macrobiotic diet, which is almost devoid of foods of animal origin (Shull et al., 1977; Dwyer et al., 1980; van Staveren et al., 1985).

As yet, two questions have remained unanswered:

1. At what age does growth in macrobiotic children slow down?
2. Does return to standards occur later in childhood, i.e. before puberty?

In order to answer these questions, we performed a cross-sectional study in the Dutch population of children on macrobiotic diets in the age of 0 - 8 years.

METHODS

Subjects and organization

Eligible for our study were children on macrobiotic diets below eight years in the Netherlands who were caucasian, had a birth weight of at least 2500 grams and did not suffer from a congenital disease. The children and their mothers should have been on a macrobiotic diet as described by Kushi (1977, revised 1987) obtained from macrobiotic organizations and from families already participating in the study. In this way, a total number of 262 addresses was obtained (Table 1). Of these, 46 families were excluded because they had no children in the range of 0 - 8 years or because they did not follow a macrobiotic diet anymore. From the remaining number of 216 families (= 100 per cent), 18 families (8 per cent) could not be traced e.g. due to departure, and 10 families (5 per cent) refused to participate in the study. In addition to this, 15 families (7 per cent) were not visited because their address was obtained only after termination of the fieldwork. In conclusion, 173 families (80 per cent) were included in the study.

All families received a mail invitation which was co-signed by two macrobiotic consultants. Some days later, a date for a home visit was arranged by telephone. During this visit a questionnaire was taken from the mothers and anthropometric measurements were taken from the children.

Table 1. Macrobiotic study population

		NUMBER OF FAMILIES	
Mailing list		262	
of these: not eligible		46	
Eligible		216	(100 %)
of these: not visited		43	
Visited		173	(80 %)

		NUMBER OF CHILDREN
Total		307
of these: not measured	5	
excluded from anthropometric analysis	59	
		64
Included in analysis		243

AGE (YEARS)	NUMBER OF CHILDREN Boys	Girls	Total
0.00 - 0.99	25	24	49
1.00 - 1.99	21	21	42
2.00 - 3.99	43	42	85
4.00 - 5.99	26	27	53
6.00 - 7.99	9	5	14
Total	124	119	243

In total, 307 children below 8 years of age were present in the study sample (Table 1). Of these, 5 children were not measured and 59 children were excluded from the analysis because they did not fulfill the selection criteria. Therefore, anthropometric data were available on 243 children, of which 124 were boys and 119 girls. The number of children in the study sample decreased with age (Table 1).

Questionnaire

Social characteristics and food habits of the participants were checked by a structured questionnaire. The first purpose of this questionnaire, which was developed with the help of macrobiotic teachers, was to check whether the participants did indeed follow a macrobiotic dietary pattern. Apart from questions on whether official macrobiotic courses had been followed, the questionnaire included a frequency list of foods considered as typical or atypical for the macrobiotic dietary pattern.

Anthropometry

Reported birth weight, birth order, and height of the parents were also included in the questionnaire. The mid-parent height was calculated as the arithmetic mean of both parent's height.

From each child, the following anthropometric measurements were taken: weight, height, mid-upper arm circumference and tricipital and subscapular skinfolds. All measurements except skinfolds were taken once. For height, a couple of two observers performed the measurement. Instruments were controlled at regular intervals. All measurements were read to 0.1 cm, except weight and skinfolds (see below).

Weight. For weight, children below two years were measured without any clothes; for older children, weight was corrected for clothes the child might wear (usually pants only). No adjustment was made for the period expired since the last meal. For infants until 18 months, a TEC electronic weighing scale was used (type SL32-bs; 0.5 - 15 kg/0.005 kg). From 18 months onwards, a Seca electronic weighing scale (types 707 and 708; 5 - 200 kg/0.1 kg) was used.

Height. Height was measured in the way described by Roede & van Wieringen (1985). Recumbent length of children below 2 years of age was measured by a house-made steel infantometer with a fixed headboard and a sliding footboard of both 10 cm high. Standing height of children of 2 years and older was measured by a flexible steel tape, which was attached to a metal bottom and top board. The subject was placed on the metal footboard with his heels, buttocks, shoulders and head in contact with the vertical plane. One observer held the head with the Frankfurt plane in a horizontal position and stretched the child gently, taking care that the feet remained standing on the floor. The other observer read the measurement.

Arm circumference. Mid-upper arm circumference was measured by means of a plastic household tape. The measurement was taken midway between the acromion and the olecranon of the left arm while the arm was relaxed and extended by the child's side.

Skinfolds. Triceps and subscapular skinfolds were measured at the nearest 0.2 mm by means of a Harpenden skinfold caliper in the way described by Tanner and Whitehouse (1975). Each skinfold was measured twice and the arithmetic mean was calculated.

Quality control

The measurements were performed by four trained observers. Control measurements on ten 6 - 7 years old children after termination of the fieldwork did not yield systematic differences between the observers. Control measurements against a reference observer (Gerver) were performed to check for a systematic difference in the direction of the results. No indication for such a difference was found.

Reference data

For birth weight, weight and height for age, and weight for height, data from Netherlands third nation-wide survey 1980 (Roede & van Wieringen, 1985) were used as a reference. For arm circumference, reference data of Gerver (1988) on 2555 children in Oosterwolde (northern Netherlands) were used. The Dutch reference curves for height do not show a break at the age of two years. Since no Dutch reference data were available for skinfolds, the reference of Tanner & Whitehouse (1975) was used.

Analysis

Similar to the Dutch reference data, the average birth weight was calculated after exclusion of birth weights below 2500 grams. Since only the median of the Dutch reference was known and birth weight showed a normal distribution, statistical significance of the difference in birth weight with the reference was tested by means of a confidence interval calculated from the standard error. In order to check for a possible influence of macrobiotic dietary habits on birth weight, a multiple regression analysis was performed, including the consumption frequency of animal foods (in three categories, using two dummy variables) and the number of years before birth during which the mother had followed a macrobiotic diet. As confounding variables, mid-parent height, sex, parity and smoking of the mother were included in the regression models.

Age curves, presenting the arithmetic mean of anthropometric parameters for age, were constructed as smoothed curves using splines (SAS Institute Inc., 1985). For further calculations, the anthropometric data were expressed as standard deviation scores (SDS) using the median (P50) and standard deviation (SD) of the reference data mentioned above. For this purpose, the P50 and SD of the reference were interpolated to each child's exact age. Because of a skew distribution of the reference data of weight for age in girls from four years onwards, for this age group the observed weight and the reference data were first transformed to achieve normal distribution by means of the equation:

$$X = \log(\text{weight} - 3.633 \times \text{age} + 14.758).$$

Similarly, skinfold data were transformed for all ages by the equation:

$$Y = \log(\text{skinfold} - 1.8)$$ (Tanner & Whitehouse, 1975).

On the basis of the growth curves, we selected for each sex three age periods in which the slope of the growth curve was parellel to the standard:

1. From 0 - 8 months in boys and 0 - 6 months in girls, representing the initial level of the growth curves;
2. From 18 - 24 months in boys and 18 - 27 months in girls, representing a minimum level for most anthropometric parameters;
3. From 36 months onwards in boys and from 42 months onwards in girls, representing a final level.

For each age interval, standard deviation scores were tested for differences with the reference after accounting for confounding variables in a multiple regression model. In each model mid-parent height, parity and birth weight were included as confounding variables.

The difference in SDS between children from families with and without regular consumption of animal foods was tested by Student's t. For this analysis, the data of both sexes were combined because of the low number of families consuming animal foods regularly. The differences were verified by means of multiple regression analysis including the same confounding variables as described above.

RESULTS

Description of the study population

The distribution of the participating families over the Netherlands closely followed the distribution of the Dutch population, but there was a minor concentration in Amsterdam and surroundings.

The educational level of the parents was high (Table 2): 64 per cent of the fathers and 45 per cent of the mothers had completed college or university education, as compared to 17 per cent for men and 9 per cent for women of the Dutch population aged 20 - 49 years (CBS, 1983).

Virtually all parents (97 per cent) had followed macrobiotic courses or lectures and 92 per cent had attended special courses or group consultations on macrobiotic child nutrition. Ninety four per cent had followed a macrobiotic diet for more than two years and 72 per cent for more than

Table 2. Educational level of macrobiotic parents (n = 173) compared to the Dutch population aged 20 – 49 years (CBS, 1983)

	PERCENTAGE			
	FATHER		MOTHER	
	macrobiotic	CBS	macrobiotic	CBS
Primary education	15	43	15	60
Secondary education	22	40	41	31
College or university	64	17	45	9
	100	100	100	100

five years.

Typical macrobiotic dietary items such as unpolished ("brown") rice, other whole grain cereals, seaweeds, pickles and misosoup were eaten regularly by the vast majority of the participating families (Table 3). In contrast, products which are considered as "extreme" in terms of yin and yang by Kushi (1987), like potatoes, honey and tropical fruits such as bananas.

Table 3. Consumption frequency of some typical foods by A. macrobiotic families (n = 173) and B. macrobiotic children (n = 307)

Table 3A.	PERCENTAGE OF FAMILIES CONSUMING THIS FOOD: 3 or more times/week	1-2 times per week	less than once/week	never
Unpolished rice	99	1	0	0
Other whole grain cereals	73	23	4	0
Seaweeds	95	3	2	0
Pickles	64	19	14	3
Misosoup	93	5	2	1
Potatoes	1	19	72	8
Honey	7	5	22	66
Bananas	1	6	43	50
Eggs	0	17	63	20
Dairy products	12	13	31	43
Meat/poultry	0	2	16	83
Fish	3	40	32	24

Table 3B.	PERCENTAGE OF CHILDREN CONSUMING THIS FOOD: daily	3-5 times per week	1-2 times per week	less than once/week
Cow's milk	5	2	2	92
Vitamin D supplements	9	1	0	90
Cod liver oil	2	0	0	97

were clearly avoided (Table 3). The same applied to most products of animal origin: 95 per cent of the families consumed meat less than once a month or never and 75 per cent consumed dairy products less than once a week. However, 43 per cent of the families took fish one to three times per week. This was almost exclusively lean fish with a low vitamin D content. Only 12 per cent of the children regularly received vitamin D or cod-liver oil supplements.

Ninety six per cent of the macrobiotic children had been exclusively breastfed for a period of at least three months as compared to 27 per cent of the Dutch infants in 1982 (Geneeskundige Hoofdinspectie van de Volksgezondheid, unpublished data).The median duration of breastfeeding was 13 months. In most children, solids had been introduced by the age of 6 - 7 months (range 1 - 13 months). The weaning food consisted of water-based, sieved whole-grain porridges with addition of vegetables, sesame seeds and (usually some months later) pulses.

Reported birth weight

A birth weight at or below 2500 grams was reported in 6.5 per cent of the children as compared to 2.0 per cent in Dutch newborn infants in 1982 (GHI, 1982; $P < 0.001$). The average birth weight was 3360 grams for boys (99.9 % upper confidence limit: 3470 g, as compared to the Dutch median of 3500 g; Roede & van Wieringen, 1985) and 3250 grams for girls (99.9 % upper confidence limit: 3360 g, Dutch median: 3390 grams).

By multiple regression analysis, we calculated the independent contribution of the consumption frequency of animal foods to birth weight after adjustment for sex, parity, mid-parent height and smoking. In families consuming dairy products 3 times a week or more, adjusted birth weight was 350 grams higher than in families consuming dairy products less than once per month ($P = 0.04$). In families consuming fish at least once per week, adjusted birth weight was 180 g higher than in families consuming fish less than once per month ($P = 0.03$). The period of following a macrobiotic diet before pregnancy did not show a significant effect on birth weight.

Growth

Age curves by sex, presenting the arithmetic mean of weight, height and mid-upper arm circumference, as well as weight for height, are presented in Fig. 1 - 8. For selected age intervals, mean standard deviation scores by sex are presented in Table 4.

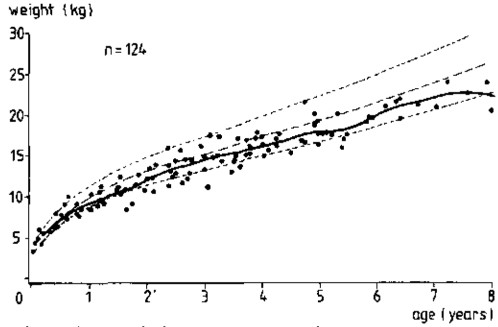


Fig. 1. Weight for age, boys

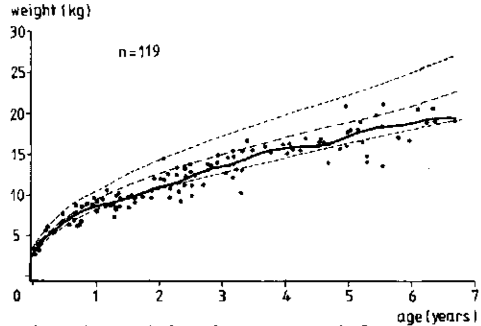


Fig. 2. Weight for age, girls

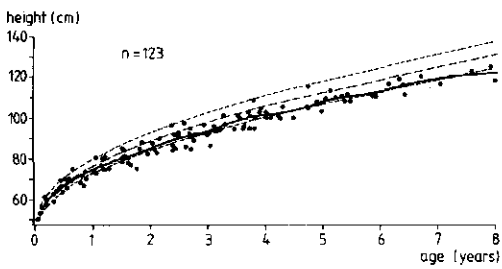


Fig. 3. Height for age, boys

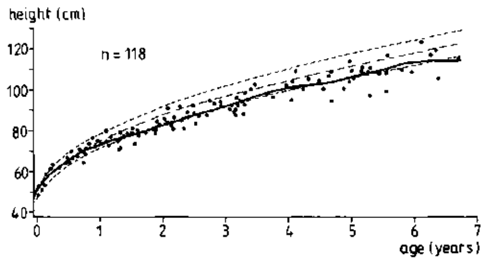


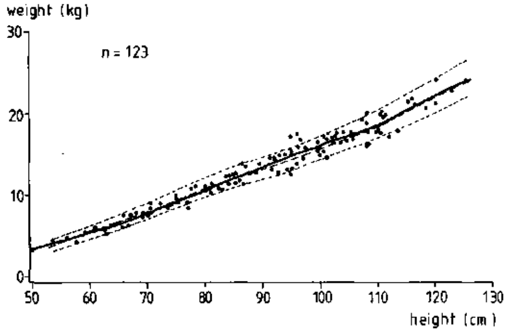
Fig. 4. Height for age, girls

Fig. 1 - 4. Weight and height for age of children on macrobiotic diets.
- - - - P10, P50, P90 of reference population (Roede & van Wieringen, 1985)

During the first 6 to 8 months of infancy, the curves of most anthropometric variables were close to the median of the standard (Fig. 1 - 8) and consequently showed SDS close to zero (Table 4). Exceptions were subscapular skinfolds and, in boys only, arm circumference and triceps, which were approximately one standard deviation (SD) below the P50 of the reference ($P < 0.05$).

From 6 to 8 months onwards, a marked decline in comparison with the reference curves was observed for weight, height and arm circumference for age. A minimum level at or below the P10, corresponding with at least 1 SD below the P50 of the reference, was reached by the age of 18 months, and this level was kept until 24 to 27 months. The curves for weight, height and especially arm circumference for age consistently showed a larger and longer lasting drop in girls than in boys.

After the age of two years, a partial return in the direction of the P50 of the reference was observed. In boys, all parameters except height showed a positive shift in comparison with the minimum level of 18 - 24 months,



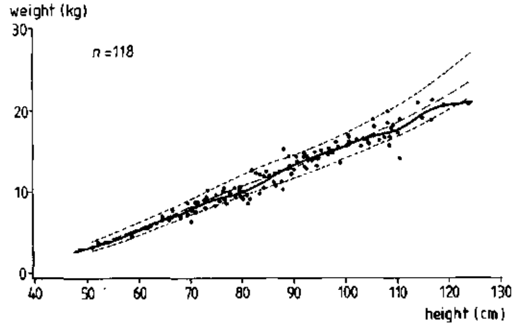
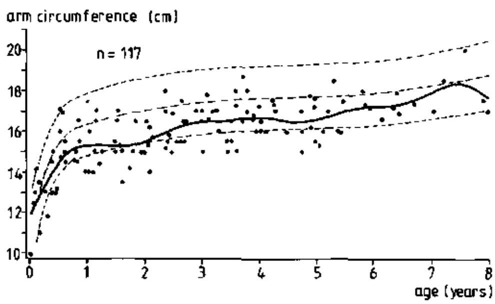


Fig. 5. Weight for height, boys **Fig. 6. Weight for height, girls**
- - - - P10, P50, P90 of reference population (Roede & van Wieringen, 1985)



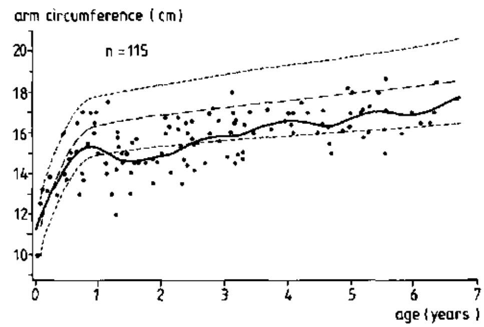


Fig. 7. Arm circumference for age, boys **Fig. 8. Arm circumference for age, girls**
- - - - P10, P50, P90 of reference population (Gerver, 1988)

which reached statistical significance for weight and arm circumference (P < 0.05) as well as for both skinfolds (P < 0.01). In girls, this effect of partial return towards the P50 of the reference was less pronounced and only reached statistical significance for arm circumference (P < 0.01). After the age of 36 months in boys and 42 months in girls, most parameters remained 0.5 to 1 SD below the P50 of the reference. For height, no increase of SDS was observed after the age of two years.

Weight for height curves showed only small deviations from the P50 of the reference for both sexes, which did not reach statistical significance. A slight decrease followed by an increase was observed between 80 and 100 cm of height, corresponding with the age period of two to four years.

SDS of weight, height and arm circumference were significantly higher in children from families consuming dairy products at least three times per week compared to children from families which rarely or never used dairy products (Student's t, P < 0.05). The association is illustrated in Table 5

Table 4. Standard deviation scores (mean ± SE) of children on macrobiotic diets at different ages and increase after the age of two years.

PARAMETER	STANDARD DEVIATION SCORES			
1. BOYS	(A) < 8 months	(B) 18-24 months	(C) > 36 months	Difference (C) - (B)
Weight/age	-0.05 ± 0.19	-1.16 ± 0.24 [3]	-0.59 ± 0.11 [3]	0.57 [1]
Height/age	0.04 ± 0.19	-1.24 ± 0.24 [3]	-1.10 ± 0.11 [3]	0.14
Arm circumference/age	-0.72 ± 0.21 [3]	-1.29 ± 0.23 [3]	-0.69 ± 0.11 [3]	0.60 [1]
Triceps skinfold/age	-1.04 ± 0.18 [3]	-1.15 ± 0.21 [3]	-0.51 ± 0.10 [3]	0.65 [2]
Subscapular skinf/age	-1.12 ± 0.20 [3]	-0.89 ± 0.23 [3]	-0.05 ± 0.10	0.84 [2]
2. GIRLS	(A) < 6 months	(B) 18-27 months	(C) > 42 months	Difference (C) - (B)
Weight/age	-0.33 ± 0.31	-1.21 ± 0.24 [3]	-0.93 ± 0.15 [3]	0.28
Height/age	0.08 ± 0.34	-1.39 ± 0.26 [3]	-1.21 ± 0.17 [3]	0.18
Arm circumference/age	0.03 ± 0.36	-1.68 ± 0.23 [3]	-0.75 ± 0.15 [3]	0.93 [2]
Triceps skinfold/age	-0.33 ± 0.36	-0.83 ± 0.20 [3]	-0.89 ± 0.14 [3]	-0.06
Subscapular skinf/age	-0.98 ± 0.37 [1]	-0.96 ± 0.20 [3]	-0.52 ± 0.14 [3]	0.44

Significance of difference from zero, i.e. from the P50 of the reference:
[1] $P < 0.05$, [2] $P < 0.01$, [3] $P < 0.001$.

Table 5. Standard deviation scores (mean ± se) of height for age in macrobiotic children according to frequency of dairy consumption in their families

FREQUENCY OF DAIRY CONSUMPTION	SDS OF HEIGHT IN CHILDREN AGED: less than 1.5 years	1.5 years or more
Less than once per month	- 0.56 ± 0.16 (43)[1]	- 1.29 ± 0.09 (94)
Once p. month - twice p. week	- 0.13 ± 0.31 (17)	- 1.15 ± 0.13 (54)
More than three times per week	0.23 ± 0.27 (10)	- 0.89 ± 0.22 (23)

[1] Figures in brackets are numbers of children.

for height. By means of multiple regression analysis, this association was partly attributed to the difference in birth weight in children from families with or without regular dairy consumption. No association was observed between SDS and family consumption of fish, meat or eggs.

DISCUSSION

In order to obtain a valid description of the situation in children on macrobiotic diets, the present study aimed at covering the complete macrobiotic child population between 0 and 8 years of age in the Netherlands. In fact, our study covered at least 80 per cent of the Dutch macrobiotic families who were eligible for the study and had regular contact with macrobiotic centres or other macrobiotic families. From the results of our questionnaire, it may be concluded that the study population indeed followed a macrobiotic food pattern as described by Kushi (1987). In addition, the great majority of the participating families had a long experience with the macrobiotic diet: 72 per cent of the participants had followed this diet for more than five years.

The figure of low birth weight in our study population (6.5 per cent) was considerably higher than in the general Dutch population (2.0 per cent). In an earlier study in macrobiotic children in Boston, USA, low birth weight was reported in 5.2 per cent of the children (Shull et al., 1977). Moreover, in the remaining children the average reported birth weight was 150 grams lower than the Dutch median birth weight. Birth weight showed a strong positive relationship with the consumption frequency of dairy products and fish. The duration of the macrobiotic diet before pregnancy did not significantly contribute to birth weight. This suggests that the composition of the macrobiotic diet during rather than before pregnancy is the cause of the lower birth weight reported in macrobiotic infants.

Since the present study had a cross-sectional design, the faltering of growth observed in macrobiotic children might be attributed to possible confounding factors. However, the high educational level of the macrobiotic parents would be expected to lead to higher instead of lower than average weight and height (Roede & van Wieringen, 1985). The mid-parent height of 1.74 m for the macrobiotic parents was equal to the average height of Dutch parents of the same age cohort and was similar for all age classes of children in our study.

Our findings are similar to those of earlier studies in smaller samples of vegetarian (Fulton et al., 1980; Sanders & Purves, 1981; Shinwell & Gorodischer, 1982; van Staveren et al., 1985) and macrobiotic children (Shull et al., 1977; Dwyer et al., 1980; van Staveren et al., 1985). In Boston, USA, Dwyer et al. (1980) observed low weight, height and arm-muscle circumference in a semi-longitudinal study of 77 macrobiotic children. The values were most depressed in the age group of 12 - 35 months. Before the age of 12 months, anthropometric measurements of the participants in the Boston study did not differ from the Harvard standard, nor did weight for height at any age (Dwyer et al., 1980). Below two years, weight and height velocities of children lagged behind longitudinal standards, whereas from two years onwards some catch-up growth was observed in weight, but not in height (Shull et al., 1977). The findings of the Boston study render it unlikely that our findings would in fact be due to cohort differences within our macrobiotic study sample.

In the Boston study, the authors mentioned the problem of a high drop-out rate. However, our findings, which are representative for the Dutch macrobiotic population, almost exactly fit with the Boston findings. Both studies indicate a growth stagnation in macrobiotic children from six months onwards, reaching a minimum level between 1½ and 2 years followed by only a partial return towards the P50 of the reference after the age of 2 years.

These stages of growth observed in macrobiotic children are similar to the three stages of childhood growth described by Thomson (1970):

1. The period from 0 - 6 months, during which growth is usually satisfactory.
2. The period from 6 - 18 months, when the child has to make the transition from (breast-)milk to a solid diet. During this period, malnutrition and other adverse circumstances may cause a serious set-back to growth.
3. The period from about 18 months to 5 years, when the rate of growth may be fairly satisfactory but often fails to achieve full recovery from the previous set-back.

In combination with the description by Thomson, it would appear that environmental factors and especially the nutritional composition of the macrobiotic weaning diet must be responsible for the observed growth deviations in macrobiotic children. Our data provide some support for this hypothesis. We observed an association of the depressed anthropometric variables with the consumption frequency of dairy products. The fact that no catch-up growth in height occurs in macrobiotic children may indicate the existence of chronic nutritional deficiencies which do not allow catch-up growth in height in spite of some catch-up in weight, arm circumference and skinfolds. Further studies will have to show whether the observed growth stagnation at weaning has any health consequences.

ACKNOWLEDGEMENTS

We would like to thank the fieldworkers for their contribution to this study as a part of their studies in human nutrition: A. van Asselt, M. Duyvenstein, H. Toussaint, and Ch. Ulmann. We are also indebted to the macrobiotic teachers for their help in recruiting the participants of the study and to the participating families for their excellent cooperation. Valuable help and advice was obtained from Dr. W.J.M. Gerver (St. Annadal Hospital, University of Maastricht), Prof. J.C. van Wieringen and Dr. J.M. Wit (Wilhelmina Children's Hospital, University of Utrecht), Dr. B.J. Otten and W. Graafsma (Paediatric Department, University of Nijmegen), Dr. M.A. van 't Hof (Department of Statistical Consulatation, University of Nymegen) and M. Pattiapon (Computing Center, University of Groningen).

This work was supported in part by the Dutch Praeventiefonds.

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4 Weaning pattern and nutrient intake of infants on macrobiotic diets and matched omnivorous control infants: a mixed-longitudinal study

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SUMMARY

Information on food intake during weaning was collected as a part of a mixed-longitudinal study on the nutritional status and growth of the 1985 Dutch birth cohort of infants on macrobiotic diets (n = 53) and a matched control group on omnivorous diets (n = 57). Three-day weighed food records including breast-milk were obtained on 49 macrobiotic and 57 control infants at two-monthly intervals between the ages of 6 and 16 months. Intake of energy and nutrients was calculated using the Dutch food composition table which was supplemented by our own analyses of 50 macrobiotic foods. Ninety six per cent of the macrobiotic infants and 74 per cent of the control infants had been breastfed, but breastfeeding continued longer in the macrobiotic group (13.6 vs. 6.6 months, $P < 0.001$). In the macrobiotic group, complementary feeding started at 4.8 months with water-based cereal porridges, followed later by vegetables, sesame seeds and pulses. Fruits were rarely given and products of animal origin were avoided. For all age groups combined, the intake of energy, protein, fat, calcium, riboflavin and vitamin B12 was significantly lower in the macrobiotic infants, whereas their intake of polysaccharides, fibre, iron and thiamine was higher than that of the control infants. The macrobiotic weaning diet tended to be bulky by a low energy density (2.4 kJ/g, controls: 3.4 kJ/g, $P < 0.05$) and a high fibre content. Protein intake of the macrobiotic infants was only 80 per cent of the Dutch recommended daily intakes at the age of 6 - 8 months, and at 8 months, 69 per cent of this was derived from plant sources. Calcium intake was 280 mg/day; correction for calcium derived from hard tap-water raised the calcium intake to 308 mg in the macrobiotic age group of 14 months. The evidence of biochemical deficiencies of iron, riboflavin, vitamin B12, vitamin D and calcium is discussed. It is suggested to supplement the macrobiotic diet with fat, fatty fish and dairy products.

INTRODUCTION

Although the nutritional consequences of alternative diets for children have been a source of concern for a number of years (Robson et al., 1974; American Academy of Pediatrics, 1977; Roberts et al., 1979; Schulpen, 1982), information about the food habits of specific well-defined child populations is incomplete. Energy and nutrient intakes have been described in selected groups of preschool children on different alternative diets (Fulton, Hutton & Stitt, 1980; Sanders & Purves, 1981; Dwyer et al., 1982; van Staveren et al., 1985), but little is known about the intake of energy and nutrients during weaning. In a study in infants aged 4 - 18 months on macrobiotic and omnivorous control diets, low plasma vitamin B12 levels associated with elevated mean corpuscular volume have been observed (Chapter 5) as well as a high prevalence of rickets (Chapter 6). In this paper, the nutritional intake and weaning pattern of the same infants are reported. The relationship between nutrient intake and biochemical findings reported in Chapters 5 and 6 is discussed.

METHODS

Selection of subjects

Infants on macrobiotic diets eligible for our study were born in 1985 in the Netherlands, were caucasian, born at term (i.e. after more than 37 weeks of gestation) and were not suffering from a congenital or neonatal disease. From their birth, these infants, and also their mothers should have been on a macrobiotic diet as described by Kushi (1977, revised 1987). In fact, all participating mothers had followed a macrobiotic diet for at least three years and 75 per cent for more than five years.

With the help of macrobiotic teachers and participating families, a total of 56 eligible infants were identified and their parents invited to join the study. One family could not be contacted and two infants dropped out during the study because the parents would not permit anthropometric measurements of their children. In total, 53 infants (26 boys and 27 girls) participated in the study. Food records were completed for 49 infants.

Selection of control group

Infants for the control group were selected from parents on omnivorous diets according to the same criteria described for the macrobiotic infants. Vegetarian or other families of alternative food habits were excluded. The control and the macrobiotic sample were matched for month of birth, sex and parity of the child as well as the educational level of the father (as an indicator of socio-economic status) and the region of residence. Since no macrobiotic infants were taken to a day nursery, this was also a prerequisite for the control infants. Infants were selected according to these criteria by health personnel from eight child health clinics throughout the Netherlands. After permission to pass on their address was gained from the parents, we sent invitations by mail to 59 families. Two infants dropped out during the study; one because of chronic respiratory disease and the other because the parents refused anthropometric measurement. In total, 57 infants (31 boys, 26 girls) took part in the study. Food records were completed for all 57 infants.

Study design

The study design was approved by the Ethical Committee of the Agricultural University, Wageningen, the Netherlands. On the basis of birth date, both macrobiotic and control infants were assigned to three cohorts of 15 - 20 infants (Fig. 1; van 't Hof, Roede & Kowalski, 1977). Each cohort was monitored for six months, during which anthropometric measurements were taken at two-monthly intervals. During the first home visit, a questionnaire

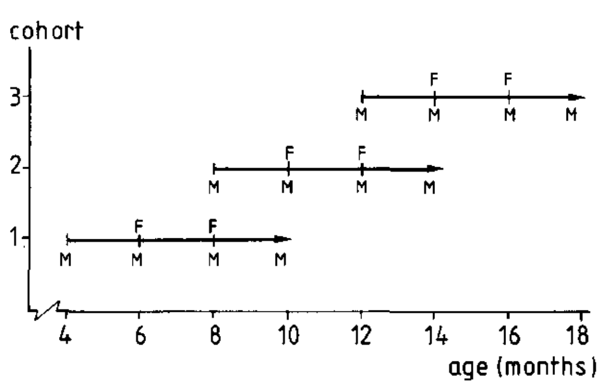

Fig. 1. Study design

was taken from the mothers in order to check the eating pattern of the family. In addition, questions on their pregnancy, delivery and the level of education were included. Information on changes in the infants' feeding pattern and spells of illness was collected during subsequent visits.

Two food record periods of each three days were included in the study design, that is just before or after the second and third anthropometric visit (Fig. 1). A single blood sample was collected by a paediatrician within three months after the end of the mixed-longitudinal study.

Food record

Based on the day-to-day variation observed in an earlier study (van Staveren et al., 1985), a record period of three rather than five days was chosen. The slight increase in precision gained by using five day records did not warrant the extra effort required of participants.

The record days were arranged so that they did not coincide with holidays and birthdays. If an infant became ill during a record period, then a new time was arranged. In the few cases where this was not possible, the data were excluded. In order to compare individual data in the first and second record period, the same weekdays were chosen in both periods for individual infants. Since food patterns have been shown to differ on working and weekend days, the record days were spread proportionally over working days, Saturdays and Sundays for each cohort. However, it was not always possible to adhere to this design because participating families were distributed throughout the Netherlands. Thus, the ration of weekend and working days (ideally 2/5 = 0.40) was 0.38 in the macrobiotic group and 0.36 in the control group.

The "precise weighing" method (Bingham, 1988) was used, in which the raw ingredients, the cooked foods, plus the individual portions (including drinks and tap-water) were weighed by the mothers. Electronic weighing scales (Sartorius 1203MP, 0 - 4 kg/0.1 g and Sartorius 1020, 0 - 3 kg/1 g) were provided for this purpose. The mothers measured the volume of breast-milk by test-weighing their infant before and after each feed during the three record days and nights, using a TEC electronic weighing scale (type SL32-bs; 0.5 - 15 kg/5 g) (Stuff et al., 1986).

In order to achieve a maximum accuracy, mothers were given careful oral and written instructions, similar to those described by Bingham (1988). The food records were checked for missing and ambiguous data.

Conversion into nutrients

Nutrient intakes were calculated using the computerized Dutch Food Composition Table (Stichting NEVO, 1986). As accurate information was available on the nutritional composition of most foods commonly used in the macrobiotic diet, representative samples of 50 of these products were purchased and analysed (Willems et al., 1987) after preparation in accordance with macrobiotic cooking practices (Goud, 1983, revised 1988), using tap-water with a calcium content of 28 mg/l. Since sieved water-based grain porridges are the main macrobiotic weaning food, 12 kinds of such porridges were prepared to macrobiotic recipes and analysed (de Graaf et al., 1987). The consistency of the results was checked by inviting an experienced macrobiotic cook to prepare five infant dishes and these were then analysed. The results showed no major inconsistencies. Finally, 21 breast-milk samples from macrobiotic mothers with an infant of either 2 - 3 months or 9 - 13 months of age and 10 control mothers were analysed (Dagnelie et al., unpublished data). Because calcium and vitamin B12 content were significantly lower in breast-milk of the macrobiotic mothers, the median values for these nutrients were used in calculations. For the remaining products, which were few and eaten in small amounts only, data from foreign food composition tables or for similar products in the Dutch Food Composition Table were taken.

The foods eaten were divided into 6 groups (Table 1) in order to describe their contribution to the intake of energy and nutrients at selected ages (6, 10 and 14 months). Because tap-water has been mentioned as a potentially important source of calcium (Sanders & Purves, 1981), the contribution of tap-water to calcium intake was calculated from the water

Table 1. Food groups

1. Breast-milk
2. Animal products, including dairy products (except butter), adapted infant formula, meat, poultry, eggs, fish and shellfish
3. Cereals and pulses, including porridges, bread, and fermented soy foods
4. Vegetables and fruits, including seaweeds and beverages
5. Fats, nuts and seeds, including oils and butter
6. Remaining foods, including sweets, malt sirups, soups and composite dishes

intake including the amount added in cooking, using figures for calcium content of local tap-water (VEWIN, 1985). The energy density of the diet was calculated including all foods and drinks. As a consequence, energy density values may be lower than those reported elsewhere for solid foods only.

Blood analysis

Erythrocytes were washed three times in a physiological NaCl solution and stored in a 0.5 % sterox solution at -20 ^{o}C until analysis (within four weeks). The activity of erythrocyte glutathione reductase (EGR) was determined in hemolysate of washed erythrocytes before (E = endogenous EGR-activity) and after (S = stimulated EGR-activity) the addition of coenzyme FAD, as described by Bayoumi & Rosalki (1976). The EGR-activity coefficient (A) was calculated as A = S/E.

Statistical analysis

In order to test differences in energy and nutrient intakes between the macrobiotic and control group, the two successive food records in all cohorts were simultaneously compared by multivariate analysis of variance (MANOVA). For presentation of nutrient intakes per age group, the first and second food records were combined, resulting in values for 6 - 8 months, 10 - 12 months, and 14 - 16 months. Differences in energy and nutrient intake between the macrobiotic and control group for these age groups were tested by Student's t.

The Dutch recommended daily intakes (Netherlands Nutrition Council, 1981) were used to evaluate energy and nutrient intakes. These recommended daily intakes (RDI) are expressed per kg body weight for children up until the age of one year, whereas only one value per nutrient is given for the age group 1 - 3 years. Therefore, we calculated RDI for each age group using the P50 of the reference weight for age (Roede & van Wieringen, 1985) as described by WHO (1985, p. 144).

RESULTS

A high proportion of infants in both groups were breastfed: 96 per cent of the macrobiotic group and 74 per cent of the control group were or had been breastfed for at least one month (Fig. 2). However, the macrobiotic mothers continued to breastfeed longer (13.6 $\pm$ 3.1 months; mean $\pm$ SD) than control mothers (6.6 $\pm$ 3.2 months; $P < 0.001$). Eighteen per cent of macrobiotic

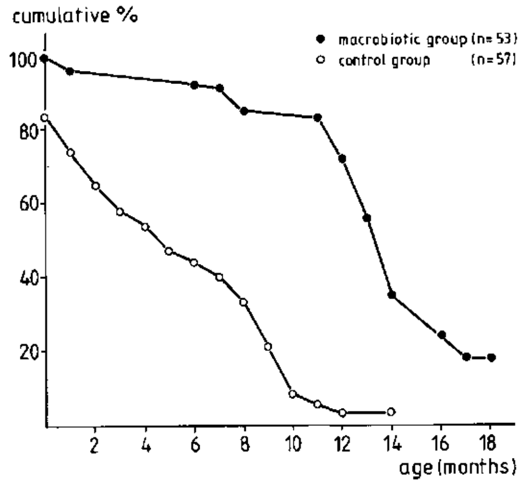

Fig. 2. Duration of breastfeeding of macrobiotic and control infants

infants were still being breastfed at eighteen months. In the control group, complementary feeding started with fruits at a mean age of 2.7 months, followed in the next two months by vegetables (4.0 months) and cereals (5.0 months). In contrast, complementary feeding in the macrobiotic group started at a mean age of 4.8 months with water-based, sieved porridges from whole grain cereals (mainly unpolished rice), followed by vegetables (5.7 months) and sesame seed (6.4 months). Pulses were added some months later (8.2 months). Fruits were either avoided or introduced much later than in the control group (7.6 months).

Dairy products or adapted infant formula had been given to 21 per cent of the macrobiotic infants at some time. Eight macrobiotic infants (15 per cent) received more than 25 g of dairy products per day during the food record periods, but only three of these received more than 100 g/day. Three macrobiotic mothers had stopped breastfeeding within six months because of insufficient milk supply. One of the infants was subsequently fed a milk-based adapted formula, one a mixture of cow's milk and water, and one cereal porridges supplemented with adapted soy formula for a periode of two months. No other products of animal origin such as eggs, meat or fish were given to any macrobiotic infants during the study.

The average daily intake of energy and nutrients in the three cohorts of the macrobiotic and the control group, as well as for all age groups combined, is presented in Table 2. For all age groups combined, the differences were significant at the $P = 0.001$ level. The contribution of various foods to the intake of energy, fat and protein at the age of 6, 10 and 14 months

Table 2. Intake of energy and nutrients by infants on macrobiotic and omnivorous (control) diets at three different ages and of the age groups combined

		PER AGE GROUP MEAN						AGE GROUPS COMBINED MEAN ± SD		
		Macrobiotic group			Control group			Macrobiotic group	Control group	
Age		6–8	10–12	14–16	6–8	10–12	14–16	6–16	6–16	
Number of infants		17	16	16	20	18	19	49	57	
Energy	MJ	2.7	3.1	3.3	3.0	3.7	4.1	3.0 ± 0.5	3.6 ± 0.7	[1]
En. density:	kJ/g	2.5	2.3	2.4	3.1	3.4	3.6	2.4 ± 0.3	3.4 ± 0.5	[1]
Protein										
animal [2]	g	7	5	2	18	27	28	4 ± 3	24 ± 8	[1]
total	g	14	21	27	23	35	37	20 ± 7	32 ± 10	[1]
energy	%	9	11	14	13	17	16	11 ± 3	15 ± 3	[1]
Fat	g	27	24	14	29	28	33	22 ± 9	30 ± 7	[1]
energy	%	37	29	17	37	29	30	28 ± 12	32 ± 7	[1]
Carbohydrate										
oligosacchar.	g	62	47	30	59	69	80	47 ± 20	70 ± 17	[1]
polysaccharides	g	25	62	104	32	52	51	63 ± 41	45 ± 18	[1]
total	g	87	109	134	92	122	131	110 ± 29	115 ± 25	
energy	%	55	60	70	52	56	55	61 ± 10	54 ± 5	[1]
Dietary fibre	g	6	13	19	5	8	8	13 ± 7	7 ± 3	[1]
energy	g/MJ	2.4	4.2	5.7	1.7	2.3	2.0	4.1 ± 1.9	2.0 ± 0.7	[1]
Calcium [3]	mg	254	306	281	595	796	872	280 ± 68	751 ± 230	[1]
Iron	mg	2.4	5.3	7.8	3.0	4.4	4.7	5.1 ± 2.8	4.0 ± 1.6	[1]
Thiamine	mg	0.3	0.6	0.8	0.3	0.5	0.5	0.6 ± 0.3	0.4 ± 0.1	[1]
Riboflavin	mg	0.3	0.4	0.4	0.8	1.1	1.2	0.4 ± 0.1	1.1 ± 0.3	[1]
Vitamin B12	µg	0.2	0.3	0.3	1.9	3.2	3.6	0.3 ± 0.2	2.9 ± 1.3	[1]
Vitamin C	mg	49	65	45	58	77	97	53 ± 22	77 ± 40	[1]

[1] Significance of differences between macrobiotic and control group (all ages combined, MANOVA): $P < 0.001$.
[2] Including breast-milk.
[3] Based on preparation of foods with water containing 28 mg of calcium/liter.

is given in Fig. 3 - 5.

The average energy intake was 3.0 MJ/day in the macrobiotic group compared to 3.6 MJ/day in the control group. This difference was smallest in the youngest age group (6 - 8 months) and increased with age. At 6 months, the most important source of energy for macrobiotic infants was breast-milk followed by cereals (Fig.3). With age, the contribution of breast-milk to energy intake decreased; the gap was filled by cereals, pulses and vegetables. The contribution of dairy products and plant fats, which were the main energy source in the omnivorous weaning diet, was negligible.

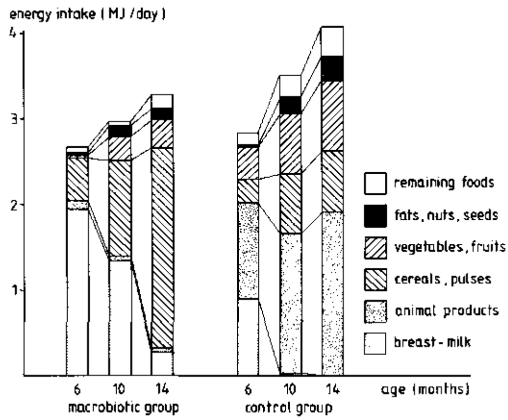

Fig. 3. Contribution of different foods to energy intake by infants on macrobiotic and omnivorous (control) diets

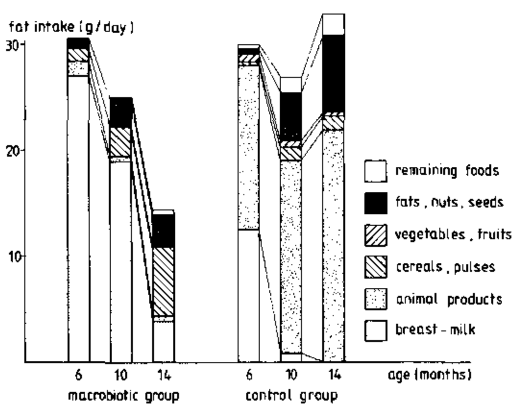

Fig. 4. Contribution of different foods to fat intake by infants on macrobiotic and omnivorous (control) diets

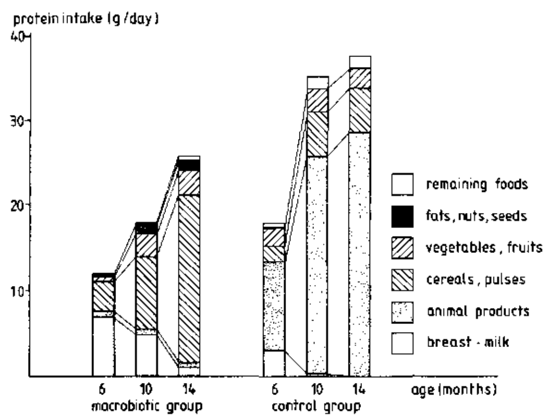

Fig. 5. Contribution of different foods to protein intake by infants on macrobiotic and omnivorous (control) diets

The energy density of the macrobiotic diet was 2.4 kJ/g and 3.4 kJ/g in the diet of the control group (Table 2). This difference was attributed to a lower intake of fat by macrobiotic infants. While between 6 - 8 months, fat contributed 37 per cent of the energy intake in both groups of infants, by 14 - 16 months this had decreased to 17 energy per cent in the macrobiotic group, but was still 30 energy per cent in the control group. Breast-milk was the main fat source in macrobiotic infants at 6 months, but this was not replaced by other fat sources such as milk products or plant fats during weaning, as it was the case in the control group (Fig. 4).

The average protein intake in the macrobiotic group was 20 g/day (11 energy per cent) compared to 32 g/day (15 energy per cent) in the control group. Intake was lowest in the macrobiotic age group 6 - 8 months, being 14 g/day (8 energy per cent). At 6 months, 60 per cent of protein was derived from animal sources, mainly breast-milk (Fig. 5). With the decreasing amount of breast-milk, the proportion of animal protein quickly decreased to 31 per cent at 8 months and further to 20 per cent at 12 months. Dairy products, meat and fish, which contributed most of the protein intake in the control group, were virtually absent in all macrobiotic age groups.

At 6 - 8 months of age, approximately 55 per cent of energy was provided by carbohydrate in both groups, but only in the macrobiotic group this proportion increased with age to 70 per cent at 14 - 16 months. The macrobiotic diet was higher in polysaccharides and lower in oligosaccharides than the omnivorous weaning diet, a difference which also increased with age.

The average fibre intake was similar in both groups at 6 - 8 months of age (5 g/day), but in the macrobiotic group, increased greatly with age to an average of 19 g/day at 14 - 16 months (control group: 8 g/day). When expressed in proportion to the energy intake, the fibre density of the macrobiotic diet was considerably higher at all ages (Table 2).

The average calcium intake was only 280 mg/day in the macrobiotic group and was 751 mg/day in the control group. The contribution of different foods to calcium intake is presented in Table 3. Although the total calcium intake was similar during weaning, the main source of calcium in macrobiotic infants changed from breast-milk at the age of 6 months to vegetables, cereals and pulses at 14 months of age. Pulses (especially tofu and tempeh), sesame seeds and seaweeds are considered to be an important calcium source by followers of the macrobiotic diet. In fact, the contribution of these foods to the calcium intake was minimal. At 14 months, tofu and tempeh provided 38 mg of calcium per day, sesame seeds only 12 mg/day, and seaweeds 10 mg/day (Table 3). In the control group, dairy products were by far the main calcium source at all ages, contributing 350 mg/day at 6 months and 785 mg/day at 14 months. The contribution of tap-water to calcium intake was 48 mg of calcium per day in the macrobiotic age group of 14 months.

Iron intake was slightly lower in the macrobiotic group at the age of 6 - 8 months (2.4 mg/day, control group 3.0 mg/day). However, in the macrobiotic age group of 14 - 16 months, the intake had increased to 7.8 mg/day compared to 4.7 mg/day in the control group. All iron in the macrobiotic

Table 3. Contribution of different foods to the calcium intake (mg) by infants on macrobiotic and omnivorous control diets at 6 and 14 months

	MACROBIOTIC GROUP		CONTROL GROUP	
Age	6 months	14 months	6 months	14 months
Number of infants	17	16	20	19
Breast-milk	172	24	93	0
Dairy products	27	17	350	785
Cereals	8	40	6	17
Tofu, tempeh	0	38	0	0
Other pulses	2	15	1	1
Vegetables and fruits	23	101	29	53
Seaweeds	0	10	0	0
Sesame seeds	2	12	1	0
Other nuts and seeds	0	1	0	2
Remaining foods	0	3	19	33
Tap-water[1]	13	48	7	8
Total	247	309	507	900

[1] Based on figures for calcium content of local tap-water.

solid food originated from vegetables and to a lesser extent from pulses and cereals. In the control group, with age an increasing proportion of iron was haem iron, amounting to 0.3 mg/day at 4 - 6 months and 0.8 mg/day at 14 - 16 months.

The thiamine intake was 0.6 mg/day in the macrobiotic group and 0.4 mg/day in the control group. The observed increase with age in the macrobiotic group was attributed to the increasing consumption of whole grain cereals.

Considerable differences between the two groups were found with respect to the intake of riboflavin and vitamin B12. Riboflavin intake in the macrobiotic group was 0.4 mg/day (control group: 1.1 mg/day). The vitamin B12 intake was 0.3 μg/day compared to 2.9 μg/day in the control group. The intake of both vitamins in the macrobiotic group was almost independent of age, in contrast to the control group where an increase with age was observed. At the age of 6 months, breast-milk was still the major source of vitamin B12 in macrobiotic infants, but at 14 months, the contribution was negligible (0.02 μg/day).

DISCUSSION

In this study, considerable differences in nutrient intake between infants on macrobiotic and omnivorous diets were observed, and these differences increased with age. In general, the results are in accordance with earlier studies on the energy and nutrient intake in weaned children on macrobiotic diets (Dwyer et al., 1982; van Staveren et al., 1985). However, to date no detailed information has been available on the composition of the macrobiotic diet during weaning. The inclusion of nutrient data on macrobiotic foods, porridges and breast-milk has greatly helped to increase the accuracy of energy and nutrient calculations. For instance, when compared to the nutrient composition approximated from existing food tables, our food analyses yielded significantly lower intakes of energy, protein, calcium and iron with a maximum difference of -22 per cent for protein intake by macrobiotic infants aged 6 - 8 months.

The low energy intake in macrobiotic infants was attributed to the composition of the weaning diet. The energy density of the macrobiotic diet was lowest in infants aged 10 - 12 months, and it was only two thirds of that of the omnivorous diet. The energy density of water-based cereal porridges, which are the major component of the macrobiotic weaning diet, has been demonstrated to be approximately 2.9 kJ/g (de Graaf et al., 1987), because cereal porridges tend to be very glutinous unless made into a thin gruel by adding water (WHO, 1985, p.116). Further, the fibre content of the macrobiotic diet was high, making the diet bulky. It is well known that young children have difficulty in eating sufficient amounts to meet their energy and protein requirements from such a bulky diet (Dearden, Harman & Morley, 1980). The addition of fat, which could have made porridges less glutinous and at the same time increased the energy density (Dearden et al., 1980; WHO, 1985, p.117), has been strongly discouraged in the macrobiotic weaning diet up to the age of two years and regular use even until five years of age (Kushi & Kushi, 1986, p. 88).

The low protein intake in macrobiotic infants is a cause for concern. Intake was less than 80 per cent of the Dutch recommended daily intake in 59 per cent of the macrobiotic infants at 6 months of age, 41 per cent at 8 months, and in 28 per cent at 14 months. The main reason for the low protein content was the need to sieve the grain porridge to remove the bran. A considerable proportion of the protein remains in the sieve (de Graaf et al., 1987). Moreover, the rapid increase with age in the macrobiotic group in the proportion of protein derived from plant sources, mainly rice and sweet rice, raises concern about the digestibility and biological value of the protein in comparison with diets including animal products (WHO, 1985, pp. 118-126).

A low calcium intake was observed in all macrobiotic age groups between 6 and 16 months. During weaning the proportion derived from plant sources, mainly vegetables, increased. This low calcium intake seems critical especially in connection with our observation, that only one out of the 53 macrobiotic infants received a daily supplement of vitamin D. We reported the finding of rickets in 15 macrobiotic infants (28 per cent) in summer, although all but four of these had plasma 25-OH-vitamin D concentrations within current norms (Chapter 6). Lack of calcium can be an independent factor causing rickets, even when the vitamin D status is adequate (Kooh et al., 1977; Fraser et al., 1980; Pettifor et al., 1981; Eyberg, Pettifor & Moodley, 1986). Substances which may impair calcium absorption in the macrobiotic diet are fibre, cellulose, phytate, oxalate and alginate (Ismail-Beigi et al., 1977; Kelsay, 1978; Slavin & Marlett, 1980; Allen, 1982; Heaney, 1988). Our data were checked for a possible association of fibre intake with biochemical findings within the macrobiotic group by means of multiple regression analysis. After adjustment for age and plasma vitamin D concentration, higher fibre intakes were found to be associated with lower plasma calcium concentrations. This confirms earlier reports on a positive association of a high fibre intake and a high incidence of rickets (Robertson et al., 1981 and 1982).

For all ages combined, 68 per cent of the macrobiotic infants and 87 per cent of the control infants had iron intakes below the Dutch recommended daily intake. Although the iron intake in the macrobiotic group increased greatly with age to 1.7 times the intake of the control group at 14 - 16 months, the recommended intake was not met by 19 per cent of this macrobiotic age group. We reported a low iron status in 11 per cent of the macrobiotic group compared to two per cent of the control group (Chapter 5). This may have been due to the lower availability of iron from plant sources in comparison to breast-milk iron or haem-iron (Dwyer et al., 1982; Hallberg, Rossander & Skanberg, 1987).

The low riboflavin intake in the macrobiotic group was reflected in biochemical evidence of riboflavin deficiency. The activity coefficient of erythrocyte glutathione reductase (EGR) was 1.14 ± 0.10 (mean $\pm$ SD) in the macrobiotic group compared to 1.01 ± 0.06 in the control group ($P < 0.001$).

Twenty six per cent of the macrobiotic infants had an EGR activity coefficient of more than 1.20 compared to 2 per cent of the control infants.

Due to the avoidance of foods of animal origin, the vitamin B12 intake of the macrobiotic group was only 10 per cent of that of the control group. Only the three macrobiotic infants who received more than 100 g of dairy products met the recommended daily intake of 0.06 μg/kg body weight (Herbert 1987A). The median vitamin B12 concentration in breast-milk of macrobiotic mothers was 0.22 μg/l as compared to 0.30 μg/l in breast-milk of omnivorous mothers (Dagnelie et al., unpublished observations). Since there is some controversy whether plant foods contain vitamin B12 (Long, 1977; Immerman, 1981; Herbert & Drivas, 1982; Briggs, Ryan & Bell, 1983; Djurtoff & Nielsen, 1983; Herbert, 1987A; Herbert, 1987B), we analysed the vitamin B12 content of some 40 plant foods by radio-immunoassay (van den Berg, Dagnelie & van Staveren, 1988). No vitamin B12 was present in any fermented foods (tempeh, shoyu, tamari, rice miso, barley miso, tofu, amesake-rice, umeboshi-prunes). Some algae (especially nori and spirulina) appeared to be rich in vitamin B12 and their values have been included in the intake figures presented in this paper. However, these intake figures do not necessarily reflect the actual intake of bio-available vitamin B12. Firstly, the figures presented here may be overestimations as algae were often eaten in portions of less than 1 g, but coded in minimum portions of 1 g. Secondly, the bio-availability of "vitamin B12" found in algae is uncertain (Chapter 9), whereas non-vitamin B12 corrinoids may block vitamin B12 metabolism (Herbert & Drivas, 1982; Kondo et al., 1982; Herbert, 1987B). Dietary fibre may also interfere with the reabsorption of biliary vitamin B12 (Anonymous, 1979). The observations of low plasma vitamin B12 concentrations in combination with low red blood cell count (RBC) and elevated mean corpuscular volume (MCV) in the macrobiotic group are presented elsewhere (Chapter 5).

Thus, in conclusion, low dietary intakes of energy, protein, calcium, vitamin D, riboflavin and vitamin B12 wer found in the macrobiotic group. For the last four nutrients, these findings reflect the clinical and biochemical deficiencies reported earlier. Supplementation of the macrobiotic weaning diet with food sources having an adequate bio-availability of these nutrients seems to be indicated. An increase in energy and protein intakes would also be advisable. This would be possible by adapting the macrobiotic diet as follows:

- Addition of a source of dietary fat. To raise the fat content of the weaning diet to 25 - 30 energy per cent, 20 - 25 grams of oil per day (that is approximately two tablespoons) would be sufficient. As a rule of thumb, one gram of oil may be exchanged for two grams of sesame or sunflower seeds which would provide the same amount of fat.
- Early introduction of fatty fish in amounts of 100 - 150 grams per week.
- The inclusion of at least one serving per day of dairy products.

The introduction of oil and fatty fish would be acceptable to macrobiotic teachers and in fact, has already been partly adopted. For the adoption of dairy products, a more fundamental change in macrobiotic beliefs is needed.

ACKNOWLEDGEMENTS

We would like to thank the following graduate students for their assistance in collecting and handling of food consumption data: A. Blokstra, V. Ceelen, I. Gosselink, P. van Leeuwen, M. Moerman, C. Remijn, M. Ridder, E. Schoffelen, A. Tops and R. Vrijburg. We are very grateful to Mr. and Mrs. Faber who kindly prepared macrobiotic child dishes needed to verify the validity of analytical data. Furthermore we are indebted to H. van den Berg and J.D. van Klaveren for assistance in blood and data analysis. Valuable advice was given by J. Burema and M.A. van 't Hof (statistic consultants). This research project was supported in part by the Dutch Praeventiefonds.

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5 Increased risk of vitamin B12 and iron deficiency in infants on macrobiotic diets

by P.C. Dagnelie, W.A. van Staveren, F.J. Vergote, P.G. Dingjan, H. van den Berg & J.G.A.J. Hautvast

SUMMARY

The iron, vitamin B12 and folate blood status of the 1985 birth cohort of Dutch infants aged 10.1 - 20.4 months on macrobiotic diets (n = 50) and matched omnivorous control infants (n = 57) was measured. The blood samples were taken by venipuncture. Ferritin, FEP and Hb did not significantly differ between the two groups, but a low iron status (combination of Hb < 120 g/l, ferritin < 10 μg/l and FEP > 750 μg/l) was observed in a higher proportion of the macrobiotic group (11 percent) than in the control group (2 percent, $p < 0.05$). Folate values were higher in the macrobiotic group (31.6 ± 11.7 nmol/l) than in the control group (21.1 ± 8.8 nmol/l, $p < 0.001$), but vitamin B12 concentrations in the macrobiotic group were far below those of the control group (170 ± 102 and 431 ± 173 pmol/l, respectively, $p < 0.001$). In the macrobiotic group MCV was higher ($p < 0.001$) and RBC was lower ($p < 0.001$) than in the control group. It has been urgently advised to and accepted by Dutch macrobiotic teachers and Michio Kushi to incorporate regular servings of animal foods such as fish into the macrobiotic diet in order to get an adequate vitamin B12 supply.

INTRODUCTION

Alternative dietary lifestyles have become increasingly popular in the past two decades. One such lifestyle is macrobiotics, which is characterized by a diet containing little food of animal origin.[1] Concern has been expressed about the risks of nutritional deficiencies, especially in children, that are posed by any diets which contain little animal food.[2-6] In children on alternative diets, so far, mainly anthropometric and dietary studies have been carried out[7-11] but there is little information on their blood chemistry.[12] In studies in Boston macrobiotic children, iron and vitamin B12 deficiencies have been reported.[12,13]

We have studied a group of macrobiotic children in the Netherlands and report here on their iron, vitamin B12 and folate status, in relation to other hematometric values. The following hypotheses were tested in this study:

1. Macrobiotic infants have a lower iron and vitamin B12 blood status than omnivorous infants;
2. These differences are reflected by differences in blood cell indices.

METHODS

Subjects and design

This study of the iron and vitamin B12 status was part of a mixed-longitudinal study in infants on macrobiotic diets. The study was approved by the Ethical Committee of the Agricultural Universitiy of Wageningen, the Netherlands. The study sample consisted of 57 infants on macrobiotic diets (which will be called the "macrobiotic infants") and 57 infants on omnivorous diets (which will be called the "control infants"), matched for month of birth, sex and parity of the child, educational level of the father and region of residence. The macrobiotic sample represented 91 % of the Dutch macrobiotic birth cohort of 1985; addresses were obtained from macrobiotic organizations and families participating in earlier studies in macrobiotic children. The control infants were recruited through infant health clinics. All infants were caucasians.

The blood study was carried out in August - November 1986 and consisted of a home visit with physical examination and blood collection by an experienced pediatrician. All but three macrobiotic parents and all parents of the control group approved of the blood sampling. The number of subjects therefore was 50, their mean age was 15.2 months (range 10.1 - 20.4 months). The number of control infants was 57 with a mean age of 14.8 months (range 10.1 - 20.9 months).

Blood sampling

Blood was collected by venipuncture (single-sample needle, Venoject R 20G x 1½") from the back of the hand or occasionally from the elbow (n = 4, all macrobiotic) or finger (n = 1, macrobiotic). Parents were asked not to feed the children just before blood collection; the time expired between the last meal and the blood sampling was between one and four hours in approximately 70 percent of the infants of both groups. From each child, 4 - 5 ml of blood was collected in a 5 ml sterile heparinized glass tube (Venoject R 86E22N) and after careful mixing immediately stored in a cooling box at approximately 4 - 8 ^{o}C. Heparin was used as anticoagulant in order to allow determination of ferritin: ferritin is reported to be 23 % lower in EDTA plasma as compared to serum.[14] For organizational reasons, it was not possible to handle the samples on the same day. Therefore, samples were stored overnight in a refrigerator at 4 ^{o}C and handled at approximately 2 p.m. on the next day. Blood collection took place over a period of four months (August - November 1986) with an equal distribution for the macrobiotic and control groups.

Laboratory analyses

After careful remixing of the bloods, analyses of hemoglobin, hematocrit and red cell indices were performed in duplicate at Gelderse Vallei Hospital, Wageningen (Baker Diagnostics JTB-7000, maximum between-assay coefficient of variation (CV) 2 - 3 %).

For determination of plasma ferritin, vitamin B12 and folate, blood samples were centrifuged at 1000 G for 10 minutes, after which plasma was frozen at -20 ^{o}C in polyethylene tubes until analysis (within 2 1/2 months). Analyses were performed in duplicate at the TNO-CIVO Toxicology and Nutrition Institute, Zeist, in two consecutive assays. For determination of "true" cobalamin and folate, extraction was performed with a boiling borate buffer, followed by a competitive protein binding assay according to methods described by Herbert et al[15] and for folate by Dunn et al.[16] The binders used were purified intrinsic factor for cobalamin and purified folate binding protein for folate (Radioassay SimulTRAC kit, Becton Dickinson Immunodiagnostics, Orangeburg, N.Y., USA). Addition of 0.003 % KCN was part of this assay. As standards, cyanocobalamin and 5-methyl-tetrahydrofolic acid were used, respectively (CV: for cobalamin: within assay 1.9 %, between assay 3.2 %; for folate: 3.5 % and 6.3 %, respectively). Ferritin was determined by a immunoradiometric assay using commercial reagents (FER-IRON kit, Ramco Lab Inc., Houston, Texas, USA) based on the method described by Miles et al[17] (overall CV 8.3 %).

For determination of free erythrocyte protoporphyrin (FEP), 0.1 ml of blood was stored frozen at -20 ^{o}C in polyethylene tubes until analysis (within one month). Zinc erythrocyte protoporphyrin (ZPP) was determined at Coronel Laboratory, Academic Medical Center of Amsterdam, using hematofluorometer "ZPP-meter" (A.V.I.V., Lakewood, N.J., USA, calibrated at 2, 7 and 40 ug ZPP/g Hb; overall CV: 4.1 - 11.5 %, depending on the range of measurement). FEP[18] was calculated by the equation: FEP = ZPP x MCHC.

Quality control. All analyses were carried out in duplicate and reanalysed if required, except for three macrobiotic samples and one control sample in which too little blood was available for duplicate analyses. For the blood cell indices, in every series, control sera of Ortho (normal/abnormal) and Hemolysate from the National Institute of Public Health and Environmental Hygiene (RIVM, Bilthoven) were analysed.

Change in time. In order to check for possible changes during storage of the blood samples, hematological values were determined in fresh heparinized and EDTA blood from ten adults, as well as in heparinized blood collected 24 hours before. No systematic differences were observed between these blood samples.

Reference values for blood cell indices and ferritin were derived from three Dutch children's hospitals and from the international literature.[19-22] For vitamin B12 and folate, reference data were derived from a TNO-CIVO study of 200 healthy adult males 20 - 60 years of age.[23]

Statistical analysis

Differences between the means of two independent groups and between two variances were tested according to standard statistical techniques. Multiple regression models for explaining Hb, RBC and MCV by different hematometric variates were fitted after $^{10}\log$ transformation of ferritin and vitamin B12 and after correction for age.

RESULTS

Hemoglobin values (Hb) of the macrobiotic and control group were not significantly different (Tablee 1). Hematocrit values (Ht) and red blood cell count (RBC, Table 1; Fig. 1) were significantly lower in the macrobiotic group than in the control group. Mean corpuscular volume (MCV, Table 1; Fig. 2) and mean corpuscular hemoglobin mass (MCH) were significantly

Table 1. Hematometric values in infants aged 10 - 20 months in the Netherlands on macrobiotic and omnivorous control diets

		MACROBIOTIC GROUP Mean ± SD	n	CONTROL GROUP Mean ± SD	n	
Hb	g/l	122.8 ± 7.9	50	124.4 ± 7.3	57	
Ht	l/l	0.372 ± 0.024	50	0.381 ± 0.023	57	1
RBC	$x10^{12}/l$	4.41 ± 0.31	50	4.71 ± 0.33	57	3
MCV	fl	84.2 ± 5.9	50	80.9 ± 4.5	57	2
MCH	pg	27.9 ± 2.0	50	26.5 ± 1.6	57	3
MCHC	g/l	332 ± 11	50	328 ± 10	57	
Ferritin	µg/l	14.4 ± 8.4	49	14.6 ± 7.6	56	
FEP	µg/l	748.1 ± 336	47	747.9 ± 227	57	
ZPP	µg/g	2.27 ± 1.02	47	2.28 ± 0.69	57	
Vitamin B12	pmol/l	170 ± 102	47	431 ± 173	56	3
Folate	nmol/l	31.6 ± 11.7	47	21.1 ± 8.8	56	3

1 Means are significantly different, $p < 0.05$ (Student's t test)
2 $p < 0.01$
3 $p < 0.001$.

higher in the macrobiotic group; besides, MCV was more variable in the macrobiotic infants than in the control infants ($p < 0.05$).

Plasma vitamin B12 values (Table 1; Fig. 3) were dramatically lower in the macrobiotics than in the controls, whereas the macrobiotics had significantly higher folate levels. The P50 of the vitamin B12 concentration in the macrobiotic group was 139 pmol/l and the P10 as low as 79 pmol/l. Plasma vitamin B12 concentrations in the macrobiotic group were independent of age.

Plasma ferritin values of both groups were similar, as were the means of free erythrocyte protopophyrin concentrations (FEP). However, in the macrobiotic group a significantly greater variability of FEP was observed ($p < 0.01$), which was attributed to a greater proportion of children with elevated FEP values.

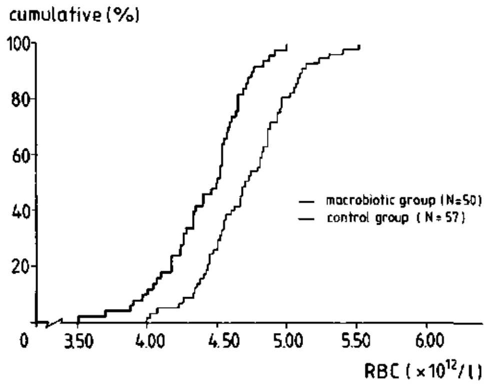

Fig. 1. Red blood cell count (RBC)

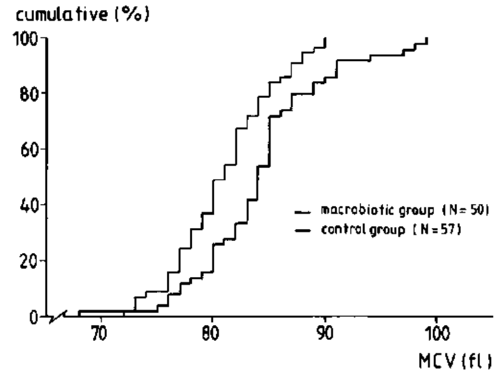

Fig. 2. Mean corpuscular volume (MCV)

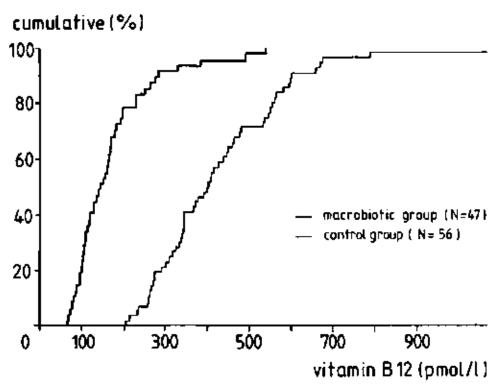

Fig. 3. Plasma vitamin B12 concentration

Fig. 1 – 3. Cumulative frequency distribution of blood values in infants on macrobiotic and omnivorous control diets

In order to obtain information on the independent effects of ferritin, FEP, vitamin B12 and folate on Hb, RBC and MCV, respectively, a multiple regression analysis was carried out for each group. It was only in the macrobiotic group that ferritin contributed significantly to Hb, and FEP to MCV (Table 2). In the macrobiotic group, besides vitamin B12 contributed significantly to RBC and MCV. The negative association between vitamin B12 and MCV in the macrobiotic group is illustrated in Fig. 4.

Table 2. Determinants of Hb (g/l), RBC ($x10^{12}$/l) and MCV (fl): partial regression coefficients for ferritin, FEP, vitamin B12, folacin and age in infants on macrobiotic (M, n = 46) and omnivorous control (C, n = 56) diets

		Hb		RBC		MCV	
		M	C	M	C	M	C
Ferritin[1]	µg/l	0.65[2]	-0.34	0.08	-0.36	4.49	-1.32
FEP x 10^3	µg/l	-0.04	-0.15	0.27	0.01	-5.28[2]	-3.73
Vitamin B12[1]	pmol/l	-0.20	-0.45	0.39[2]	-0.11	-10.57[3]	-5.92
Folacin	nmol/l	-0.01	0.01	0.00	-0.00	0.05	0.08
Age	months	0.06[4]	0.03	0.02	0.00	0.04	0.35
R^2		0.29	0.09	0.31	0.07	0.26	0.15

1 Regression coefficients for ferritin and vitamin B12 after ^{10}log transformation.
2 $p < 0.05$ (t test, one-sided).
3 $p < 0.01$.
4 $p < 0.001$.

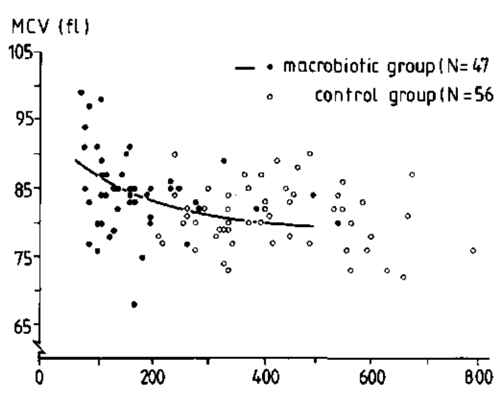

Fig. 4. Association between plasma vitamin B12 and mean corpuscular volume (MCV) in infants on macrobiotic and omnivorous control diets

DISCUSSION

This study was carried out in a "true" macrobiotic population group. In the first place, in our sampling procedure we recruited the complete birth cohort of 1985 after a thorough inventory of macrobiotic families in the Netherlands. Secondly, nearly all parents involved in the study (97 percent) had followed macrobiotic courses or lectures and 92 percent had attended special courses or group consultations on macrobiotic child nutrition. All parents had practiced macrobiotics for more than two years and 75 percent for more than five years. The educational level was high and no apparent adverse social circumstances prevailed.

The majority of the macrobiotic infants had been exclusively breast-fed for a period of 4 - 8 months (median 5 months), after which solids were introduced in the form of vegetables and water-based, sieved whole-grain porridges, with the addition of small amounts of sesame seeds and from 8 months onwards pulses. Breast-feeding was continued until 10 - 18 months of age by most mothers (median 13 months). None of the macrobiotic infants had ever received products of animal origin or vitamin B12 supplements except for 10 infants (20 %) who had received small amounts of dairy products at any time of their life. Detailed information on the food consumption pattern will be published elsewhere.

Iron status

In this study, the mean hemoglobin concentration for the macrobiotic group was similar to that for the omnivorous control group. Twelve percent of the macrobiotic infants and 5 percent of the control infants had hemoglobin values below 110 g/l ($p = 0.18$, Fisher's exact test), but there were no values below 100g/l in either group. Hematocrit values were significantly lower in the macrobiotic infants.

Although the average ferritin and FEP levels were equal in both groups, it was only in the macrobiotic group that ferritin was significantly associated with Hb and FEP with MCV. Moreover, FEP was more variable in the macrobiotics than in the controls. Because FEP may be also elevated in cases of lead intoxication,[24] we examined our data for possible associations of high FEP values with the geographical location and the degree of urbanization of the areas where the participants lived. In neither group was any such association found.

The prevalence of "low iron status" (defined as a combination of Hb below 120 g/l, ferritin below 10 μg/l, and FEP over 750 μg/l) was higher in the macrobiotic group (11 percent) than in the control group (2 percent, p = 0.06, Fisher's exact test).

Our findings thus partly confirm those of an earlier study in 39 selected vegetarian macrobiotic children aged 0.8 - 8.4 years in Boston, U.S.A.[12] In the Boston study, hematological indices suggested the prevalence of mild iron deficiency anemia in approximately a quarter of the macrobiotic children. Although we did not find such a high prevalence of iron deficiency in the present study, our data do indicate an increased risk of iron deficiency in macrobiotic infants.

Vitamin B12 status

Plasma vitamin B12 values of the macrobiotic group were far below those of the control group. Forty five percent of the macrobiotics had vitamin B12 levels below 136 pmol/l, the P2.5 value of data from the same laboratory for an adult reference population; in the control group, no children had such low values. Nineteen percent of the macrobiotics had values below 96 pmol/l, a level below which morphological changes of the blood are expected.[25] Indeed, the low vitamin B12 values in the macrobiotic group were associated with higher MCV and lower RBC values than in the control group.

In view of our findings with regard to the folate and iron status, it may be concluded that these changes were caused by vitamin B12 deficiency. This conclusion is supported by multiple regression analysis, in which vitamin B12 but not folate was found to contribute to RBC and MCV within the macrobiotic group.

As far as we know, this association of low vitamin B12 with low RBC and high MCV has not been reported before in a population study of children on alternative diets, though the association of vitamin B12 with MCV has been reported in lacto-vegetarian adults.[26] In the Boston study of 39 vegetarian and macrobiotic children carried out in 1977, vitamin B12, RBC and MCV values were reported to be within the normal range.[12] However, In a recent study in 17 breastfed Boston macrobiotic infants, aged 1.2 - 13.1 months, vitamin B12 deficiency was demonstrated by elevated urine methylmalonic acid (UMMA) excretions in combination with low maternal serum vitamin B12.[13] It therefore seems that the apparently normal vitamin B12 values found in Boston in 1977 may have been caused by a different vitamin B12 assay used at that time (contaminated IF-binder,extraction without addition of cyanide).[27]

Our findings indicate that the plasma vitamin B12 concentration in macrobiotic infants is sufficiently low to have physiological consequences that also raise legitimate concerns about neurological development. In the pediatric examination that was a part of our study, no significant clinical symptoms of neurological degeneration were found. However, such symptoms are non-specific due to the great variation in normal development in infants, and consequently only major deviations from normal development can be diagnosed. The risk of vitamin B12 deficiency therefore lies in a slowly progressing degeneration of the spinal cord and brain without overt clinical symptoms, which may be overlooked until serious damage has occurred. In children, this risk is likely to be greater than in adults because of their smaller nutrient reserves at a critical development period. In addition to this, the macrobiotic infants had higher plasma folate levels than the control infants. It is wellknown that folate supplementation in patients with vitamin B12 deficiency can mask the hematopoietic manifestations of vitamin B12 deficiency without however correcting the neurological lesions that arise from prolonged vitamin B12 deprivation.[28-30] It is unknown whether the same is true for dietary folate.

Cases of children with vitamin B12 deficiency combined with neurological symptoms and sometimes brain damage have been well described in the literature.[31-40] As a consequence, all children with low vitamin B12 blood levels must be considered to be at risk of sudden deterioration in their condition.

In conclusion, our data strongly confirm that young children in western populations which virtually exclude foods of animal origin are at high risk of vitamin B12 deficiency. At present, naturally occurring plant foods cannot be relied upon as an adequate source of vitamin B12.[41] Recent studies using radio-immunoassays have shown that vitamin B12 is absent in fermented soy products such as tempeh.[13,41] Although the occurrence of vitamin B12 in some algae has been reported, information on its bioavailability is highly controversial.[13,41-42] For this reason, we have urgently advised macrobiotic teachers both at a national and international level to incorporate regular servings of vitamin B12 containing foods into the macrobiotic diet. At present, the consumption of eggs, dairy products, or meat as a source of vitamin B12 is not acceptable for many persons practicing a macrobiotic diet, nor are vitamin B12 pills. Therefore regular consumption of fish with a high vitamin B12 content such as sardines, pilchard, mackerel, herring, salmon and tuna, in amounts of at least 100 - 150 grams per week (providing approximately 0.8 - 2.5 μg of vitamin B12 per day), was strongly promoted, and accepted by the Dutch macrobiotic teachers and Michio Kushi.

ACKNOWLEDGEMENTS

We are indebted to the macrobiotic teachers and staff of child health clinics for their indispensable help in recruiting and assisting in this study. We also express our gratitude to all participating parents and children for their excellent cooperation. Further we like to thank the following investigators for their assistance: S.A.J.M. Verschuren (dietitian); R. Mulder and H. Leever (Gelderse Vallei Hospital, Wageningen), J. van Rooyen-van Beek (TNO-CIVO Toxicology and Nutrition Institute, Zeist), and Dr. A.A.E. Wibowo (Coronel Laboratory, Amsterdam) for determining blood values; J.D. van Klaveren (computer analysis); J. Burema (statistical consultant); Prof. Dr. E.D.A.M. Schretlen (pediatric consultant); and Dr. P.W. Helleman (National Institute of Public Health and Environmental Hygiene (RIVM), Bilthoven).

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6 Rickets in infants on macrobiotic diets

by P.C. Dagnelie, F.J. Vergote, W.A. van Staveren, H. van den Berg, P.G. Dingjan & J.G.A.J. Hautvast

SUMMARY

The vitamin D status of 53 caucasian infants aged 10 - 20 months on a macrobiotic diet and 57 matched control infants on omnivorous diets was studied. In late summer (August - November), physical symptoms of rickets were present in 28 % of the macrobiotic group; these infants had lower average plasma 25-OH-D concentrations (34.0 $\pm$ 15.3 nmol/l) than the macrobiotic infants without such symptoms (49.7 $\pm$ 21.9 nmol/l, $p < 0.02$). Follow-up of a subsample of 25 macrobiotic infants in March - April revealed physical symptoms of rickets in 55 % of the macrobiotic infants. All blood levels were considerably below those in the preceding summer; the average 25-OH-D level was 12.3 $\pm$ 4.3 nmol/l. Further analysis indicated that the low availability of calcium in the macrobiotic diet was an independent factor in causing the high prevalence of rickets in summer. Avoidance of milk products in combination with a high fiber intake may damage bone development in young children.

INTRODUCTION

In the Netherlands as well as in other western countries, an increased incidence of rickets has been reported in the last years, especially in non-caucasian children[1-10] and in children from parents with alternative[1,2,6-14] and macrobiotic[15-17] food habits, who did not receive oral vitamin D supplements. However, most of these reports are based on cases referred to a hospital.

We have examined the clinical and biochemical vitamin D status of the 1985 birth cohort of infants on macrobiotic diets in the Netherlands. The macrobiotic weaning diet consisted of unpolished rice, pulses and vegetables with a high fiber content. Vitamin D supplements and any products of animal origin such as fish and dairy products were avoided.

METHODS

Subjects and design

This study of the vitamin D status was part of a mixed-longitudinal study in infants on macrobiotic diets. The study was approved by the Ethical Committee of the Agricultural University of Wageningen, the Netherlands. The study sample consisted of 53 infants on macrobiotic diets (which will be called the "macrobiotic infants") and 57 infants on omnivorous diets (which will be called the "control infants"), matched for month of birth, sex and parity of the child, educational level of the father and region of residence. The macrobiotic sample represented 91 % of the Dutch macrobiotic birth cohort of 1985. Ninety seven percent of the parents had followed macrobiotic courses or lectures; 75 % had practiced macrobiotics for more than five years. The educational level was high and no apparent adverse social circumstances prevailed. All infants were caucasians. The mean age of the subjects was 15.2 months (range 10.1 - 20.4 months) and the mean age of the control infants was 14.8 months (range 10.1 - 20.9 months).

The vitamin D study consisted of two parts (Fig. 1). The first part was carried out in August - November 1986 and consisted of a home visit with physical examination and blood collection by an experienced pediatrician. All but three macrobiotic parents and all parents of the control group approved of the blood sampling. 25-OH-vitamin D (25-OH-D) could be determined in the blood of 45 macrobiotic infants and 54 control infants. One macrobiotic infant's blood values were excluded from the analysis because

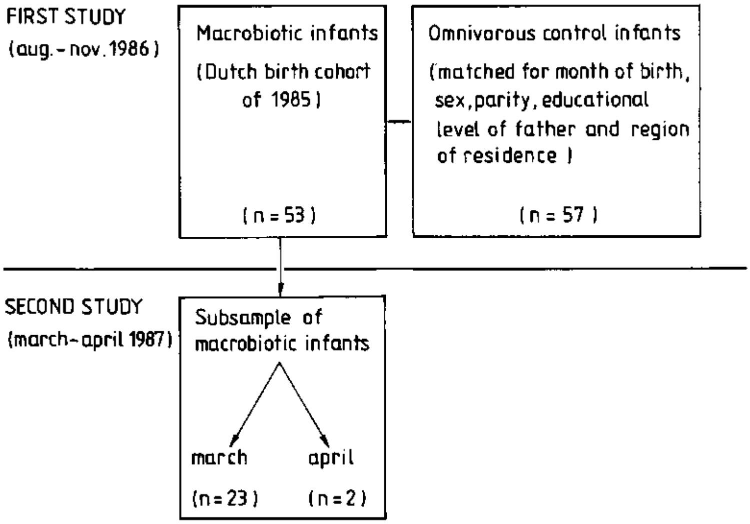

Fig 1. Study design

of pathologically high calcium and phosphate values.

Although originally no follow-up was planned, the blood and physical findings of the first study in summer indicated the need of a second examination some months later for children with clear nutritional deficiencies. Therefore, a follow-up study was planned in March - April 1987 (Fig.1). For this, 29 macrobiotic infants were selected with serious growth retardation, muscle wasting and/or abnormal blood values of vitamin B12 or iron. Two additional infants, who had been selected because of clearcut vitamin D deficiency at the first examination, were excluded from the analysis of the follow-up study for this publication.

Four parents out of 29 did not agree to a second blood collection. The remaining "follow-up group" of 25 infants did not differ significantly from the original macrobiotic cohort in age, sex distribution, or vitamin D blood parameters and physical findings related to rickets in summer.

Out of 25 infants, 23 were followed up in the second week of March and two in the last week of April 1987; the blood data for the last two infants were processed separately. The average period between the first and follow-up visits was 5.7 months (range 4.0 - 7.8 months).

Physical examination and blood sampling

A child was considered to show physical evidence of rickets if at least three different symptoms of rickets were present, including at least one symptom specific to rickets, such as bow legs, rickety rosary, flaring of epiphyses, caput quadratum and craniotabes. Lithium-heparin blood sampling was done by venipuncture from the back of the hand or occasionally from the elbow or foot. During both studies, one blood sample of a macrobiotic infant was collected by finger prick. The time elapsed between the last meal and the blood sampling was between one and four hours in approximately 70 % of the infants of both groups.

Laboratory analyses

After storing the blood samples overnight at 4 °C, they were centrifugated at 1000 G for 10 minutes. Alkaline phosphatase was determined at Gelderse Vallei Hospital, Wageningen with p-nitrosophenyl phosphate as substrate[18] at a temperature of 30 °C, using an IL Multistat III Centrifugal Analyser (between-assay coefficient of variation (CV): 4.7 %).

For determination of 25-OH-vitamin D (25-OH-D), calcium and phosphate, plasma was frozen at -20 °C until analysis (within 2½ months). Analyses were performed at the Department of Clinical Biochemistry, CIVO-TNO, Zeist (NL) in two consecutive assays. 25-OH-D in plasma was determined by a competitive protein binding assay[19] after extraction with methanol-dichlormethane and prepurification on a silica column (CV: within assay 4.9 %, between assay 5.4 %). In this assay, no difference was made between 25-OH-vitamin D2 and 25-OH-vitamin D3. Total plasma calcium was determined by a complexometric method with O-cresolphtalein complexone, without deproteinization, using the reagents and protocol from Boehringer Mannheim Diagnostics, FRG[20] (Cat.No.704032; CV: within assay 2.2 %, between assay 5.9 %). Plasma phosphate was measured by an UV-method (as ammoniumphosphate molybdate) using the reagents and protocol from Boehringer[21] (Cat.No.836281; CV: within assay 2.4 %, between assay 5.4 %).

Analyses were carried out in duplicate and reanalysed if required except for three macrobiotic samples and one control sample of which too little was left over for second analyses. The cut-off value for 25-OH-D (25 nmol/l) was derived from a study in 200 healthy adult Dutch males from the same laboratory.[22]

Statistical analysis

Differences between the means of two independent groups and Spearman's rank order correlation coefficients were tested according to standard statistical techniques. Differences between blood values for macrobiotic infants in summer and winter were tested by Student's paired t-test.

RESULTS

Eighty-two percent of the control infants received oral vitamin D supplements daily in the recommended amounts of 400 IU (10 μg) or more, usually during summer and winter. In the macrobiotic group, at the first examination in August - November 1986 only one out of 53 infants received a vitamin D supplement daily and three infants had received such a supplement during the preceding winter, at doses of 20 - 360 IU per day. By the follow-up examination in March - April 1987 still only five out of 25 macrobiotic infants were receiving vitamin D supplements, at doses of 200 - 540 IU per day.

At the first physical examination in late summer, 15 of the 53 macrobiotic infants (28 percent) showed evidence (i.e. three or more symptoms) of rickets. The average plasma 25-OH-D concentration of these 15 infants was 34.0 $\pm$ 15.3 nmol/l, whereas the 38 macrobiotic infants without such clear symptoms had 25-OH-D values of 49.7 $\pm$ 21.9 nmol/l ($P < 0.02$). At the follow-up examination in late winter, 11 out of the 20 unsupplemented infants showed physical evidence of rickets. Of the five infants who had received vitamin D supplements, only one infant showed such evidence as a late result of vitamin D deficiency in the preceding summer.

Plasma concentrations of 25-OH-D, calcium and phosphate in August - November 1986 were significantly lower in the macrobiotic group than in the control group (Table 1). There was no relation between the month of blood sampling and the 25-OH-D concentration in either group. Eleven percent of the macrobiotic infants but none of the control infants had 25-OH-D concentrations of less than 25 nmol/l. The mean values of alkaline phosphatase were not significantly different between both groups and the P50 was slightly lower in the macrobiotic group (198 U/l, control group 218 U/l). However, the P90 of the macrobiotic infants was higher (710 U/l, control group 307 U/l).

In the 18 macrobiotic infants without supplements who were followed up in early March 1987, plasma concentrations of 25-OH-D, calcium and phosphate were far below the values of the preceding summer (Table 1, Fig. 2). Average 25-OH-D values were 12.3 $\pm$ 4.3 nmol/l (range 5 - 20 nmol/l). The five infants who had received vitamin D supplements had normal blood values (Table 1, Fig. 2). Two infants whose blood was sampled six weeks later (late April) had normal 25-OH-D values (Fig.2) but both had elevated alkaline phosphatase values (498 and 499 U/l) and showed physical evidence of rickets.

Table 1. Plasma concentrations for infants on macrobiotic and omnivorous control diets in August – November 1986, and for a subsample of the macrobiotic infants in March 1987 [1]

		AUGUST – NOVEMBER 1986		MARCH 1987	
		Control group	Macrobiotic group	Macrobiotic subsample No vit.D-suppl.	Vit.D-suppl.
25-OH-D	nmol/l	79.4 ± 20.8 [4] (54)	44.8 ± 21.2 (45)	12.3 ± 4.3 (17)	64.8 ± 17.4 (5)
Alkaline phosphatase	U/l	272 ± 290 (57)	397 ± 656 (49)	311 ± 196 (17)	171 ± 57 (5)
Calcium	mmol/l	2.80 ± 0.21 [2] (55)	2.72 ± 0.20 (46)	2.18 ± 0.23 (17)	2.35 ± 0.07 (5)
Phosphate	mmol/l	1.90 ± 0.24 [3] (54)	1.76 ± 0.25 (43)	1.50 ± 0.38 (17)	1.76 ± 0.21 (5)
Calcium x phosphate	$mmol^2/l^2$	5.33 ± 0.81 [4] (53)	4.75 ± 0.81 (43)	3.29 ± 0.99 (17)	4.16 ± 0.58 (5)

[1] Numbers in parentheses are numbers of infants.

Significance of differences between control group and macrobiotic group in August – November (Student's t test): [2] $P < 0.05$; [3] $P < 0.01$; [4] $P < 0.001$.

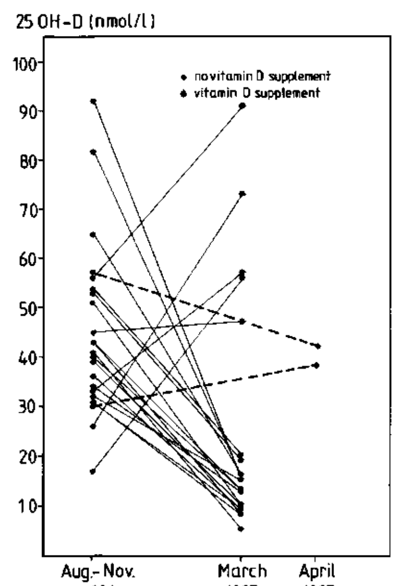

Fig. 2. Plasma 25-OH-vitamin D concentrations of 25 macrobiotic infants in August – November 1986 (age 10 – 20 months) and at follow-up in March – April 1987.

In the control group, plasma concentrations of vitamin D, calcium and phosphate were not significantly correlated. In the macrobiotic group, however, 25-OH-D values were significantly correlated with calcium values both in summer ($r = 0.38$, $P = 0.01$) and winter ($r = 0.61$, $P < 0.01$), and with phosphate values in winter ($r = 0.74$, $P < 0.001$). In winter,the correlation coefficient of 25-OH-D and the product of plasma calcium x phosphate was 0.80 ($P < 0.001$).

DISCUSSION

This study in the 1985 birth cohort of macrobiotic infants and matched omnivorous control infants strongly confirms that, in a temperate climate, infants on macrobiotic diets who do not receive vitamin D supplementation are at high risk of rickets. In the first place, physical examination and blood values in late summer (August - November) already indicated the presence of rickets in a considerable proportion of the macrobiotic infants. Moreover, when a subsample of 25 infants was followed up in the following late winter (March - April), a sharp decline of blood values and an increased prevalence of physical symptoms of rickets was observed. When five infants who received vitamin D supplementation in winter were excluded, the prevalence of specific symptoms of rickets in winter was as high as 55 percent.

Within the received maximal cooperation from the participants, it was not possible to include radiographic examination. However, great care was taken to guarantee the objectivity of the gathered data. The physical examination in both summer and winter was performed by the same paediatrician, who was unaware during the examination in winter of the biochemical and physical findings of the preceding summer. The association of physical symptoms of rickets with low plasma 25-OH-D concentrations in the macrobiotic group supports the validity of our physical findings. The validity of our findings is further supported by significant correlations between the plasma 25-OH-D, calcium and phosphate concentrations in the macrobiotic group, which became more pronounced in winter, but were absent in the control group.

Our data confirm earlier publications that suggested the presence of rickets in macrobiotic infants and children.[15-17] Dwyer et al[15] studied the vitamin D status in a sample of 24 macrobiotic children aged 0.3 - 8.4 years in Boston, whose parents volunteered them for the study. Roentgenograms were available from the physicians of five of these children; two of these showed rickets. In Britain[16] and Ireland[17] hospital admissions of macrobiotic children with rickets have been described. However, detailed information on the prevalence of rickets in macrobiotic infant populations has been lacking.

An important question is, which factors may have contributed to the high prevalence of rickets in this cohort of macrobiotic infants. Two factors can be excluded: skin colour could not play a role, as only caucasian infants were included in the analysis, and histories of serious malabsorption or use of anticonvulsant drugs, which could have caused conditioned vitamin D deficiency, were not present in our study population.

The dietary intake of vitamin D in the macrobiotic infants was extremely low, since vitamin D supplements and fish were virtually excluded from their diet. The importance of the factor of dietary vitamin D is further indicated by the cases of 5 macrobiotic infants examined in March who had received vitamin D supplementation during the last 2 - 6 months. In four of these, blood values and physical appearance were normal, whereas the fifth infant showed physical deficiency symptoms as a late consequence of earlier vitamin D deficiency.

However, vitamin D deficiency alone cannot explain why we unexpectedly found clear physical symptoms of rickets in 15 out of 53 macrobiotic infants in late summer. Although these 15 infants had lower average 25-OH-D values than the remaining macrobiotic infants, only 5 infants had 25-OH-D values below 25 nmol/l. This indicates that other factors than vitamin D deficiency must have played a contributory role in causing rickets. Here, it is important to note that the weaning diet of our study population almost exclusively consisted of unpolished rice, pulses and vegetables with a very low calcium content (89 - 445 mg/day) and a high fibre content (1 - 28 g/day). Dairy products were avoided. Several authors have reported an increased prevalence of rickets in populations on similar diets[23-28], even if the vitamin D status was adequate. Casual information has provided further evidence that dietary calcium deficiency can be an independent factor in the etiology of rickets.[29-31] Experimental high fiber diets have been reported to reduce calcium absorption, resulting in a negative calcium balance,[23,32-34] and to reduce plasma half-life of 25-OH-D.[35] By multiple regression analysis, after correction for age and plasma 25-OH-D concentration, we found that fiber intake was an independent factor contributing to both the physical finding of rickets and to the plasma calcium concentration ($p < 0.01$). No independent contribution was found for the calcium intake ($p > 0.40$). This may have been caused by low availability of calcium in the macrobiotic diet, or by the observed positive association of calcium and fiber intake in the macrobiotic group ($r = 0.32$, $p = 0.02$).

In 1977, Kooh et al[30] put forward the question, why rickets was not observed more frequently in children on calcium-deficient diets. We suggest that the macrobiotic population is an example of such a population, in which the high prevalence of rickets in summer is the result of long term depletion of body calcium stores due to a diet with a low calcium and a high fiber content, in combination with vitamin D deficiency during a part of the year.

In contrast to the other blood values and physical findings of our study, alkaline phosphatase concentrations in the macrobiotic group in summer and winter were not significantly different. Moreover, in summer the P50 value in the macrobiotic group was slightly lower than in the control group, in spite of the higher P90 value of the macrobiotic group. This unexpected finding may have been caused by coinciding protein energy malnutrition in the macrobiotic group, which has been reported to reduce alkaline phosphatase activity.[36-37] This hypothesis is supported by the observation of stunted growth in height in our population of macrobiotic infants.

It may be questioned if perhaps the high prevalence of rickets in macrobiotic infants in winter was caused by too little sunshine exposure, due to lack of outdoor activities. We did not ask the parents to keep a diary on the exposure of the infants to sunshine prior to blood sampling, in order not to influence the mothers' behaviour which could have biased our data. However, since the publication of the paper on rickets in macrobiotic children by Dwyer et al,[15] macrobiotic teachers and families have been well aware of the importance of regular outdoor activities for young children. In the temperate climate it therefore seems unlikely that the vitamin D status of macrobiotic infants in the winter season could improve much by further increasing the time spent outdoors.

At the time of our study, many macrobiotic teachers and parents would not consider the inclusion of vitamin D supplements and dairy products into the macrobiotic diet. Therefore, as a first step in preventing the occurrence of rickets in macrobiotic infants, we have proposed the regular inclusion of fatty fish like herring, mackerel, halibut, salmon, sardines, trout and tunafish in amounts of at least 100 - 150 grams a week (providing an average daily intake of 2 - 3 μg of vitamin D). Michio Kushi, the leading teacher of macrobiotic principles, has accepted our findings and included the advice to eat fatty fish into the macrobiotic dietary recommendations. However, it is necessary to be aware that the amounts of vitamin D and calcium provided in this way are still considerably below the recommended daily intake of 10 - 15 μg of vitamin D and 600 - 800 mg of calcium per day for young children.[38-40] Future studies will therefore be necessary to check if the regular consumption of fish will be sufficient to prevent the occurrence of rickets in children on macrobiotic diets. In general, more information on the consequences of inadequate calcium intakes in young children is needed. The avoidance of dairy products in combination with a high intake of dietary fiber may damage bone development in young children.

ACKNOWLEDGEMENTS

We would like to thank the macrobiotic teachers and the staff of child health clinics for their help in recruiting the participants of this study, as well as the parents and children involved in the study. We also thank the following persons for their assistance and valuable advice: S.A.J.M. Verschuren, R. Mulder, H. Leever, P.G. Boshuis, G. Pieters, J.D. van Klaveren, J. Burema, E.D.A.M. Schretlen, G. Schaafsma and H.G.J. Nijhuis.

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7 Growth and psychomotor development in infants aged 4 to 18 months on macrobiotic and omnivorous diets: a mixed-longitudinal study

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SUMMARY

A mixed-longitudinal study was carried out in the 1985 Dutch birth cohort of macrobiotic infants aged 4 - 18 months (n = 53) and 57 omnivorous control infants matched for month of birth, sex, parity, educational level of the father and the residential area. Study methods included regular anthropometric measurements and a psychomotor testing. Reported birth weight was 180 grams lower in the macrobiotic group than in the control group and was positively associated with maternal weight increase during pregnancy. Between 4 and 18 months of age, mean values for all anthropometric parameters were considerably lower in the macrobiotic infants. From birth to 4 months, weight gain was less in macrobiotic infants, and from 6 months the rate of growth in weight and length decreased further reaching its lowest value between 8 and 14 months of age. A similar pattern was also observed for other anthropometric parameters. Between 8 and 14 months, arm circumference showed an absolute decrease. During this period, increase in arm muscle mass in the macrobiotic group was only half of that in the control group. From 14 months of age, growth stabilized parellel to the 10th percentile of the Dutch references. Gross motor and language development were also slower in the macrobiotic infants. The paediatrician observed major wasting of skin and muscles in 30 per cent of them. The growth rate for weight and arm circumference was independently associated with the intake of energy per kg body weight and the protein energy per cent of the macrobiotic diet. Growth in length was associated with protein energy per cent of the diet, but not with energy intake.

INTRODUCTION

Children on macrobiotic diets have been reported to be smaller and to weigh less than children on omnivorous diets (Shull et al., 1977; Dwyer et al., 1980; van Staveren et al., 1985). Anthropometric measurements taken in a cross-sectional study in children on macrobiotic diets from birth to 8 years of age suggest that growth retardation occurs between 6 and 18 months of age (Chapter 3). In this paper the results of a mixed-longitudinal study in macrobiotic infants aged 4 - 18 months and a matched omnivorous control group are presented. This study aimed to examine firstly whether growth retardation in macrobiotic children observed in the cross-sectional study was supported by longitudinal data and subsequently whether this had consequences for physical and psychomotor development. Secondly, data were examined for a relationship between growth and intakes of energy and protein.

METHODS

Selection of participants

The macrobiotic study group consisted of the 1985 birth cohort of caucasian infants (n = 53) born at term (that is, after gestation of longer than 37 weeks) and not suffering from a congenital or neonatal disease. All participating mothers had been on a macrobiotic diet as described by Kushi (1977, revised 1987) for at least three years and 75 per cent for more than five years. From birth, all infants had been fed according to macrobiotic practice. The subjects were from families of relatively high socio-economic levels and from all parts of the Netherlands.

Control infants were selected from parents on omnivorous diets using the same criteria as for the macrobiotic infants. Both groups were matched for month of birth, sex and parity of the child, as well as the educational level of the father as an indicator of socio-economic status. They were also matched for residential area since differences in length have been reported for various districts in the Netherlands (Roede & van Wieringen, 1985). The control infants (n = 57) were selected by health personnel from eight child health clinics throughout the country.

The two groups were well matched (Table 1). Since a sufficient number of infants who were third child or more in the family could not be found for the control group, also second children were accepted instead. After match-

Table 1. Distribution of matching characteristics in macrobiotic and omnivorous control group

	MACROBIOTIC GROUP n = 53 Number	(Per cent)	CONTROL GROUP n = 57 Number	(Per cent)
Sex				
Boys	27	(51)	31	(54)
Girls	26	(49)	26	(46)
Parity				
First child	15	(28)	15	(26)
Second child	18	(34)	26	(46)
Third child or higher	20	(38)	16	(28)
Educational level of father				
Primary education	7	(13)	7	(12)
Secondary education	11	(21)	16	(28)
College or university	35	(66)	34	(60)
Region of residence				
Northern three provinces	5	(9)	6	(11)
Southern three provinces	9	(17)	8	(14)
Remaining provinces	39	(74)	43	(75)

ing for educational level of the father, macrobiotic mothers were found to have a slightly higher level of education than the control mothers. Theoretically, this might lead to macrobiotic infants being heavier and longer than the control infants (Roede & van Wieringen, 1985). The average age of the mothers was 32 years in the macrobiotic group and 30 years in the control group. No differences were found in smoking habits during pregnancy and length of pregnancy in macrobiotic and control mothers.

Study design

The study had a mixed-longitudinal design (van 't Hof, Roede & Kowalski, 1977). On the basis of date of birth, infants in each group were assigned to three cohorts of each 15 - 20 infants. The cohorts were monitored during two-monthly home visits over a period of six months, during which anthropometric measurements and a psychomotor test were taken from each child. Two food record periods of each three days were included in this design. The mother's output of breast-milk was determined by test-weighing the infants before and after each feed. Energy and nutrient intakes were calculated from the Dutch Food Composition Table supplemented with analytical data for 50 macrobiotic foods (Chapter 4). Information on pregnancy, delivery and periods of illness was collected by means of a questionnaire. Within two months after the end of the mixed-longitudinal study, an experienced paediatrician visited the parents and examined each child.

Anthropometry

Anthropometric measurements included weight, supine length, crown-rump length, biiliacal width, head circumference, arm circumference, tricipital and subscapular skinfolds. All linear measurements except skinfolds were read to the nearest 0.1 cm. The measurements were taken once only unless stated otherwise. Test-retest correlations were estimated from an interperiod correlation matrix analysis according to the method of van 't Hof & Kowalski (1979) (r_0), as well as observed in case of duplo measurements (R_0).

Weight. Body weight without clothes was measured on a Seca electronic scale (type 747, 0 - 20 kg/0.005 kg). No adjustment was made for the period expired since the last meal (r_0 = 1.00).

Crown-to-heel length. Recumbent crown-to-heel length was measured in twofold using a house-made steel supine infantometer with a fixed headboard (10 cm high) and a sliding footboard (3 cm high). The infant's head was held in the supinated Frankfurt plane. With both the legs extended and feet at right angles, the length of the child was measured as described by Cameron (1978). The arithmetic mean of both measurements was calculated (r_0 = 1.00, R_0 = 1.00).

Crown-rump length was measured twice using the infantometer described above, but with attachment of a higher footboard (10 cm). After the thighs were placed in a vertical plane, the footboard was pulled firmly against the buttocks (r_0 = 0.99, R_0 = 0.98).

Biiliacal diameter was measured twice whilst the mother held the child with the legs hanging down freely in the way described by Cameron (1978). Firm pressure was applied on the soft tissue for reading the measurement (r_0 = 0.97, R_0 = 0.99).

Head circumference. Maximal head circumference was measured by placing a 15 mm wide, insertion-type plastic measuring tape over the most extending point of the occiput and just above the brow ridges of the forehead (r_0 = 0.96).

Arm circumference. Mid-upper arm circumference was measured with the same plastic tape as above, midway between the acromion and the olecranon of the left arm ($r_0 = 0.94$).

Triceps and subscapular skinfolds were measured at the left side to the nearest 0.2 mm with a Harpenden skinfold calliper in the way described by Tanner & Whitehouse (1975). Each skinfold was measured at least three times. If two measurements deviated by more than 0.5 mm, one to three additional measurements were taken. The median value of all observations was calculated (triceps skinfold: $r_0 = 0.86$, subscapular skinfold: $r_0 = 0.87$).

Arm area (AA), **arm-muscle area** (AMA) and **arm fat area** (AFA) were calculated from the arm circumference (MAC in mm) and triceps skinfold (TSF in mm) by the equations (Frisancho, 1981):

$AA = (MAC)^2 / (4 \times 3.14)$,

$AMA = (MAC - 3.14 \times TSF)^2 / (4 \times 3.14)$ and

$AFA = AA - AMA$

(AMA: $r_0 = 0.84$, AFA: $r_0 = 0.89$).

Birth weight was reported by the mother and when in doubt checked with the child's health chart.

Mid-parent height. The height of both parents was measured and the arithmetic mean calculated. No significant difference in mid-parent height was found between the macrobiotic and control group.

Quality control and analysis of anthropometric data

The measurements were taken by two trained observers. An equal number of macrobiotic and control infants from each cohort was assigned to the two observers. Each child was measured by the same observer throughout the study. Control measurements taken on nine children after termination of the fieldwork did not yield systematic differences except for crown-rump length. Values for one observer were adjusted by adding a constant for this parameter.

Ninety four per cent of the measurements were taken within ten days from the exact date. The period between two subsequent measurements (exactly two months = 61 days) was 50 days or more in 99 per cent of the pairs of subsequent observations. The mean age difference between the macrobiotic and control group was less than 3.5 days for all times of measurement and all cohorts. To adjust for individual discrepancies between the scheduled date of visit and date of measurements, the anthropometric measurements were interpolated or extrapolated to values at the intended date, so that they corresponded exactly to selected ages. This procedure has been described by Ziegler & Fomon (1982). Because the sex distribution was not equal in the subsequent cohorts, the arithmetic mean of the average for boys and the average for girls was calculated for the construction of growth curves. Similarly, the arithmetic mean of the sex-specific percentile values was taken for constructing reference percentiles on the growth curves.

The following data were used as reference:

- for birth weight, weight, length and head circumference for age, and weight for height, data from the Netherlands third nation-wide survey in 1980 (Roede & van Wieringen, 1985) were used. For head circumference, data for infants from 0 - 15 months were extrapolated until 18 months of age;
- for arm circumference and crown-rump length, reference data of Gerver (1988) from children in Oosterwolde (northern Netherlands) were used;
- for biiliacal width, reference data of Sempé, Pédron & Roy-Pernot (1979) were used;
- for skinfolds, data of Tanner & Whitehouse (1975) were used.

Standard deviation scores (SDS) were calculated from the median (50th percentile, P50) and standard deviation of the reference data. Except for skinfolds, the reference data were almost normally distributed in the selected age range. To obtain a normal distribution, skinfold data were transformed prior to calculation of SDS by the equation:

$Y = \log(\text{skinfold} - 1.8)$ (Tanner & Whitehouse, 1975).

Growth velocity (expressed in units per year) was calculated as the increment from the first to the last measurement. For parameters with a calculated test-retest correlation below 0.90, the slope B of the regression line through all four measurements was taken instead.

For presenting the increase in SDS during two-monthly intervals (Fig. 5), the average value for the two cohorts was taken for ages at which the data of two subsequent cohorts overlapped.

Finally, our data were checked for a possible confounding effect of season on growth. No major difference was found which could have biased our data.

Psychomotor development

During each home visit psychomotor development was appraised by means of a standardized checklist used widely in child health clinics in the Netherlands ("adapted Van Wiechen checklist", Schlesinger-Was, 1982 and 1985; Meesters-Timmermans, 1982). This checklist, which was validated by Schlesinger-Was (1981), consisted of 6 to 7 items for each age group covering five areas of development: gross motor, fine motor, adaptation, speech and language, and personal-social behaviour. For some items the child had to be observed and for others the child was either observed or information obtained from the mother. The items of personal-social behaviour were not included in the analysis as these were found to be closely associated with cultural differences between the macrobiotic and the control group.

Since the group consisted entirely of infants born at term, no correction for the duration of pregnancy was necessary. For analysis, items with a separate score for the right and left hand or foot were combined. The lowest age at which a positive score was obtained on either side was used for calculations. The items were assigned to five clusters: 1. sitting and head balance; 2. locomotion (standing, walking, etc.); 3. fine motor development, including adaptation; 4. speech and language. For each cluster, a correlation matrix was calculated by cohort to find the most coherent subset of items, as judged by maximal reliability (Cronbach's alpha, Hull & Nie, 1979). For combining data from different cohorts, the scores per item were expressed as standard deviation scores (SDS). In order to deal efficiently with missing values, the sum of the available scores for each child was calculated, and the standardized sum of SDS used for further analysis.

Paediatric examination

The paediatrician performed a general clinical examination including tonic and trophic condition of skin and muscles. An infant was categorized as having "skin and muscle wasting" (dystrophy) only if there was a major trophic disorder of the skin and muscles, appearing from wasting of subcutaneous fat and muscle tissue together with hypotony and muscle weakness.

Statistical analysis

For each anthropometric parameter, the level of four successive measurements was simultaneously compared between all cohorts of the macrobiotic and the control group by multivariate analysis of variance (MANOVA). Differences in mean birth weight and growth velocities between the macrobiotic and the control group over the total observation period were subjected to Student's t test. The relationship between maternal weight increase and birth weight was tested in a multiple regression model, after adjustment for parity and spacing with the last sibling. Differences in group means for psychomotor development were also subjected to Student's t test and confidence intervals of the differences calculated.

To check whether the observed growth retardation could be explained by a reduced intake of energy or protein by macrobiotic infants, a multiple regression analysis was performed including as independent variables both energy intake (expressed per kg body weight) and protein (in energy per cent). In order to exclude the confounding influence of age, growth velocities were expressed in terms of change in standard deviation scores and age was included as an independent variable in the regression models.

A multiple regression analysis was also performed to define possible risk factors for retardation of psychomotor development and skin and muscle wasting. This included as independent variables birth weight, and weight gain between birth and the start of the mixed-longitudinal study (that is, over the age intervals of 0 - 4, 0 - 8, and 0 - 12 months). For the first cohort only, the mother's breast-milk output when the infant was 6 months old was included as an independent variable.

RESULTS

Pregnancy, birth weight and vaccinations

Mean reported weight increase during pregnancy was 8.3 $\pm$ 2.9 kg (mean $\pm$ SD) in the macrobiotic mothers and 10.8 $\pm$ 3.5 kg in the control mothers ($P < 0.001$). Mean birth weight was 3290 $\pm$ 480 g in the macrobiotic infants and 3470 $\pm$ 420 g in the control infants ($P = 0.03$). For an additional weight increase of 1 kg during pregnancy the expected birth weight increased by 75 g in the macrobiotic group ($P = 0.01$). The birth weight of one macrobiotic infant, born after 40 weeks gestation, was 2030 grams. The mother weighed 47 kg before pregnancy and gained 4 kg during pregnancy.

Only 45 per cent of the macrobiotic infants had been taken to infant health clinics regularly for a period of at least ten months and 21 per cent had never visited a clinic, whereas 96 per cent of the control group were taken to the baby health clinic regularly for the same period. The vaccination schedule for infants comprising diphteria (D), tetanus (T), poliomyelitis (P) and whooping cough (W) was followed for only six of 53 macrobiotic infants (11 per cent; control group: 96 per cent). A further five infants received DTP and one infant P only. In total three macrobiotic infants (6 per cent) compared to 98 per cent of control infants were vaccinated against measles.

Anthropometry

The mean value for all anthropometric parameters (tested by MANOVA) was significantly lower in macrobiotic infants ($P < 0.001$). As shown in Table 2, growth velocities from 4 to 18 months of age were significantly lower in the

Table 2. Mean growth velocities (units per year) of infants on macrobiotic (M) and omnivorous control (C) diets

		COHORT 1		COHORT 2		COHORT 3		COHORTS COMBINED	
Age		4–10 ms		8–14 ms		12–18 ms		4–18 ms	
Group		M	C	M	C	M	C	M	C
Number of infants		17	20	19	18	17	19	53	57
Weight	kg	4.4	5.4	2.4	4.5^{3}	2.6	3.3^{1}	3.1	4.4^{3}
Length	cm	17.0	19.6^{2}	11.4	15.7^{3}	11.4	14.5^{3}	13.2	16.7^{3}
Crown-rum length	cm	8.9	10.1	5.0	6.2	4.9	5.7	6.3	7.4
Biiliacal width	cm	2.6	2.5	1.7	2.2	1.8	2.2	2.1	2.3
Head circumference	cm	7.6	8.5^{1}	4.4	5.6^{2}	3.5	3.9	5.2	6.1^{1}
Arm circumference	cm	2.4	3.6	0.1	2.8^{3}	0.7	0.6	1.0	2.3^{2}
Triceps skinfold	mm	–3.5	–4.0	–6.8	–4.1^{1}	–3.1	–3.3	–4.5	–3.8
Subscapular skinfd	mm	–1.2	0.3	–1.0	0.1	–0.6	–0.3	–0.9	0.0
Arm muscle area	mm^2	575	820^{1}	373	749^{3}	287	299	413	624^{2}
Arm fat area	mm^2	–50	–26	–351	–101^{2}	–142	–154	–185	– 92

Test results for M versus C:
^{1} $P < 0.05$
^{2} $P < 0.01$
^{3} $P < 0.001$.

macrobiotic group for weight, length, head and arm circumference, and arm muscle area. The largest growth deficit was observed in the second macrobiotic cohort (8 – 14 months of age), where growth in triceps skinfold and arm fat area were also significantly lower in the macrobiotic group. The tendency for decreased growth velocity was also observed in other parameters but the difference was not statistically significant. When the data were log-transformed or calculated as standard deviation scores (SDS), the findings were similar. For the growth velocity of head circumference, the significance increased ($P < 0.01$) when expressed as SDS.

Mean growth curves for weight, height and arm circumference for age for both groups are presented in Fig. 1 – 3 (see overleaf). Growth curves of the control infants followed closely the P50 of the references, although there were some differences in level between the cohorts. These may be considered

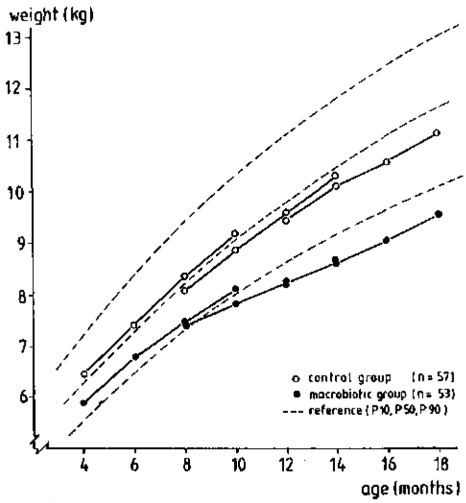

Fig. 1. Weight for age

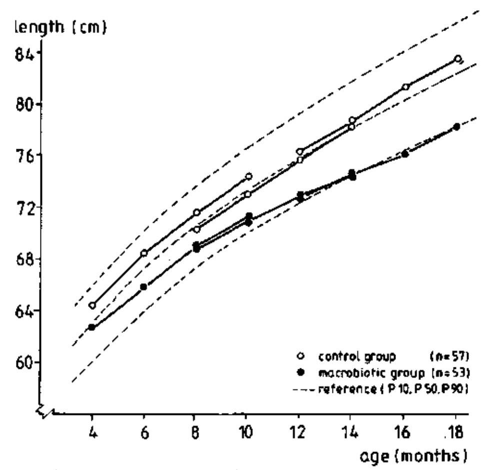

Fig. 2. Length for age

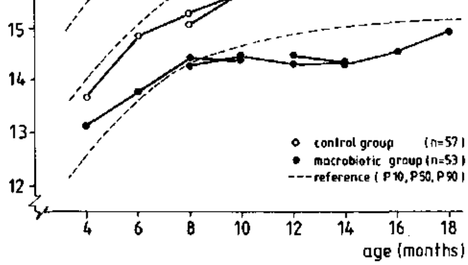

Fig. 3. Arm circumference for age

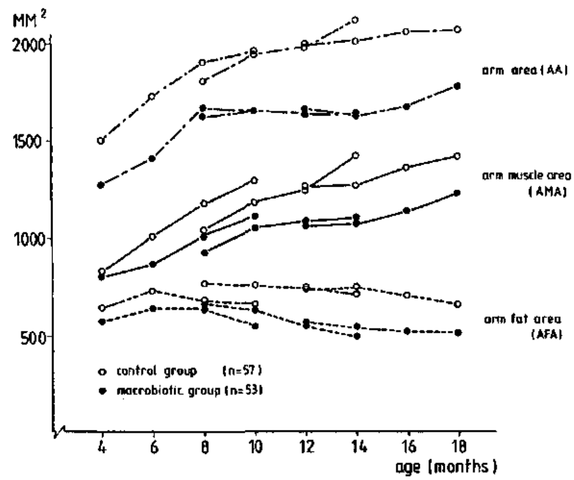

Fig. 4. Arm area, arm muscle area and arm fat area for age

Fig. 1 – 4. Growth curves of infants on macrobiotic or on omnivorous diets

(reference data in Fig. 1 and 2: Roede & van Wieringen, 1985; in Fig. 3: Gerver, 1988)

to be sampling fluctuations. A growth deficit discernible in macrobiotic infants from four months continued to increase with age. The lowest growth rate was observed in the second cohort (8 - 14 months). Faltering growth was most evident for weight and also arm circumference (Fig. 1 and 3), which clearly decreased between 8 and 14 months. A similar but less pronounced age pattern was observed for body length (Fig. 2).

Growth curves for arm area, arm muscle area and arm fat area are given in Fig. 4. Arm fat area, which was rather constant in the control group between 4 and 18 months, declined in the macrobiotic group mainly between 8 and 14 months. A similar but more pronounced growth retardation in arm muscle area was already present from 4 months onwards. Increase in arm muscle mass between 8 and 14 months in the macrobiotic group was calculated to be only 50 per cent of that in the control group but between 14 and 18 months the increase was similar in both groups.

Growth velocities by age group, expressed as change in SDS per year, are shown in Fig. 5. A value below zero means a decrease in SDS, that is

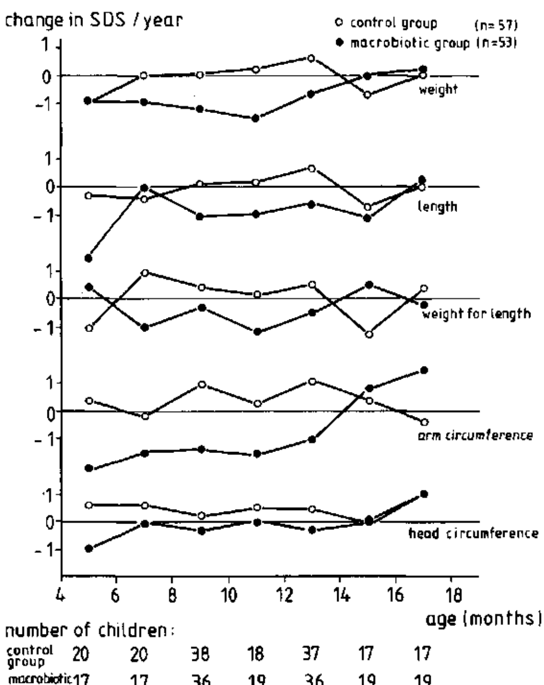

Fig. 5. Change in standard deviation scores (SDS) of anthropometric parameters in infants on macrobiotic (M) and omnivorous control (C) diets in two-monthly intervals between 4 to 18 months (references: Roede & van Wieringen, 1985; Gerver, 1988).

faltering in growth compared to the (cross-sectional) Dutch growth references. In the control group, growth velocities were in general at or above the growth reference. From the age of four months, a negative change in SDS for weight, length and arm circumference occurred in the macrobiotic group.
Between 6 and 14 months, growth velocities for weight were comparatively lower than for length. Consequently, there was a negative change in SDS in weight for length during this period. From 14 months onwards, growth velocities stabilized at the percentile reached except for length, which remained depressed until 16 months of age. There was a tendency for arm circumference to catch-up after 14 months. Although a difference in growth velocity in head circumference was observed between the two groups, the position of macrobiotic infants on the Dutch cross-sectional growth reference changed only slightly.

A multiple regression analysis was carried out to determine whether the observed growth retardation could be explained by a reduced intake of energy or protein by macrobiotic infants from 6 months of age. The results are presented in Table 3. Both the energy intake (expressed per kg body weight)

Table 3. Determinants of growth: standardized regression coefficients for energy and protein intake in infants on macrobiotic and omnivorous diets (both groups combined)

GROWTH VELOCITY (SDS per year)	ENERGY PER BODY WEIGHT		PROTEIN ENERGY PER CENT	
	Regression coefficient	P-value	Regression coefficient	P-value
Weight	0.34	< 0.001	0.29	0.005
Length	0.07	0.43	0.40	< 0.001
Arm circumference	0.26	0.004	0.28	0.007

and the protein content of the macrobiotic diet (expressed as energy per cent) contributed independently to growth in weight and arm circumference. This suggests that a combination of lack of energy and protein may have caused the growth retardation in weight and arm circumference observed in macrobiotic infants. Growth in length was only associated with the protein content of the diet, but not with energy intake (Table 3).

Psychomotor development

Differences in psychomotor development as measured by the standardized checklist are presented in Table 4 and Fig. 6. The macrobiotic group was significantly later in gross motor and, to a lesser degree, in speech and language development. The difference was greatest for locomotion, that is motor development mainly of the legs. For instance, half of the control

Table 4. Difference in psychomotor development (standard deviation scores) of infants on macrobiotic and omnivorous diets

	MEAN	95% CONFIDENCE INTERVAL	P-VALUE
Gross motor development			
Sitting and head balance	-0.48 [1]	-0.94 to -0.02	0.04
Locomotion	-0.60	-0.97 to -0.24	0.001
Overall	-0.63	-1.00 to -0.26	< 0.001
Fine motor development/adaptation	-0.13	-0.52 to 0.25	0.49
Speech and language development	-0.42	-0.78 to -0.05	0.03

[1] A negative value expresses later development in the macrobiotic group.

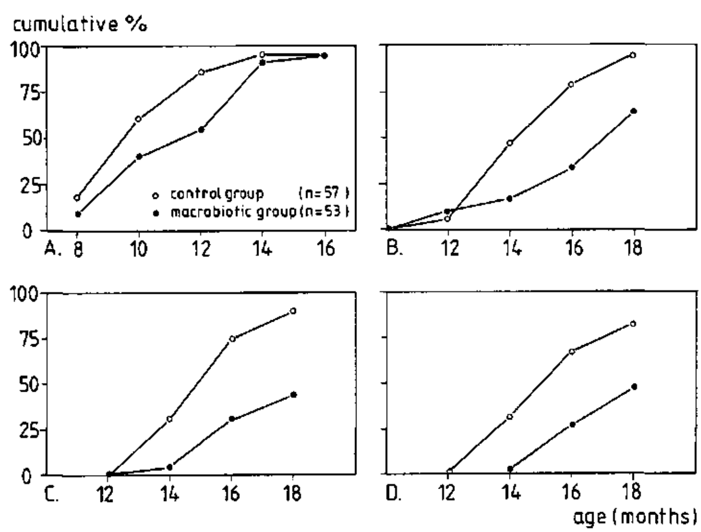

Fig. 6. Cumulative frequency distribution of positive scores on four gross motor development items by infants on macrobiotic and omnivorous diets: A. Pulls self to stand, B. Walks alone, C. Squats to pick up object, D. Throws ball without falling

infants were walking unaided by 14 months, but this was not the case in the macrobiotic group until 3 months later (Fig. 6). In an endeavour to define possible risk factors for retardation in motor development, its relationship with birth weight and postnatal weight gain was investigated by means of multiple regression analysis for both groups combined. The difference in gross motor development between the two groups was attributed to differences in birth weight ($P < 0.05$) and, to a greater extent, weight gain between birth and 4, 8 and 12 months (all $P < 0.001$). The difference in speech and language development was attributed to birth weight differences ($P < 0.05$). Similar relationships were also found within the macrobiotic group but not in the control group.

Paediatric examination

The paediatrician observed major skin and muscle wasting in 30 per cent of macrobiotic infants compared to 2 per cent in the control group. Values for most anthropometric parameters were lower in the "wasted" infants than in the other macrobiotic infants, especially weight for height ($P < 0.001$) and triceps skinfolds ($P < 0.01$), as well as biiliacal width and head circumference ($P < 0.05$). Growth velocities in weight, length and head circumference were also lower in the "wasted" infants ($P < 0.05$) and they were slower in locomotor development ($P = 0.05$).

As possible risk factors for later wasting, we checked our data for differences within the macrobiotic group in birth weight and postnatal weight gain. Weight gain from birth to 4, 8 and 12 months was lower in wasted infants ($P < 0.01$). In addition, for the first cohort our data were checked for differences in the mothers' breast-milk output when the infant was 6 months old, that is 4 - 6 months prior to the medical examination. Breast-milk output of mothers of wasted infants was 606 $\pm$ 230 ml compared to 898 $\pm$ 190 mlk for mothers of the other infants ($P < 0.05$).

DISCUSSION

The present study is likely to be representative of children on macrobiotic diets, as almost 95 per cent of the Dutch macrobiotic 1985 birth cohort participated in this study (Chapter 4). The matching variates, and other possible confounders for which our data were checked, showed only minor differences between the macrobiotic and the control group. Thus the observed differences in growth and development cannot be influenced by these variates. Nutritional differences between the groups are more likely to be causal factors.

The observation that birth weight was 180 grams lower in the macrobiotic group confirms our finding of lower birth weight in an earlier cross-sectional study in macrobiotic children aged 0 - 8 years. In that study, birth weight was found to be closely related to the frequency of fish and dairy products consumption by the mother (Chapter 3). Our present findings indicate that the lower birth weight in macrobiotic infants can be explained by a low weight increase of the mother during pregnancy, which in turn may be caused by too strict a macrobiotic diet at this time. Thomas & Ellis (1977) in a study of 14 vegan mothers (28 pregnancies) and 18 controls (41 pregnancies) also observed a 200 grams lower birth weight in the vegans. This difference was not statistically significant, probably because of the small number of participants. No information is given about maternal weight gain during pregnancy or related nutritional variables.

On the basis of our findings in the cross-sectional study, no difference between the anthropometric parameters of the macrobiotic and omnivorous infants until after the age of six months was expected. However, the results show that the weight deficit of 180 grams at birth increased to approximately 570 g during the first four months of life. Apparently, the macrobiotic infants grew more slowly than the control infants from birth onwards, even though their lower birth weight would normally lead to an increased weight gain over the first 4 months of life (Tanner, 1986). This difference could not be explained by a higher prevalence of breastfeeding in the macrobiotic group, as no differences in postnatal weight gain were observed between bottlefed and breastfed control infants.

Our data confirm the findings of Shull et al. (1977), who in a sample of 72 vegetarian and macrobiotic children observed that, before two years of age, growth in weight and length lagged behind the longitudinal Harvard standard. A critique in Nutrition Reviews (Anonymous, 1979) suggested that Shull et al.'s study did not provide conclusive evidence on whether the growth retardation was caused by vegetarianism or was just a consequence of prolonged breastfeeding. We checked this in our data by comparing weight at 12 months and weight gain between 12 and 14 months of macrobiotic infants still being breastfed, and those not. No difference in weight level or increments was found. Moreover, as most macrobiotic infants had received solid food at or before the age of 6 months, prolonged breastfeeding could be excluded as a cause of the growth retardation in macrobiotic infants.

Together with the low energy and protein intakes in macrobiotic infants reported earlier (Chapter 4), it would appear that both the low energy and protein content of the macrobiotic weaning diet are responsible for the observed growth deviations after 6 months of age.

In growth studies, it is important to distinguish two types of malnutrition (Waterlow, 1973 and 1978): wasting, characterized by a deficit in weight for height, and stunting, characterized by a deficit in height. Both wasting and stunting occurred in the macrobiotic group. In the past, a close interrelationship was established between changes in growth and patterns of morbidity and mortality (van Wieringen, 1978), but this does not necessarily apply to infants in Western countries at the present time. In our study population, the following observations have been made:

- Growth velocity was not steady but showed a marked drop associated with weaning to stabilize by the age of 18 months;
- Retarded growth velocities in weight and height were accompanied by other changes. There was an absolute decrease in arm circumference between the age of 8 and 14 months, due to reduction of both arm muscle and fat tissue. Muscle mass may exhibit a greater reduction during malnutrition than body weight (Frisancho, 1974). In the macrobiotic group, the increase of arm muscle mass between 8 and 14 months was only half of that in the control group.
- Growth retardation was associated with retardation in gross motor and language development and with a high prevalence of skin and muscle wasting.

These observations indicate that growth retardation did have important consequences for the well-being of the macrobiotic infants. The conclusion seems justified that growth was far below optimal in this macrobiotic birth cohort.

Growth retardation did not occur at exactly the same age for all infants. This will tend to flatten the drop in the combined growth curve of a group of children, similarly to the flattening which is observed at the pubertal growth spurt. Consequently, the sigmoid shape of the macrobiotic growth curves, i.e. the drop between 6 and 14 months of age and the subsequent growth restoration thereafter (Fig. 1 - 3), underestimates the growth retardation in individual macrobiotic infants.

We do not know the consequences of the smaller size and increments in head circumference in the macrobiotic group. Within the macrobiotic group, head velocity and increase in weight for length were closely related between

4 and 14 months of age. Correlation coefficients were 0.51 from 4 - 10 months, ($P = 0.03$); 0.75 from 8 - 14 months ($P < 0.001$); but only -0.16 from 12 - 18 months ($P = 0.54$). The observation that the correlation was highest between 8 - 14 months of age, when growth retardation was most pronounced, and absent from 12 - 18 months, when growth stabilized, suggests that the slower head growth velocity was related to the occurrence of wasting. Since the Dutch reference is based on cross-sectional data, we compared the head growth velocity of macrobiotic infants with longitudinal reference data on Swedish children (Karlberg & Taranger, 1976). The cross-sectional P50 of these reference data is parallel to the Dutch reference. In the first and second cohorts, growth in head circumference of the macrobiotic infants was significantly slower than the Swedish reference ($P < 0.05$).

A mental development test carried out in 46 Dutch macrobiotic children aged 4 to 6 years (Herens et al., unpublished observations) showed no delay in intellectual development at this age compared to the norm population. This indicates that the retardation in motor and language development observed in the present study may not cause permanent damage to the mental development of macrobiotic children.

ACKNOWLEDGEMENTS

The authors thank Ms S.A. Verschuren for her important contribution to this study. They also appreciate the advice given by Prof. J.C. van Wieringen, Dr. E.A. Schlesinger-Was, Prof. E.D.A.M. Schretlen, and Dr. R.J. Kleber. This work was supported in part by a grant from the Dutch Praeventiefonds.

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8 Contaminants in breast-milk of mothers on macrobiotic and omnivorous diets

by P.C. Dagnelie & W.A. van Staveren

Little information is available about the effect of life-style variables on the presence of contaminants in breast-milk.[1-3] We performed a study in lactating mothers on macrobiotic diets and a control group of mothers on omnivorous diets to obtain information on this issue.

Subjects and methods

The macrobiotic sample consisted of nine lactating mothers with a child aged 2 - 3 months and twelve mothers with a child of 9 - 13 months old. The mothers had been on a macrobiotic diet for an average period of 4.6 years (range 2 - 11 years). The macrobiotic diet consists mainly of cereals, vegetables and pulses with small amounts of other plant products and occasionally fish.[4] Other animal products are avoided. Ten control mothers with a child aged 2 - 3 months were recruited through child health clinics in the municipality of Wageningen. Information on occupation, residence, maternal height and weight, smoking and food habits was collected by a structured questionnaire. The mothers sampled 50 ml of breastmilk during the first morning feed of two consecutive days according to standardized instructions and stored the samples at 4 ^{o}C in provided glass bottles with a teflon insert to avoid contamination. After collection on the second day, the samples were mixed and a sodiumazide tablet was added. All samples were stored at 4 ^{o}C until the sampling had been completed. After fat extraction, the samples were analysed according to the procedures described by Tuinstra et al.[5] The results were checked by duplo analyses and recovery experiments which were in general higher than 80 %.

Results and discussion

The contaminant levels of the "younger" and "older" macrobiotic groups were close to each other (Table 1). Contaminant levels were lower in the combined macrobiotic groups than in the control group. For all presented contaminants the difference was statistically significant ($P < 0.10$) when we, by means of multiple regression analysis, corrected for possible confounders (area of

TABLE 1. CONTAMINANT LEVELS IN BREASTMILK OF MOTHERS ON CONVENTIONAL AND MACROBIOTIC DIETS

	MEDIAN CONCENTRATION (RANGE) IN MG/KG BREASTMILK FAT		
Group	Control group	Macrobiotic group	
Age	2 - 3 ms	2 - 3 ms	9 - 13 ms
Number of samples	10	9	12
HCB	0.083 (0.025 - 0.230)	0.051 (0.014 - 0.073)	0.034 (0.018 - 0.280)
DDT	0.705 (0.200 - 1.000)	0.490 (0.150 - 0.790)	0.430 (0.081 - 1.200)
PCB 118	0.032 (0.012 - 0.052)	0.026 (0.006 - 0.038)	0.020 (0.006 - 0.052)
PCB 138	0.140 (0.062 - 0.210)	0.092 (0.049 - 0.120)	0.088 (0.036 - 0.200)
PCB 153	0.170 (0.080 - 0.260)	0.140 (0.059 - 0.160)	0.120 (0.058 - 0.320)
PCB 180	0.071 (0.038 - 0.700)	0.049 (0.025 - 0.079)	0.067 (0.039 - 0.120)

residence, occupation, parity, age of the child, maternal weight, smoking). For PCB's and especially PCB 153, significant dietary factors in this analysis were the consumption frequency of meat, dairy products and (to a lesser extent) fish. DDT levels were determined both by dietary factors and smoking; the DDT concentration in breast-milk from smoking mothers was 0.912 $\pm$ 0.084 mg/kg milk fat compared to 0.458 $\pm$ 0.047 mg/kg in milk from non-smoking mothers ($P = 0.02$, Student's t).

These findings indicate that food habits influence the degree of contamination of breast-milk with organochlorine contaminants. More research into this issue is indicated to achieve lower contamination of the breastfed infant.

Acknowledgements

The authors thank Miss S.A.J.M. Verschuren, R.D. for collecting the breast-milk samples and Mr. R.J. van Mazijk, Mr. A.H. Roos and Dr. L.G.M.Th. Tuinstra, State Institute for Quality Control of Agricultural Products, for performing the chemical analyses.

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9 Discussion

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9.1. INTRODUCTION

This research project aimed to provide information on the nutritional status of children on alternative diets. From a literature review, it was concluded that insufficient data were available on which to base a conclusion about the effects of these diets. In particular, it was not known whether cases of malnutrition are incidental or represent ubiquitous nutritional deficiencies in children on alternative diets. In this project, the nutritional status, growth and development of children on macrobiotic diets was investigated.

Firstly, a cross-sectional study was undertaken on the growth pattern of children on macrobiotic diets between the ages 0 to 8 years (Chapter 3). Subsequently, a mixed-longitudinal study was carried out in macrobiotic infants aged 4 to 18 months and a matched control group of omnivorous infants (Chapters 4 - 7).

Below, we shall first discuss the extent to which the design of these studies and the selection of the participants permits conclusions to be drawn on the nutritional status of the macrobiotic child population as a whole, or in other words, on the nutritional consequences of the macrobiotic diet as it is currently practised in Western countries. Subsequently, we shall discuss the main study findings in terms of whether malnutrition is an isolated occurrence in individual macrobiotic children or whether there is evidence of malnutrition in the macrobiotic population as a whole.

9.2. STUDY METHODS

9.2.1. DESIGN

The main part of the present research project was the mixed-longitudinal study, in which information on growth, psychomotor development and food intake was combined with a paediatric examination and blood sampling. There were several reasons for using a mixed-longitudinal design instead of a pure longitudinal design:

- It enabled us to shorten the study period ("accelerated approach", Bell, 1954). Collecting information on 53 children over an age period of 4 - 18 months would have taken more than two years in a pure longitudinal design instead of 10 months using the mixed-longitudinal approach.
- The shorter study period also reduced the burden on the parents, thus

reducing the study drop-out rate.
- Since it was not known beforehand, whether nutritional deficiencies would occur, for ethical reasons we wished to avoid the need to maintain the observational character of the study for a period longer than six months.

Further measures taken to restrict the drop out rate included:
- limiting the time-consuming weighed food record in the mixed-longitudinal study to two periods of each three days;
- placing the medical examination and blood sampling at the end of the anthropometric study;
- carrying out the study in the homes of the participating families.

9.2.2. POPULATION

Sample representativity

In order to obtain a representative picture of the nutritional status in a truly macrobiotic population,
- We aimed to cover the entire Dutch macrobiotic child population both in the cross-sectional and the mixed-longitudinal study;
- We recruited the participants through macrobiotic teachers and families already participating in the study, and checked their dietary pattern as well as the presence of possible confounding variables by means of a questionnaire developed with the help of macrobiotic teachers.

Both in our contacts with macrobiotic teachers and in our invitation letter to participants, the aim to collect objective information on the nutritional status of children on macrobiotic diets was clearly stated. It was thus possible to keep the rate of refusal to participate at or below 5 per cent in both the cross-sectional and the mixed-longitudinal anthropometric study and 10 per cent for the dietary record and blood sampling in the mixed-longitudinal study. This excellent cooperation was certainly due in part to the positive attitude of macrobiotic teachers towards our project.

Macrobiotic diet of the study population

As was discussed in the Chapters 3 and 4, our questionnaire showed that the study population well followed the macrobiotic food pattern as described by Kushi (1977, revised 1987). In addition, the participants had had long experience with the macrobiotic diet: approximately 75 per cent had followed this diet for more than five years.

Comparability of macrobiotic and control group

In the mixed-longitudinal study, an omnivorous control group was included which was matched for month of birth, sex, parity, educational level of the parents and region of residence. Consequently, the observed differences between the nutritional status of the two groups were not influenced by these variables.

Adverse circumstances in the macrobiotic group

Very few indications were found for the presence of adverse social circumstances in the macrobiotic group. Educational level was high, although 36 per cent of macrobiotic fathers and 30 per cent of macrobiotic mothers had not finished their education. In the control group, this proportion was 7 and 14 per cent, respectively. Ninety two per cent of the macrobiotic infants were in a two-parent family (control group: 100 per cent).

Use of soft drugs before the macrobiotic period by one or both parents, which is considered in macrobiotic teachings to have an adverse effect on child health, was reported for 26 per cent of the macrobiotic group (control group: 4 per cent). However, within the macrobiotic group no association was found between former drug use by parents and growth retardation, low vitamin B12 status, the presence of rickets or skin and muscle wasting, or a retarded psychomotor development.

Forty two per cent of parents stated that they had started on a macrobiotic diet for health reasons. According to some adherents of the macrobiotic diet, this might also have an adverse effect on child health. However, weight and body length for age were higher ($P = 0.007$ and 0.03, respectively) in infants from parents having changed to macrobiotics for health reasons. No significant association was found between changing to macrobiotics for health reasons and a low vitamin B12 status, the presence of rickets or skin and muscle wasting, or slow psychomotor development.

In conclusion, it seems justified to attribute the differences in nutritional status, growth and development which have been described in the preceding chapters to differences in food pattern between the macrobiotic and omnivorous group.

9.3. NUTRITIONAL STATUS OF MACROBIOTIC CHILDREN

An overview of the main study findings presented in the preceding Chapters is given in Table 1. The implications are discussed below.

Table 1. Main nutritional deficiencies observed in infants aged 4 - 18 months on macrobiotic diets

Low intake of	Observed primary consequences	Observed secondary consequences
Energy, protein	Growth retardation	Skin and muscle wasting, retarded motor development
Vitamin B12, iron	Low plasma concentration of vitamin B12	Low Ht and RBC, high MCV [1]
Vitamin D, Calcium	Low plasma levels of vitamin D, calcium, phosphate	Rickets
Vitamin B2	-	Elevated EGR activity coefficient [1]

[1] **Abbreviations: Ht:** Haematocrit; **RBC:** Red blood cell count; **MCV:** Mean corpuscular volume of red blood cells; **EGR:** Erythrocyte glutathione reductase.

9.3.1. GROWTH AND DEVELOPMENT

The pattern of growth and somatic development in children is not constant, but changes with time (van Wieringen, 1978). This change is known as a "secular trend". For example, in industrialized countries, a positive secular trend, that is an increase in height and an earlier onset of puberty, has been observed over the last hundred years or more. In the past, a close interrelationship was established between a positive secular trend and a decrease in morbidity and mortality (van Wieringen, 1978), but this does not necessarily apply to children in industrialized countries nowadays. For instance, children developing obesity have a tendency for accelerated height gain (Shukla et al., 1972; Anonymous, 1977; Forbes, 1977; Biervliet & de Wijn, 1978) and for earlier onset of puberty (Anonymous, 1977).

In addition, the present-day Western diet is associated with a number of diseases such as cardiovascular diseases, diabetes and gout. Such observations may have led to the assumption in macrobiotic circles that children on present-day conventional diets grow "abnormally" fast. Consequently, adherents of the macrobiotic diet have interpreted the comparatively low weight and height for age in their children as a sign of "optimal" growth. We shall discuss in how far this hypothesis is supported by our data.

In our study, a small but significant intrauterine growth retardation was indicated by a lower birth weight of macrobiotic children. Weight gain between birth and the age of 6 months in macrobiotic infants was less than in the control group. From 6 months of age, the growth rate decreased further to the lowest value between the age of 8 and 14 months. From 14 months of age onwards, growth slowly increased, first to parellel the 10th percentile of the growth reference. A tendency for catch-up growth was observed for some anthropometric parameters mainly after 2 years of age.

A number of findings in this study suggest that the described growth pattern of macrobiotic children is not optimal. These are:

- The irregular growth pattern observed between birth and 2 years;
- The association of growth retardation with a reduction of muscle and fat tissue as indicated by anthropometric measurements, in particular the considerably slower gain in arm muscle area and arm fat area than in infants on omnivorous diets, as well as the clinical indications of skin and muscle wasting in 30 per cent of the macrobiotic infants;
- The association between growth retardation and retardation in gross motor and language development;
- The catch-up growth observed in macrobiotic children after 2 years of age. This finding is in accordance with earlier longitudinal observations (Shull et al., 1977) in macrobiotic children in Boston, USA. There is congruence in the literature that catch-up growth is a self-correcting response, which attempts to restore the individual to his or her original growth channel after a period of retarded growth (Ashworth & Millward, 1986; Tanner, 1986). Catch-up growth occurs as soon as the retarding factor is removed or, as in malnutrition, as soon as an adequate diet is provided (Ashworth & Millward, 1986). Consequently, catch-up growth may serve as a retrospective diagnostic tool (Bergmann & Bergmann, 1978) and in macrobiotic children indicates a previous period of malnutrition.

These observations indicate that the growth pattern of macrobiotic children is suboptimal.

The study findings indicated an association between the observed deviations in infant growth and dietary factors. Low birth weight was associated with a low maternal weight increase during pregnancy as well as with a low frequency in the consumption of fish and dairy products by the mother, indicating a relationship between low birth weight and the strictness of adherence to the macrobiotic diet during pregnancy. Furthermore, the weight increase in macrobiotic infants between 4 and 18 months of age was associated with both the energy intake and the protein content of the macrobiotic weaning diet. The energy density of the diet was low because of the extremely low fat content combined with the high water and fibre content. The protein intake was low because of the absence of dairy products and because a considerable proportion of plant protein remained behind when the porridge was sieved (T. de Graaf et al., 1987).

It would appear that nutritional deficiencies are responsible for the anthropometric deviations found, with retardation in psychomotor development as the ultimate consequence.

The occurrence of catch-up growth after the age of two years could be interpreted as a sign that the macrobiotic diet of older children would be adequate. This supposition is not supported by our data. In fact, to the contrary the macrobiotic child population did not reach the level of the reference until the age of eight years, the upper age limit in the study. This supposition is also contradicted by the absence of catch-up growth in height.

Mainly on the basis of animal experiments, it has been assumed that a height deficit is the result of undernutrition at a period when growth is particularly sensitive to adverse influences, that is below two years of age (Waterlow, 1978). This would result in irreversible growth retardation in height. However, catch-up growth in height does seem to be possible, provided conditions are favourable (Prader, Tanner & von Harnack, 1963; Waterlow, 1978; Branko, 1979; Ashworth & Millward, 1986). Even a large deficit in height can be caught up over a period of years under such favourable conditions (Waterlow, 1978). Thus the question remains whether the lack of catch-up growth in height can be attributed to continued nutritional deficiencies in older macrobiotic children. Two observations support this supposition.

Firstly, studies in macrobiotic children of preschool and school age have shown that the macrobiotic diet continues to be low in a number of nutrients (Dwyer, 1982; van Staveren, 1985). Secondly, during our study we had the opportunity to see several children with catch-up in height after the introduction of dairy products. As an illustration, we here present growth curves of three siblings from an almost vegan macrobiotic family, in which the mother introduced dairy products and fatty fish later (Fig. 1). In all children, a catch-up in height can be observed after the introduction of these products (shown in Fig. 1 as 'A').

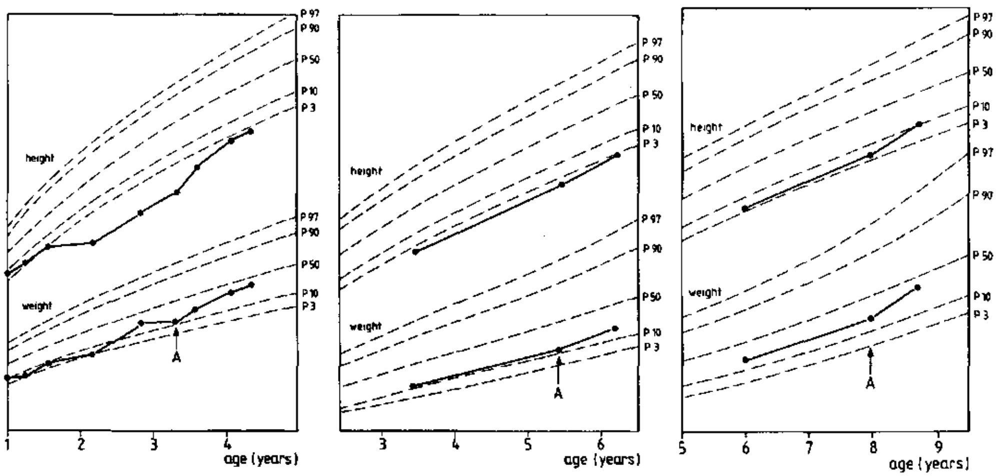


Fig. 1. Growth in weight and height of three siblings before and after the introduction of dairy products and fatty fish (shown as 'A')

This suggests that the lack of complete catch-up growth in older macrobiotic children may be caused by continued marginal deficiency of one or more nutrients.

The question remains, what are the factors in the macrobiotic diet which lead to this permanent retardation in height ("stunting"). In a review of the literature, Waterlow (1978) has described several hypotheses on the causes of stunting. These include:

- Stunting is the result of the same process which causes faltering in weight gain and leads to low weight-for-height ("wasting"). This "single cause" hypothesis was based on the observation of a close parellel between height and weight velocities of individual children (Waterlow, 1978), the changes of height being of lesser magnitude than the changes in weight. A similar a parellel was observed between supine length and weight in macrobiotic infants during the mixed-longitudinal study (Fig. 2).
- However, the two effects of wasting and stunting do not always go together. In some populations in developing countries, wasting is more prevalent, whereas in others stunting prevails. It has been suggested that height is

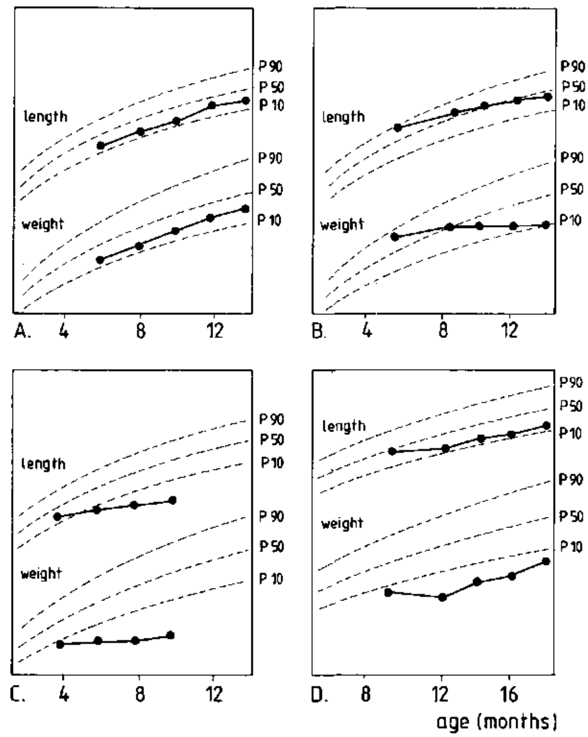


Fig. 2. Growth curves for individual macrobiotic infants participating in the mixed-longitudinal study

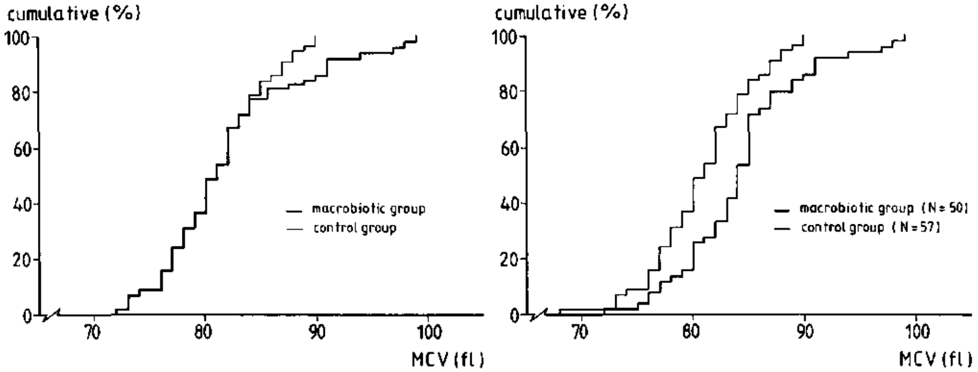
affected most by protein deficiency (Malcolm, 1978; Ashworth & Millward, 1986), whereas weight is more sensitive to a low energy intake (Waterlow, 1978; Malcolm, 1978). Our data support this hypothesis. A relationship was found between the retardation of growth in length in macrobiotic infants and the low protein content of their diet, but not with energy intake (Chapter 7). In contrast, slow growth in weight was associated both with a low energy intake and a low protein content of the diet.

This hypothesis of different causes of wasting and stunting would also provide a plausible explanation of the difference observed between growth patterns of children on macrobiotic and lacto-vegetarian diets. In macrobiotic children above the age of two years, whose diet lacks dairy products, stunting is combined with a normal weight-for-height, whereas children on lacto-vegetarian diets, who receive dairy products, show some degree of wasting but virtually no stunting (Dwyer et al., 1980; van Staveren et al., 1985). Thus, lack of energy may be responsible for wasting in lacto-vegetarian children, whereas lack of protein may cause the stunting observed in macrobiotic children. Consequently, continued protein deficiency in the macrobiotic diet would prevent catch-up growth in height in older macrobiotic children. This requires further investigation.

9.3.2. VITAMIN B12 STATUS

One of the main topics of discussion on the nutritional consequences of vegetarian diets continues to be the risk of vitamin B12 deficiency. It seems that man, more than any animal, is particularly sensitive to the effects of vitamin B12 depletion (England & Linnell, 1979). Vitamin B12 deficiency leads to haematological changes, such as a raised volume of red blood cells (Herbert, 1987). In this study, both a low plasma vitamin B12 concentration and a high red cell volume (mean corpuscular volume, MCV) were found in the macrobiotic group (Chapter 5). Within the macrobiotic group, lower vitamin B12 concentrations were associated with higher values for MCV.

To assess whether vitamin B12 deficiency is incidental or is present in a high proportion of macrobiotic infants, we compared the frequency distribution curves of MCV in the macrobiotic and the control group. If vitamin B12 deficiency were restricted to a few macrobiotic infants, then



A. Theoretical curve of MCV B. Actual curve of MCV

Fig. 3. Theoretical and actual frequency distribution of mean corpuscular volume (MCV) in infants on macrobiotic and omnivorous control diets

the two curves could be expected to be identical with the exception of the few deficient infants (theoretical curve: Fig. 3A). However, in fact, a relative rise in MCV can be observed in all macrobiotic infants (actual curve: Fig. 3B). Similarly, the red blood cell count (RBC) was depressed for the macrobiotic group as a whole (Chapter 5), indicating that subclinical vitamin B12 deficiency may be present in most macrobiotic infants.

This hypothesis is supported by the recent observation by Herbert (1987), that the laboratory test for MCV becomes abnormal in the individual before it exceeds the normal range for the population. This observation implies that a low plasma vitamin B12 concentration should be considered as a warning sign even if other haematological parameters are within current norms.

9.3.3. PLANT SOURCES OF VITAMIN B12

In connection with this study, vitamin B12 was determined in about 40 macrobiotic plant foods by means of a radio-immunoassay (Van den Berg, Dagnelie & van Staveren, 1988; see Chapters 4 and 5). No vitamin B12 was found to be present in fermented soy foods and most other foods. All previous reports of vitamin B12 in these products have been based on microbiological assays, which are not specific for true vitamin B12. However, as was discussed in Chapter 4, vitamin B12 was found in spirulina (48 μg/100 g) and some seaweeds, especially nori (18 - 69 μg/100 g) but also kombu and wakame (3 - 5 μg/100g). Consequently, we advised mothers of macrobiotic infants having low plasma vitamin B12 and high MCV to give their child ample amounts of seaweeds, nori or spirulina especially. However, follow-up examination 1 to 5 months after giving nori or spirulina in amounts equivalent to 0.3 - 2.7 μg of vitamin B12 per day, showed a rise in MCV despite increasing plasma vitamin B12 levels (Dagnelie et al., unpublished observations). It seems that vitamin B12 in seaweeds is not bio-available for humans.

Thus it may be concluded that naturally occurring plant foods cannot be relied upon as an adequate source of vitamin B12.

9.3.4. VITAMIN D AND CALCIUM STATUS

A child was only considered to have rickets if at least three symptoms were present, including at least one specific to rickets (Chapter 6). Even according to this restricted definition, rickets was present in 28 per cent of the macrobiotic infants in summer and 55 per cent in winter.

To ascertain whether the presence of rickets in summer was only an isolated problem in some macrobiotic infants, we divided the participants into four categories (Table 2):

Table 2. Presence of rickets in macrobiotic and omnivorous control infants

	CONTROL GROUP	MACROBIOTIC GROUP	
Period	Summer	Summer	Winter
Number of infants	57	53	20
A. Apparently healthy infants			
No rickets	57	25	2
Subclinical rickets	0	13	7
Total	57	38	9
B. Infants with clinical rickets			
Infants with 3 - 4 symptoms	0	13	2
Infants with 5 or more symptoms	0	2	9
Total	0	15	11

A. Apparently healthy infants

- Without rickets, i.e. with at most one aspecific symptom (no rickets);
- With 1 - 2 specific symptoms or 3 aspecific symptoms of rickets (subclinical rickets);

B. Infants with clinical rickets

- With 3 - 4 symptoms of rickets, of which 1 or more was specific;
- With 5 or more symptoms of rickets, of which 2 or more were specific.

In summer, 13 of 38 macrobiotic infants (34 %) had subclinical rickets but none of the control infants (Table 2; $P < 0.001$, Fisher's exact test). In winter, this proportion increased ($P = 0.02$) to 7 of 9 macrobiotic infants. Deterioration in winter also occurred in those infants categorized as having clinical rickets (B), indicated by a larger proportion of infants with five or more symptoms of rickets than in the preceding summer (Table 2). Including infants with subclinical rickets, the total prevalence of rickets can be estimated to be 53 per cent in summer and 90 per cent in winter.

An important question is, what is the cause of this high prevalence of rickets. Our data indicated that in addition to vitamin D, calcium deficiency was an independent cause of rickets. The shortage of calcium seemed to results from a combination of a diet low in calcium and high in fibre content. Calcium deficiency in the macrobiotic diet needs further study. Apart from bone development, calcium shortage may have other consequences. For instance, the first tooth was not reported until after the age of 10 months in 23 per cent of the macrobiotic infants whereas this was the case in only 9 per cent of the control infants ($P<0.02$).

9.3.5. BREAST-MILK CONTAMINANTS

There is a macrobiotic saying that "what has a front, has a back", meaning that all phenomena usually have both favourable and unfavourable aspects. In this study, we also found such a favourable aspect of the macrobiotic diet. The level of contaminants in breast-milk of macrobiotic mothers was 1.5 to 2 times lower than in omnivorous mothers.

Certainly, the number of participants was small and there was an overlap in the range of scores of the two groups. Still, this finding indicates that the contamination of breast-milk may be influenced by the maternal diet, which confirms the findings of other studies (Hergenrather et al., 1981; Norén, 1983; Cetinkaya et al., 1984).

The mean duration of breastfeeding in the macrobiotic group was 13.6 months compared to 6.6 months in the control group. Thus, our findings imply that the total intake of contaminants in infants of macrobiotic mothers during the prolonged lactation period would not be higher than in infants of omnivorous mothers.

9.3.6. CONCLUSION

The findings of this study do not support the supposition that nutritional deficiencies are only present in a limited number of isolated macrobiotic children. On the contrary, our findings show that the cases of malnutrition in children on macrobiotic diets described in the literature are just the "top of the iceberg" of nutritional deficiencies, which to a lesser degree are present in the vast majority of the macrobiotic infant population.

We did not find any indication that adverse circumstances were responsible for the observed nutritional deficiencies. Neither did we find any indication that malnutrition was only prevalent in families not following macrobiotic teachings. On the contrary, low birth weight and retarded growth were more pronounced the stricter the adherance to the macrobiotic diet.

The supposition that growth in macrobiotic children is optimal must also be rejected. On the contrary, a clear nutrition-dependent growth stagnation with changes in psychomotor development occurs at weaning without complete restoration of growth later in childhood.

Nutritional deficiencies appear firstly in the most vulnerable groups, such as growing children and women of child-bearing age (Jelliffe, 1966). Therefore, when such deficiencies are found in young children, the question arises if similar deficiencies occur in older children and acults on macrobiotic diets. Reference has already been made to the possible continuation of marginal deficiencies in older children. The association of low birth weight with low weight gain of macrobiotic mothers during pregnancy and avoidance of dairy products and fish suggest that nutritional deficiencies may occur during pregnancy. Vitamin B12 content of breast-milk was also found to be lower in macrobiotic mothers than in omnivorous mothers (Dagnelie et al., unpublished observations). Recently, vitamin B12 deficiency has been described in breastfeeding macrobiotic mothers in Boston, USA (Specker et al., 1988). In macrobiotic adult men in Belgium, similar low plasma vitamin B12 values were observed as we found in Dutch children (Knuiman et al., 1982). Although less likely to occur in adults, deficiency symptoms may develop in situations of higher physiological needs. It would therefore seem that some adaptation of the macrobiotic diet is needed both for children and adults.

9.4. IMPLICATIONS

9.4.1. RECOMMENDATIONS FOR THE MACROBIOTIC DIET

A number of changes in keeping with the macrobiotic philosophy are recommended to make the macrobiotic diet nutritionally adequate.

- The addition of **fat** as an additional source of energy to a level of at least 25 - 30 energy per cent of fat in children, is required. This could be achieved by including 20 - 25 g of oil per day (or double this amount in exchange for nuts and seeds; see also Dearden, Harman & Morley, 1980).
- As a source of vitamin B12, products of animal origin such as fish are needed.
- The inclusion of 100 - 150 grams per week of **fatty fish** would provide approximately 2 - 3 μg of vitamin D per day. However, the amount of vitamin D provided in this way is still considerably below the recommended daily intake of 10 - 15 μg (Netherlands Nutrition Council, 1981).

In addition, the inclusion of **dairy products** (at least one serving per day) as a source of calcium, protein and vitamin B2 is recommended, even though past experience has indicated that some followers of the macrobiotic diet found this more difficult to adopt.

9.4.2. IMPLICATIONS FOR NUTRITIONAL STUDIES

The conclusions drawn in this study were based on four essential elements of the study design:

- combination of longitudinal information on anthropometry, psychomotor development and dietary intake with blood chemistry and physical examination;
- participation of the majority of the Dutch macrobiotic population;
- verification of the dietary habits of the participants;
- presence of a matched control group.

Many previous studies in vegetarians have not identified significant deviations in their nutritional status. This may be attributed to the fact that they have not included all of these elements in the study design. Therefore further studies need to be undertaken before any definite conclusions on the nutritional adequacy of vegetarian diets can be drawn. An issue deserving high priority is the calcium deficiency in diets of a low calcium and high fibre content, especially for children and women of child bearing age.

Another pressing issue is the vitamin B12 status of lacto-vegetarians and vegans. Increasing values of mean corpuscular volume (MCV), similar to that found in macrobiotic infants in connection with vitamin B12 deficiency, has been described in vegan men, regardless of whether they were taking vitamin B12 supplements (Sanders, Ellis & Dickerson, 1978), as well as in adult lacto-vegetarian Seventh Day Adventists (Armstrong et al., 1974). The assumption that lacto-vegetarian or vitamin B12-supplemented vegan diets prevent symptoms of vitamin B12 deficiency may not be correct.

9.4.3. CLINICAL IMPLICATIONS

In connection with vitamin B12, mention has already been made that haematometric variables such as MCV may be abnormal for the individual long before they exceed the normal range for the population. The shift in MCV described in this study for the macrobiotic group would not have been detected in individual macrobiotic children using current methods. But also, MCV beyond the normal range was observed in some macrobiotic infants with normal plasma folate concentrations and vitamin B12 values far above the current cut-off value of 136 pmol/l (for example, MCV 89 fl, B12 329 pmol/l, folate 27.5 pmol/l). Thus, neither a "normal" vitamin B12 concentration nor "normal" MCV would exclude the possibility of vitamin B12 deficiency in vegetarians.

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Summary

This dissertation contains the main findings of a research project on the nutritional status and growth of children on macrobiotic diets. Case studies of malnutrition in children on different alternative diets have appeared in the literature over the past 15 - 20 years, but it is not clear whether these are incidental or whether they represent ubiquitous nutritional deficiencies in these child populations (Chapter 2). This issue was investigated in one specific population, i.e. in children on a macrobiotic diet. The macrobiotic diet consists of cereals, pulses and vegetables with small additions of seaweeds, fermented foods, nuts and seeds. Meat, dairy products and fruits are avoided. Lean (white) fish may be taken occasionally if desired, but was rarely given to young children during the study.

As set out in Chapter 1, the objectives of the study were:

- to describe the relationship between diet, growth, blood chemistry, psychomotor development, and clinical findings;
- if deficiencies would be found, to assist in overcoming these by providing practical guidelines within the scope of the macrobiotic food system.

In order to ensure a representative study sample, the total Dutch macrobiotic population was invited to join the study. At least 80 per cent of families participated and the refusal rate was below 5 per cent.

A cross-sectional anthropometric study in macrobiotic children aged 0 - 8 years (Chapter 3) revealed that the age curves followed the median (P50) of the Dutch standard from birth to 6 months, after which there was a marked decline to the level of the 10th percentile (P10) by 18 months of age. A partial return towards the P50 was observed after the age of 2 years for weight and arm circumference, but not for height. Birth weight of macrobiotic children was 150 g lower than standards.

Subsequently, a mixed-longitudinal study was carried out in the 1985 macrobiotic birth cohort (n = 53) and a control group of infants on omnivorous diets matched for month of birth, sex, parity, educational level of the father and region of residence (n = 57). Both groups were divided into three cohorts which were followed in bimonthly intervals over a six month period (i.e. 4 - 10, 8 - 14 and 12 - 18 months, respectively). The study methods included regular anthropometric measurements and a standardized psychomotor checklist, dietary information (a weighed food

record), as well as a paediatric examination with blood sampling in summer and winter.

The study design, weaning pattern and intake of energy and nutrients are described in Chapter 4. Breastfeeding was common in both the macrobiotic and the control group, but was continued longer in the macrobiotic group (13.6 months) than in the control group (6.6 months). Supplementary feeding started later in the macrobiotic group (4.8 months, control group: 2.7 months). Individual energy and nutrient intakes were calculated from two subsequent three-day food records using the Dutch food table, supplemented with our own analytical data on 50 macrobiotic foods. The intake of energy, protein, fat, riboflavin and especially calcium and vitamin B12 of the macrobiotic group was lower, whereas the intake of fibre and iron was higher than in the control group. The macrobiotic weaning diet was bulky because of the extremely low fat content in combination with a high water and fibre content. The low riboflavin intake was reflected by an elevated activity coefficient of erythrocyte glutathione reductase (EGR).

In comparison with the control group, the macrobiotic group showed low plasma vitamin B12 concentrations in combination with high mean red cell volume (MCV) and low red blood cell count (RBC, Chapter 5). Also, a higher proportion of macrobiotic infants had a low iron status.

Only 1 out of 53 macrobiotic infants daily received a vitamin D supplement (Chapter 6). In summer, 28 per cent showed clinical symptoms of rickets and in winter, 55 per cent. Plasma concentrations of 25-OH-vitamin D, calcium and phosphate showed an association with physical symptoms of rickets, but the high prevalence of rickets in summer in spite of normal 25-OH-D concentrations made the coexistence of calcium deficiency likely.

Values for all anthropometric parameters were lower in the macrobiotic group (Chapter 7). Weight velocity was lower between birth and 4 months. After the age of 6 months, growth slowed down further to reach its lowest value between 8 and 14 months. Growth retardation was associated with a retardation in gross motor and language development in macrobiotic infants. Major skin and muscle wasting (dystrophy) was present in 30 per cent of the macrobiotic infants. Within the marobiotic group, lower growth velocities in weight and arm circumference were associated with lower energy intake per kg body weight and, independently, with the protein content of the diet.

A study of contaminants in the breast-milk of 21 macrobiotic and 10 omnivorous mothers (Chapter 8) showed lower levels of HCB, DDT, PCB 118, PCB 138, PCB 153 and PCB 180 in breast-milk of the macrobiotic mothers.

The study findings are discussed in Chapter 9. It is shown that, apart from the reported deficiencies, subclinical deficiencies of vitamin B12 and vitamin D are likely to be highly prevalent in the macrobiotic child population. Thus it is concluded that the cases of malnutrition in children on macrobiotic diets reported in the literature are not incidental, but represent only the "top of the iceberg" of nutritional deficiencies in a major proportion of the macrobiotic infant population. In addition, continued nutritional deficiencies may be responsible for the only partial catch-up growth in older macrobiotic children.

On the basis of our findings, it was advised to incorporate regular servings of fatty fish (100 - 150 g per week) and to add at least 20 - 25 g (2 table-spoons) of oil per day to macrobiotic children's diet. These recommendations were acceptable to macrobiotic teachers. It was also advised to include dairy products (one serving per day) into the macrobiotic diet. Some macrobiotic practitioners may consider the latter advice more difficult to adopt.

Samenvatting

Dit proefschrift bevat de voornaamste bevindingen van een onderzoek naar de voedingstoestand en groei van kinderen met een macrobiotische voeding. Gedurende de laatste 15 - 20 jaar zijn in Nederland en andere landen herhaaldelijk gevallen van ondervoeding bij alternatief gevoede kinderen beschreven. Het is echter niet duidelijk of het hierbij om incidentele gevallen gaat dan wel om het "topje van de ijsberg" van ondervoeding bij alternatief gevoede kinderen (hoofdstuk 2). Deze vraag is onderzocht voor één specifieke alternatieve populatie, en wel kinderen met een macrobiotische voeding.

De macrobiotische voeding bestaat uit granen, peulvruchten en groenten met kleine hoeveelheden zeewier, gefermenteerde produkten, noten en zaden. Vlees, zuivelprodukten en fruit worden vermeden. Het af en toe gebruiken van magere (witte) vis wordt niet afgewezen, maar ten tijde van het onderzoek werd deze nauwelijks aan jonge kinderen gegeven.

Doel van het onderzoek (hoofdstuk 1) was:

- na te gaan of er een relatie bestond tussen de macrobiotisch voeding en de groei, bloedwaarden, de psychomotorische ontwikkeling en klinische bevindingen;
- indien zich bepaalde problemen mochten voordoen, tot een oplossing hiervan bij te dragen door het geven van praktische adviezen.

Om een representatief beeld van de Nederlandse macrobiotische populatie te krijgen werden alle Nederlandse macrobiotische gezinnen uitgenodigd aan het onderzoek deel te nemen. Adressen werden verkregen in de eerste plaats door welwillende medewerking van macrobiotische organisaties en daarnaast via gezinnen die reeds aan het onderzoek deelnamen. De totale deelname was tenminste 80 % van de gezinnen uit de macrobiotische populatie. Slechts 5 % van de benaderde gezinnen zag van deelname af.

Uit een eenmalig (transversaal) onderzoek naar lengte, gewicht en andere lichaamsmaten bij macrobiotisch gevoede kinderen van 0 - 8 jaar (hoofdstuk 3) bleek dat de "groei"-curve van 0 - 6 maanden gelijk was aan de mediaan (P50) van de Nederlandse groeistandaard. In het leeftijdstraject van 6 - 18 maanden boog de curve sterk naar beneden af om vanaf ongeveer 18 maanden tot 2 jaar de bereikte percentiellijn (P10) te volgen. Vanaf 2 jaar was een beperkt inhaaleffect waarneembaar voor gewicht en armomtrek, maar niet voor lengte. Het aantal kinderen met een laag geboortegewicht (2500 gram of lager) was 6,5 %, in vergelijking tot het gemiddelde Nederlandse cijfer van 2,0 % in 1982. Van de overige kinderen lag het gemiddelde geboortegewicht 150 g beneden het Nederlandse gemiddelde.

Vervolgens werd een semi-longitudinaal onderzoek uitgevoerd bij alle kinderen die in 1985 bij macrobiotische ouders waren geboren (53 kinderen) en een gangbaar gevoede vergelijkingsgroep (57 kinderen). De twee groepen waren vergelijkbaar (gematched) met betrekking tot geboortemaand, geslacht, rangnummer van het kind in het gezin (pariteit), opleidingsniveau van de vader, en regio. Beide groepen werden verdeeld in drie leeftijdsgroepen die gedurende 6 maanden werden gevolgd, en wel respectievelijk van 4 tot 10, van 8 tot 14 en van 12 tot 18 maanden. Alle kinderen werden elke 2 maanden thuis bezocht en gemeten, waarbij ook de psychomotorische ontwikkeling werd gevolgd met behulp van het herziene Van Wiechenschema. Tweemaal tijdens het onderzoek wogen de moeders gedurende drie dagen de voeding van hun kind af en noteerden deze. Na afloop van de 6 maanden kwam een ervaren kinderarts langs, die de kinderen onderzocht en bloed afnam.

De onderzoeksopzet en voeding wordt in hoofdstuk 4 nader beschreven. Borstvoeding kwam in beide groepen veel voor, maar de macrobiotische moeders gingen hiermee langer door (gemiddeld 13½ maand, gangbare groep: 6½ maand). De macrobiotische ouders begonnen later met bijvoeding, namelijk gemiddeld rond 5 maanden (gangbare ouders: 2½ à 3 maanden). De inneming van energie, vet, eiwit, vitamine B2 en vooral calcium en vitamine B12 was lager in de macrobiotisch gevoede groep, terwijl de inneming van vezel en ijzer hoger was in vergelijking tot de gangbaar gevoede groep. De macrobiotische bijvoeding bestond voornamelijk uit gezeefde graan-waterpappen met een zeer laag vetgehalte en een hoog water- en vezelgehalte.

Uit het bloedonderzoek bleken afwijkingen met betrekking tot vitamine B12 en voor een deel van de kinderen ijzer (hoofdstuk 5). Slechts één van de 53 kinderen kreeg dagelijks een vitamine D supplement (hoodstuk 6). In de zomer bleek 28 % en in de winter zelfs 55 % duidelijke tekenen van rachitis te vertonen, die samengingen met een daling in de bloedwaarden van vitamine D, calcium en fosfaat. Uit een nadere analyse van de gegevens bleek, dat het onverwachte veelvuldige vóórkomen van rachitis in de zomer waarschijnlijk voor een aanzienlijk deel was veroorzaakt door gebrek aan calcium en het hoge vezelgehalte van de voeding.

De groei in gewicht bleek al tussen 0 en 4 maanden langzamer dan die van de gangbaar gevoede groep (hoofdstuk 7). In de periode van 6 - 18 maanden nam de groeisnelheid in gewicht, lengte en andere lichaamsmaten sterk af. De groei was het langzaamst in de leeftijd van 8 - 14 maanden. De groeivertraging ging gepaard met een vertraging in ontwikkeling van de grove motoriek (zitten, staan, lopen e.d.) en van de taal. Huid- en spierdystrofie was bij 30 % van de kinderen aanwezig. In de macrobiotische groep bestond een samenhang tussen de groei en de inneming van energie en eiwit.

Uit onderzoek naar het gehalte aan gifstoffen in moedermelk van 21 moeders met een macrobiotische voeding en 10 moeders met een gangbare voeding (hoofdstuk 8) bleek dat, al bestond er een overlapping tussen de waarden in de twee groepen, gemiddeld het gehalte van HCB, DDT, en de vier belangrijkste PCB's in de moedermelk van de macrobiotische moeders lager was. Dit onderzoek geeft aan dat de voedings- en leefgewoonten het gifstoffengehalte van moedermelk kunnen beïnvloeden.

De betekenis van de resultaten wordt besproken in hoofdstuk 9. Uit een verdere analyse van de bloed- en medische gegevens blijkt, dat een marginaal (subklinisch) tekort aan vitamine B12 en vitamine D naar alle waarschijnlijkheid in het merendeel van de onderzochte macrobiotische groep voorkomt. Het eerdere vermoeden, dat gerapporteerde gevallen van ondervoeding bij macrobiotisch gevoede kinderen incidentele gevallen zouden zijn, voortkomend uit een verkeerd begrijpen en toepassen van de macrobiotische richtlijnen door de ouders, blijkt dus niet juist te zijn. Zulke gevallen lijken het topje van de ijsberg van marginale tekorten te vormen.

Op basis van deze resultaten is ernaar gestreefd, aanbevelingen te formuleren die de waargenomen problemen binnen het kader van de macrobiotische voedingswijze zouden kunnen oplossen. Naar aanleiding van de eerste bevindingen (tekort aan energie c.q. vet, vitamine B12 en vitamine D), is in eerste instantie aanbevolen de macrobiotische voeding aan te vullen met:

- meer vet (tenminste 20 gram per dag, d.i. 2 eetlepels),
- regelmatig vette vis (100 - 150 gram per week).

Aangezien ook tekort bleek te bestaan aan eiwit, calcium en vitamine B2, waarvan melkprodukten de beste voedingsbron zijn, is geadviseerd om hiernaast ook melkprodukten te gebruiken (tenminste één portie per dag).

Deze adviezen zijn in de allereerste plaats van belang voor kinderen tussen 6 maanden en 2 jaar. Aangezien tekorten in de voeding het eerst tot uiting komen bij groepen in situaties waar een verhoogde behoefte bestaat, zoals bij groei, zullen jonge kinderen het meest van een aanpassing van de macrobiotische voeding profiteren. Echter, het onderzoek wijst erop dat het ontbreken van volledige inhaalgroei bij oudere kinderen ook door marginale voedingstekorten wordt veroorzaakt. Kinderen die op latere leeftijd een ruimere voeding krijgen met onder meer zuivelprodukten, blijken namelijk duidelijke inhaalgroei te vertonen, ook in lengte. Het lagere geboortegewicht van macrobiotische zuigelingen blijkt samen te hangen met een geringe gewichtstoename van de moeder tijdens de zwangerschap en met het minder vaak gebruiken van zuivelprodukten en vis in het gezin. Dit geeft aan dat ook voor oudere kinderen en volwassenen, in het bijzonder vrouwen op vruchtbare leeftijd, een verruiming van de macrobiotische voeding gewenst lijkt.

Curriculum vitae

De auteur werd geboren op 21 maart 1952 te Rotterdam. Na het behalen van het gymnasium ß diploma aan het Erasmiaans Gymnasium te Rotterdam in 1970, studeerde hij Voeding van de Mens aan de Landbouwuniversiteit te Wageningen. Voor het propaedeutisch examen slaagde hij met lof. Als praktijkstage bracht hij een jaar door in Kenya met onderzoek op het gebied van ondervoeding bij kinderen. In 1979 behaalde hij het doctoraalexamen met als vakken Voeding, Gezondheidsleer en Voorlichtingskunde. Na het vervullen van de vervangende dienstplicht (1979 - 1981) bracht hij enkele jaren in de Bondsrepubliek Duitsland door voor een aanvullende opleiding op het gebied van voeding en voedingstherapie in instellingen (1981 - 1983). Per 1 september 1984 trad hij in dienst bij de Vakgroep Humane Voeding van de Landbouwuniversiteit Wageningen alwaar, met financiële steun van het Praeventiefonds, het in dit proefschrift beschreven onderzoek werd verricht.