Early-Life Contributors to Child Well-Being

DOI: 10.1159/000499152

5 Editorial
Lifschitz, C. (Buenos Aires); Lin, W. (Chapel Hill, NC)

8 Determinants of Well-Being and Their Implications for Health Care
Helliwell, J.F. (Vancouver, BC)

16 Microbiota and Neurodevelopmental Trajectories: Role of Maternal and Early-Life Nutrition
Codagnone, M.G. (Cork); Stanton, C. (Cork/Fermoy); O’Mahony, S.M., Dinan, T.G., Cryan, J.F. (Cork)

28 Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness
Daniels, L.A. (Brisbane, QLD)

44 The Contribution of Food Consumption to Well-Being
Holder, M.D. (Kelowna, BC)
Early-life contributors to child well-being

The gut-brain axis is bi-directional. A deeper understanding of this two-way relationship creates opportunities to change the focus of healthcare from the diagnosis and treatment of illness to the fostering of well-being.

Diet plays a key role in supporting healthy physical and cognitive development

Factors supporting physical and cognitive development

- **Mother's Diet**
  - Vaginal delivery: Microbiome transferred
  - Caesarean section: Microbiome not transferred

- **Type of Delivery**
  - Vaginal delivery: Increased risk of neonatal infection, allergies, asthma, obesity, type 1 diabetes

- **Breast-feeding**
  - Breastfeeding increases the abundance of Bacteroides and Bifidobacterium in the infant's gut

Factors supporting the development of healthy behaviours

- **Exposure**
  - "Learning to Like, Learning to Eat"

- **Response Feeding**
  - "Parent Provides, Child Decides"

- **Positive Parenting**
  - "Feeding is Parenting – Be a Good Role Model"

Healthy food choices

- Boost:
  - Immune function
  - - vitamin D
  - - vitamin C
  - - antioxidants
  - Well-being
  - - Longevity

- Reduce:
  - Blood pressure
  - Colorectal cancer
  - Lung cancer
  - Pulmonary disease
  - Type 2 diabetes

Maternal factors, feeding practices and healthy food choices contribute to optimal physical and cognitive development and support child well-being.
Reprint of Annals of Nutrition and Metabolism Vol. 74, Suppl. 2, 2019

Sponsor Note
This publication was supported by an unrestricted educational grant by the Nestlé Nutrition Institute. The institute is a not-for-profit association which was created to provide latest medical and scientific information to health professionals in the field of pediatric and adult nutrition and nutrition-related disorders (available at www.nestlenutrition-institute.org).

Any liability of the sponsors for the content of the papers is hereby expressly excluded.

Disclosure Statement Guest Editors
C.L. is a member of the Faculty Board of the Nestlé Nutrition Institute and has received honoraria from Danone, Mead Johnson Nutrition, and the Nestlé Nutrition Institute.

W.L. has an ongoing research grant funded by Nestec Inc, serves as a consultant for Nestlé Nutrition, Wyeth Nutrition, and Mead Johnson Nutrition, is a member of the Scientific Advisory Committee, NNI, and has received travel support from Wyeth Nutrition Science Center.
Contents

DOI: 10.1159/000499152
Early-Life Contributors to Child Well-Being – Infographic – Poster
available as online supplementary material at:

5 Editorial
Lifschitz, C. (Buenos Aires); Lin, W. (Chapel Hill, NC)

7 Focus/Summary

8 Determinants of Well-Being and Their Implications for Health Care
Helliwell, J.F. (Vancouver, BC)

15 Focus/Summary

16 Microbiota and Neurodevelopmental Trajectories: Role of Maternal and Early-Life Nutrition
Codagnone, M.G. (Cork); Stanton, C. (Cork/Fermoy); O’Mahony, S.M., Dinan, T.G., Cryan, J.F. (Cork)

28 Focus/Summary

29 Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness
Daniels, L.A. (Brisbane, QLD)

43 Focus/Summary

44 The Contribution of Food Consumption to Well-Being
Holder, M.D. (Kelowna, BC)

The above articles were originally published as a supplementary issue of
Annals of Nutrition and Metabolism and are reprinted here with permission.
The Nestlé Nutrition Institute was created to provide health professionals with up-to-date information on nutrition and nutrition-related disorders in order to enable them to continuously improve patient care based on the latest medical and scientific developments.

One of the key pillars of the Nestlé Nutrition Institute is *Annales Nestlé*, a pediatric journal that has been published on a regular basis since 1942. It contains review articles on clinical practice and research in all fields of pediatrics with focus on nutrition.

*Annales Nestlé* appears three times a year. Each article is supported by a Focus Page, and each issue by an Infographic illustrating the core topic. Published on www.nestlenutrition-institute.org as well as in print, *Annales Nestlé* is one of the most widely read pediatric journals in the world.

*Annales Nestlé* is edited by an independent editorial board of opinion leaders in pediatric research, thus guaranteeing the medical and scientific impartiality of the journal, and hence the high regard it enjoys in medical and scientific circles. The editorial board sets the editorial policy, identifies topics to be addressed, selects authors, and oversees the review process for each issue.

Every issue of *Annales Nestlé* initially appears as a supplement to *Annals of Nutrition and Metabolism* – a journal from Karger Publishers, Basel, Switzerland – and is listed in all major bibliographic services, such as Medline, PubMed, and Web of Science. This has been our practice since 2011.

We are pleased to offer you our innovative product, which results from a creative and effective cooperation with *Karger Publishers, Switzerland*.

*Natalia Wagemans, MD*
Global Head
Nestlé Nutrition Institute
Vevey (Switzerland)
Early-Life Contributors to Child Well-Being

The Merriam-Webster Dictionary defines “happiness” as a state of well-being and contentment. While “happiness” is typically subjective, relative and varies widely among individuals, happiness can be broadly viewed as the feeling that comes over you when you know life is good and you can’t help but smile. It’s the opposite of sadness. Happiness is a feeling of well-being, joy, or contentment. For example, when people feel successful, safe, or lucky, they feel happy. Therefore, for happiness to occur there has to be a balance between positive experiences and some which are less positive. The title of this volume reflects an umbrella that covers important issues that relate the human body and well-being to nutrition.

The World Happiness Report is a landmark survey of the state of global happiness and is an annual publication of the United Nations Sustainable Development Solutions Network. The World Happiness Report 2018 specifically highlights key variables to support well-being (or happiness), including income, healthy life expectancy, social support, freedom, trust, and generosity.

We invited John F. Helliwell, one of the editors of the World Happiness Report and a member of the Global Happiness Council, to contribute a chapter to this issue. Happiness is related to quality of life, and health-related quality of life has become a major area of research evaluating the impact of illnesses and therapies. The ultimate goal of preventive health care and medicine is to achieve the highest quality of life, which in turn could lead to the sense of happiness.

The connection between the brain and the gastrointestinal tract has been extensively studied, but the existence of a bidirectional microbiota-gut-brain axis has gained substantial attention in the last decade. The individual microorganisms that live in our body, the microbiota, exert considerable influence on host brain and behavior. Variations in microbiota composition have been linked to neuropsychiatric disorders, including autism, stress, anxiety, and major depressive disorder. That microbiota can influence our well-being is quite an amazing proposition. This interaction is explored in the chapter by Martin G. Codagnone et al.

Feeding and parenting are inextricably linked. The complex bidirectional interactions between parent feeding practices and child eating behavior shape the early feeding environment, which in turn interacts with genetic predispositions to lay the foundation for life-long eating habits and health outcomes. Parent feeding and child (and parent) eating are central to the fabric of family life and are strongly rooted in culture and tradition. Yet, many parents experience stress and anxiety related to this ubiquitous parenting task and perceive their child as a “fussy eater” or a “difficult feeder.” Lynne Allison Daniels describes her research and experience on this topic in the third chapter. Eating is intrinsically linked to good feelings, and it is difficult to believe that a family can be happy if their child has abnormal feeding behaviors.

Finally, Mark D. Holder addresses the newly emerging field of positive psychology which focuses on the positive facets of life, including happiness, life satisfaction, personal strengths, and flourishing. Research in this field has empirically identified many important benefits of enhanced well-being, including improvements in blood pressure, immune competence, longevity, career success,
and satisfaction with personal relationships. Recognizing these benefits has motivated researchers to identify the correlates and causes of well-being to inform them in the development and testing of strategies and interventions to elevate well-being. As positive psychology researchers throughout the world have turned their attention toward facets of food intake, a consensus is emerging that the consumption of healthy foods can enhance well-being in a dose-response fashion. Nevertheless, the readers are reminded that most of the research results described in this chapter do not fulfill the criteria of optimal clinical studies as it is not possible to do double-blinded studies when one is administering different kinds of food. Therefore, we need to consider the value of this type of research as the best possible way to study the subject, even if it cannot meet the expected rules.

We sincerely hope that this issue will contribute to the happiness of our readers.

Carlos Lifschitz, MD
Weili Lin, PhD
Whether across nations or among individuals within a society, subjective well-being is determined by the circumstances of life, and especially by the social context in which people live.

Determinants of Well-Being and Their Implications for Health Care

by John F. Helliwell

Key insights

For health-care professionals and policy-makers, subjective well-being is gaining increasing recognition as an encompassing measure of quality of life. Research on well-being has revealed the importance of the social context of people's lives as a key determinant of health and happiness. Along these lines, it is important to define and measure subjective well-being in order to document human progress and transform health care.

Current knowledge

There is growing evidence showing that life evaluations, as well as positive and negative affects, can capture different aspects of happiness in a consistent manner. Life evaluations themselves can take various forms, such as life satisfaction questions, questions asking how happy people are with their lives as a whole, and the Cantril ladder rating system wherein people rank their lives. The results from these tools provide a coherent reflection of an individual's well-being. Key determinants of subjective well-being encompass not only economic factors (i.e., national average Gross Domestic Product per capita) and health (i.e., life expectancy) but also include social parameters, such as the presence of trust, freedom, and generosity.

Practical implications

An understanding of the factors that influence subjective well-being can be harnessed to improve health care. By including well-being as part of the criteria for evaluating health outcomes, we not only prioritize mental and emotional health but can also improve other facets of health care, such as palliative treatments and geriatric care. Another way of expressing the consequences of well-being is by examining how it is linked to subsequent health outcomes: studies have shown an association between current well-being and longevity. Addressing the social, psychological, and biological factors that underlie personal well-being will broaden the horizon beyond diagnosis and treatment of disease and will pave the way for the creation of wellness.

Recommended reading

Determinants of Well-Being and Their Implications for Health Care

John F. Helliwell

Vancouver School of Economics, University of British Columbia, Vancouver, BC, Canada

Key Messages

- Having an umbrella measure of subjective well-being permits the relative importance of its sources to be compared, making it possible to move beyond a general wish to improve well-being to establishing a standard for comparison of alternative policies, both within and beyond health care.
- Subjective well-being research results underscore the importance of the social context as a first-order determinant of health and happiness.
- Some have argued that it is misleading to use “happiness” as a generic term to cover subjective well-being more generally. While “subjective well-being” is more precise, it simply does not have the convening power of “happiness.”
- The World Happiness Report uses 6 variables, including national averages for Gross Domestic Product per capita, World Health Organization measures of healthy life expectancy, and 4 more socially oriented variables, to explain roughly three-quarters of the variation across countries and over time in annual national average life evaluations from usually 1,000 respondents to the Gallup World Poll in each of more than 150 countries.
- It has been calculated that to raise 6 key variables from the world’s lowest levels to their world averages would raise a nation’s average life evaluations by almost 2 points on the 0–10 scale, with almost 1.2 points due to having more people with someone to count on in times of trouble. This social support effect alone is more than the estimated impact of the 18-fold increase in GDP per capita required to shift the poorest country to the world average.

Keywords

Happiness · Subjective well-being · Social prescribing · Reforming health care · Wellness · Sources of happiness · Social context · Trust

Abstract

The paper explains how subjective well-being can be measured, how the resulting data are being used to document human progress and how health care can be changed to take advantage of what has been learned. The evaluations that people make of their own lives document, and permit the explanation of, life satisfaction levels that differ greatly among countries and communities. Research seeking to explain these happiness differences, and their related differences in mortality and morbidity, exposes the importance of the social context. There is an opportunity and need to change health care from the diagnosis and treatment of illness to the fostering of wellness. The importance of the social context in the successful design and delivery of health and happiness is so great as to support a prescription to turn
the “I” into “we,” thereby turning illness into wellness by making the production and maintenance of health and happiness a much more collaborative activity, even in the presence of the increasing complexity of medical science.

© 2019 Nestlé Nutrition Institute, Switzerland/ S. Karger AG, Basel

Introduction
The idea of using happiness as a focal point for policy has emerged in parallel with growing dissatisfaction [1] with using production of goods and services (the most usual measure being Gross Domestic Product, or GDP, per capita) as a sufficient measure of human progress. The choice of happiness as a more encompassing measure of the quality of life has been fueled by decades of research aimed at creating a transdisciplinary science of happiness. These converging threads came together on July 19, 2011, when the United Nations General Assembly adopted a Bhutan-sponsored resolution that “called on United Nations Member States to undertake steps that give more importance to happiness and well-being in determining how to achieve and measure social and economic development” (https://news.un.org/en/story/2011/07/382052).

That resolution led to a “High-Level Meeting on Well-Being and Happiness: Defining a New Economic Paradigm,” convened by the Prime Minister of Bhutan, at the United Nations on April 2, 2012. The meeting marked the release of the first World Happiness Report, which presented the available global data on national happiness and reviewed related evidence from the emerging science of happiness. That report, and the underlying research, provided strong support for the view that the quality of people’s lives can be coherently, reliably, and validly assessed by a variety of subjective well-being measures, collectively referred to in this report as “happiness.”

The first two main sections of this paper first review ways of measuring subjective well-being and a number of key determinants, while the third sketches the implications of these results for how health care might be designed and delivered so as to contribute to happiness.

Measuring Population Well-Being
Life evaluations have been granted a central role in the World Happiness Reports because they provide an umbrella measure by which the relative importance of the supporting pillars for good lives can be compared. The subsequent Guidelines on Measuring Subjective Well-Being developed by the Organization for Economic Cooperation and Development [2] also emphasized the need to measure life evaluations as a primary indicator, ideally in concert with monitoring affect (i.e., the frequency of feelings, states and emotions, both positive and negative) and “eudaimonia” (i.e., measures of life purpose). The guidelines also discuss the need to consider other factors that have been found to support better lives (e.g., income, health, good jobs, family and friends, welcoming communities, good government, trust, generosity, and a healthy environment). Having an umbrella measure of subjective well-being permits the relative importance of these factors in supporting well-being to be assessed, making it possible to move beyond a general wish to improve well-being towards establishing a standard for comparison of alternative policies.

Evidence continues to accumulate showing that life evaluations, positive affect, and negative affect, long thought to capture different aspects of subjective well-being [3], are now seen to do so in a consistent manner, so much so as to be used as indicators of national progress [4]. Of these 3 ways of measuring subjective well-being, life evaluations provide the most encompassing indicator of the quality of life. Life evaluations themselves have taken 3 different forms: life satisfaction questions of the sort advocated by the Organization for Economic Cooperation and Development [2], questions asking how happy people are with their lives as a whole, and the Cantril ladder question used in the Gallup World Poll, wherein people are asked to think of their lives as a ladder, with the worst possible life for them as a 0 and the best as a 10. If these different life evaluation questions are asked of the same respondents (life satisfaction and the Cantril ladder in one year of the Gallup World Poll, and both life satisfaction and happy with life regularly in the European Social Surveys), the answers tell structurally equivalent stories about the correlates of a good life, even though the means and shapes of the distributions of the answers differ among the questions [5].

Questions asking about emotions usually relate to a particular time, while emotions, but not life evaluations, are found to vary by time of day and time of week [6]. Although positive and negative emotions are less appropriate as overall measures of the quality of life, they are important in several other key ways. First, their short-term nature makes them natural to use as outcome variables in experimental studies. Second, as will be discussed in the next section, the frequency of a number of emotions, and especially positive affect [7], has been found to add to life satisfaction in predicting a number of future health outcomes [8]. Third, positive emotions have been found to contribute directly to life evaluations, much as Aristotle
predicted, and supported by research [9], showing that positive emotions encourage individuals to broaden their networks and activities in ways that build their overall satisfaction with life [10]. Thus, at the aggregate level, the frequency of positive emotions adds significantly to explanations of life evaluations, while the presence or absence of negative emotions has no such effect [10, Table 2.1, col. 4].

Measures of subjective well-being, and especially life evaluations or judgments about how happy people are with their lives as a whole, require the design and collection of other social indicators as candidate variables for the explanation of well-being. The relative sizes of the influences discovered then provide a way to establish the relative importance of many different circumstances thought to influence well-being.

Some have argued that it is misleading to use “happiness” as a generic term to cover subjective well-being more generally. While “subjective well-being” is more precise, it simply does not have the convening power of “happiness.” The main linguistic argument for using “happiness” in a broader generic role is that happiness plays two important roles within the science of well-being, appearing once as a prototypical positive emotion and again as part of a cognitive life evaluation question. This double use has sometimes been used to argue that there is no coherent structure to happiness responses. The converse argument made in the World Happiness Reports is that this double usage helps to justify using happiness in a generic role, as long as the alternative meanings are clearly understood and credibly related. Evidence from a growing number of large-scale surveys shows that the answers to questions asking about the emotion of happiness differ from answers to judgmental questions asking about a person’s happiness with life as a whole in exactly the ways that theory would suggest. Answers to questions about the emotion of happiness relate well to what is happening at the moment. Evaluative answers, in response to questions about life as a whole, are supported by positive emotions, as noted above, but are also driven much more than are answers to questions about emotions by a variety of life circumstances, including income, health, and social trust.

Only life evaluations, among the variety of social indicators considered in a recent retrospective survey [11], meet the two primary tests for an encompassing measure.

First, they have good claims to be themselves global assessments of the quality of life, without any further construction or manipulation. Second, since they are primary measures and also encompassing in their scope, they provide the research base for answering the fundamental questions about sources of a better life. To answer these questions, of course, requires the design and measurement of precisely those social indicators that have been the focus of the past 50 years of social indicators research.

Determinants of Subjective Well-Being

The World Happiness Report uses 6 variables to explain roughly three-quarters of the variation across countries and over time in annual national average life evaluations from usually 1,000 respondents to the Gallup World Poll in each of more than 150 countries. These explanatory variables include national averages for GDP per capita, World Health Organization (WHO) measures of healthy life expectancy, and 4 more socially oriented variables. These additional variables are based on average answers to other Gallup World Poll questions: (a) having someone to count on in times of trouble, (b) having a sense of freedom to make key life decisions, (c) trust (as measured by a perceived absence of corruption in government and business), and (d) generosity (as measured by having given money to others in the previous month).

Taken together, these variables are the most important correlates of national happiness, even after allowing for their effects that flow through income and healthy life expectancy. For example, it has been calculated that to move all of those variables from the world’s lowest levels to world average levels would raise average life evaluations by almost 2 points on the 0–10 scale, with almost 1.2 points due to having more people with someone to count on in times of trouble. This social support effect alone is more than the estimated impact of the 18-fold increase in GDP per capita required to shift the poorest country to the world average [10]. These estimates of course rely on correlations, and there are many complex feedbacks in play, so that the empirical results are best seen as illustrative rather than definitive, although most of the implied causal channels have been established by more experimental strategies having a clearer causal interpretation.

These same variables are also very important in explaining differences in life satisfaction between individu-
Happiness and Health Care

Both the extent and nature of time spent with friends and family are important sources of happiness

much higher life evaluations. This is shown by the effects of being married [12], especially relative to being divorced or separated, by having a workplace superior who is seen as a partner rather than a boss [13], and by having a sense of belonging to the local community. A stronger versus a weaker sense of community belonging has a powerful influence at all ages, but especially for those over 60 years.

Both the extent and nature of time spent with friends and family are important sources of happiness, whether measured by life evaluations or positive affect. There is a steady dose-response life satisfaction benefit of having a larger circle of real friends, although not of online friends [14].

Trust is an important measure of the quality of the social context and is estimated to have significant effects in all areas of life. For example, a change of 1 point on a 10-point scale for trust in management at one’s workplace is equivalent, in life satisfaction terms, to a 30% change in income [15]. Trust also increases resilience, such that the large happiness reductions suffered by those who are in ill-health, subject to discrimination, or unemployed are significantly less for those who feel that others can be trusted [16].

Generosity is another often ignored support for happiness. Correlational and experimental studies alike have shown that giving either money or care to others raises happiness [17]. Studies of the happiness gains from generosity have shown gains to be larger when the generosity facilitates and accompanies social connection, when it is done for altruistic rather than selfish motivations, when the generous acts are freely done of one’s own volition, and when the acts are felt to make an effective and positive impact on the lives of others [18]. Although there is an established positive feedback loop between generosity and happiness [19], experimental evidence shows a causal link from generosity to happiness even for toddlers, who smile more when they give away a treat than when they consume it themselves [20].

Nutrition enters the picture via a Gallup World Poll question asking whether the respondent has in the past 12 months not had enough money to buy needed food. Variations across individuals or across countries in this measure of food security affect happiness significantly, even when income differences are controlled for [5, Table 10.3].

Implications for Health Care

One way of using research on the determinants of subjective well-being to influence health care is to reform cost-effectiveness analysis to use happiness outcomes as the basic criterion for success [21]. Looking at the consequences of alternative treatments through the lens of happiness leads to more attention being paid to mental health (especially for children [22]), to the better provision of later-life and palliative care, and to a different way of ranking competing elements within health-care budgets.

A second way of finding the health consequences of happiness is to assess the extent to which greater levels of affective or evaluative happiness are linked to subsequent health outcomes [23]. Prospective studies have found an association between current happiness and subsequent longevity that seems to be generally stronger among healthy than unhealthy populations [24], being greatest in studies with the longest duration, such as the well-known study of the longevity of nuns over a 60-year follow-up period [25]. An even longer longitudinal study of a cohort of Harvard undergraduates born in the 1920s did not collect measures of life satisfaction but did measure a number of variables, including especially measures of social support, that have been shown to be strong supports for life satisfaction. That study showed social support to be the most important factor in longevity and health in later life [26], as did a combined companion study including men and women from a broader range of backgrounds, over an evaluation period now well into the tenth decade of the lives of the surviving members of the study cohorts [27].

A third and potentially more important route from happiness research to health care is to consider what treatments could and should be done differently in the light of what has been found about the determinants of happiness. Several of the key results reported in the previous section on the determinants of well-being have implications for health care.
In the light of these results, health care needs to be changed fundamentally from the diagnosis and treatment of illness to the measurement and delivery of wellness. Such a transformation requires major changes in medical practice to build the evidence base required to support such an effective transition for treatment. Depression inventories have been worked and reworked for decades [28] and provide a core of common questions for doctors to ask of their patients [29]. Only in the past decade has there been serious development and psychometric testing of comparable inventories of questions about positive states of mind. Shorter and longer versions of such question inventories have been developed, with answers that have been closely associated with a variety of health outcomes [30]. This is what would be expected in the light of evidence showing that the susceptibility to and severity of responses to variable degrees of experimental exposure to a rhinovirus depended much more on the strength of a subject’s pre-existing positive affect than on the negative affect measures [31]. But thus far, there has been little take-up or even much discussion in general or specialty clinical practices. Without a broader clinical base of evidence, it will be difficult to build the scientific understanding of the two-way linkages between positive states of mind and medical outcomes [7]. To get these measures into clinical practice, they must be seen as of the highest priority.

One recent positive development in clinical practice has been the growing use of “social prescribing,” whereby clinicians and associated nonmedical staff direct patients to community resources and tactics that are likely to improve the social context within which people live [32–37]. Given the primary importance of positive social connections for happiness, increased use of social prescribing is almost sure to be part of a happiness-based clinician’s tool kit. Even within the context of social prescribing, the emphasis currently remains focused on diagnosing and treating illness rather than on creating wellness. For example, a screening tool [38] recommended to improve the implementation of social prescribing measures the patient’s social context primarily in terms of deficits, including violence, street safety, and isolation. But as positive psychology and happiness research continue to show, to remove established risk factors for illness offers a return to stasis rather than opening up new opportunities for patients to enrich lives for themselves and others. Another way of putting this basic point is that social prescriptions should be received by all patients, including those who show none of the symptoms in the depression inventory.

Research shows that people tend to underestimate the happiness benefits, both for themselves and others, of generosity and other positive social connections [39]. This opens up an opportunity for universal social prescribing that might be filled by the physician who inquires after the patient’s social context, including at home, in the workplace, the neighborhood, and the community at large. However positive the responses, the physician could underline the health-supporting nature of these positive connections, emphasize their ability to improve the lives of others, and pass along links to further opportunities to enjoy and contribute to local organizations. There is an example in the area of children’s nutrition, where it has been found that the Healthy Start food program in the United Kingdom fails to reach a number of its intended beneficiaries in part because the program has not been a regular part of the information and advice provided by health-care professionals [40].

The importance of having a sense of freedom in making key life decisions would seem to imply happiness advantages for operating a health-care system so that patients are informed and engaged. This could be achieved by better information availability and exchange, a feeling that different elements of the health-care team, including the patients themselves, were working together rather than at cross-purposes, along with the ability to make their own decisions about the form and duration of late-life care. This goes far beyond the points made earlier about the nature of palliative and end-of-life care; in happiness terms, it has more to do with the quality of life for those still living [41]. For example, research in a UK elder care facility showed that residents who were asked to design their own social spaces in a move to a new facility were subsequently happier and healthier, and used the new facilities more, than their peers who had the supposed benefits of access to a professionally designed space [42].

The importance of the social context, and of doing things with others, suggests that happiness benefits from group activities, whether related to regime maintenance, fitness, or simply social engagement. Although much of the related research on the happiness effects of social connections focuses on adults, they have also been documented for young children [43]. Experimentally induced
group activities have been found to deliver health benefits [44], spouses who improve their health behavior at the same time are more likely to achieve and maintain the gains [45], and even doing hard physical training in unison rather than independently delivers better performance, measured by pain thresholds [46].

Finally, there is growing evidence that the social context within the health-care environment is a first-order determinant of the happiness of health-care workers and patients and of clinical effectiveness. There is thus a likely application within health care of the results found more generally in the workplace, that happier employees and work teams are also more productive ones [47]. There is some evidence, for example, that in places where the WHO surgical guidelines have improved outcomes, the key channels are related to teamwork and communication in the operating room and are driven importantly by the flattening of hierarchy implied by the preoperative introduction and the mask-free timeout [39].

Conclusion

Whether across nations or among individuals within a society, subjective well-being is determined by the circumstances of life, and especially by the social context in which people live. Morbidity and mortality are also determined by these same factors, both directly and mediated by happiness. These results suggest that health care needs to be changed fundamentally from the diagnosis and treatment of illness to the measurement and delivery of wellness. Such a transformation needs to be informed by an expanded evidence base that gives the measurement and monitoring of positive outcomes a central place.

Disclosure Statement

The writing of this article was supported by Nestlé Nutrition Institute and the author declares no other conflicts of interest.

References

11. Land KC, Michalos AC. Fifty years after the social indicators movement: Has the promise been fulfilled? Soc Indic Res. 2018 Feb;135(3):835–68.


30 Su R, Tay L, Diener E. The development and validation of the Comprehensive Inventory of Thriving (CIT) and the Brief Inventory of Thriving (BIT). Appl Psychol Health Well-Being. 2014 Nov;6(3):251–79.


The individual microorganisms that live in our body, the microbiota, and their collective genomes, the microbiome, exert considerable influence over host brain and behaviour.

The gut microbiota in human females undergoes dynamic compositional changes during gestation to support the developing fetus. Microbiota composition during pregnancy is affected by a variety of external factors, including diet, drugs, infections, hospitalization and stress. Inadequate intake of micro- and macronutrients, maternal overweight, and high-fat diets have also been associated with poor neurodevelopmental outcomes in the offspring. Emerging data suggests that maternal consumption of prebiotics, probiotics, as well as psychotropic drugs may affect the stability of maternal and infant microbiota and influence offspring behaviour.

The moment of birth provides the first major opportunity for large-scale bacterial colonization of the newborn. Nevertheless, the impact of the mode of delivery on the infant microbiota is only transitory: over time, the microbial population in infants born by C-section evolves to resemble those in vaginally delivered infants. Diet is one of the major drivers of the abundance and diversity of intestinal microbiota. In infants, a key influential parameter is breastfeeding versus formula feeding. Not only do breastfed infants have a distinct gut microbial fingerprint, but breastfed infants also show enhanced verbal and non-verbal cognitive abilities during childhood compared to formula-fed infants. Further research is needed in order to understand how diet and the microbiome shape neurocognitive outcomes in early life.

Pre- and post-natal factors that interfere with and support gut microbiota development:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Effect on the microbiota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet</td>
<td>• High-fibre diets improve gut microbial diversity.</td>
</tr>
<tr>
<td></td>
<td>• Prebiotics stimulate healthy bacterial populations.</td>
</tr>
<tr>
<td></td>
<td>• Probiotics modulate microbiota function, intestinal immunity and responsiveness.</td>
</tr>
<tr>
<td>Mode of delivery</td>
<td>• Vaginal delivery is involved in the direct transmission of the maternal microbial signature to the infant.</td>
</tr>
<tr>
<td>Breastfeeding</td>
<td>• Breastmilk supports early-life microbial development.</td>
</tr>
<tr>
<td>Stress</td>
<td>• Alters the composition of early-life microbiota.</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>• Inhibit growth and reduce the stability of the microbiota.</td>
</tr>
</tbody>
</table>

**Recommended reading**

Microbiota and Neurodevelopmental Trajectories: Role of Maternal and Early-Life Nutrition

Martin G. Codagnone\textsuperscript{a,b} Catherine Stanton\textsuperscript{a,c,d} Siobhain M. O’Mahony\textsuperscript{a,b}
Timothy G. Dinan\textsuperscript{a,c} John F. Cryan\textsuperscript{a,b}

\textsuperscript{a}APC Microbiome Ireland, University College Cork, Cork, Ireland; \textsuperscript{b}Department of Anatomy and Neuroscience, University College Cork, Cork, Ireland; \textsuperscript{c}Department of Psychiatry and Neurobehavioural Science, University College Cork, Cork, Ireland; \textsuperscript{d}Teagasc Food Research Centre, Moorepark, Fermoy, Ireland

**Key Messages**
- The microbial trajectory across pregnancy and early life coincides with key neurodevelopmental periods.
- Diet, drugs and stress modulate early-life microbial colonization.
- Early-life interventions with prebiotics and probiotics could modulate the microbiota and neurodevelopment.

**Keywords**
Microbiota · Neuropsychiatry · Gut-brain axis · Brain development · Early life · Stress · Diet · Nutrition

**Abstract**
Pregnancy and early life are characterized by marked changes in body microbial composition. Intriguingly, these changes take place simultaneously with neurodevelopmental plasticity, suggesting a complex dialogue between the microbes that inhabit the gastrointestinal tract and the brain. The purpose of this chapter is to describe the natural trajectory of microbiota during pregnancy and early life, as well as review the literature available on its interaction with neurodevelopment. Several lines of evidence show that the gut microbiota interacts with diet, drugs and stress both prenatally and postnatally. Clinical and preclinical studies are illuminating how these disruptions result in different developmental outcomes. Understanding the role of the microbiota in neurodevelopment may lead to novel approaches to the study of the pathophysiology and treatment of neuropsychiatric disorders.

© 2019 Nestlé Nutrition Institute, Switzerland/S. Karger AG, Basel

**Introduction**
The connection between the brain and the gastrointestinal tract has been extensively studied, but the existence of a bidirectional microbiota-gut-brain axis has only received attention in the last decade [1, 2]. The individual microorganisms that live in our body, the microbiota, and their collective genomes, the microbiome, exert considerable influence over host brain and behaviour [3, 4] (Table 1). Variations in microbiota composition have been linked to neuropsychiatric disorders, including autism, stress, anxiety and major depressive disorder [3, 5].
Almost 30 years ago, it was proposed that prenatal and postnatal environmental factors interact with genetics to program health and disease in adulthood [6, 7]. Building on Barker’s hypothesis, it was recently proposed that the microbiota could play an important role in programming adult brain health and disease [8]. Whether diet or other factors, such as stress and drugs, interact with the microbiota in early life to program brain health is currently being addressed by clinical and preclinical studies. This chapter reviews the natural trajectory of the composition of the microbiota during pregnancy and early life and outlines the current knowledge on the interaction between the microbiota and neurodevelopment.

Table 1. Glossary of terms related to the gut-brain axis

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gut-brain axis</td>
<td>The multidirectional biological system comprising the central nervous system, the neuroendocrine and neuroimmune systems, the gastrointestinal tract and components of the enteric and autonomous nervous system</td>
</tr>
<tr>
<td>Microbiota</td>
<td>The collection of microbes (including bacteria, viruses and fungi) that inhabit a particular site</td>
</tr>
<tr>
<td>Microbiome</td>
<td>The totality of the microbial genes at a particular site</td>
</tr>
<tr>
<td>Host</td>
<td>The organism that houses a given microbial population</td>
</tr>
<tr>
<td>Commensal microorganisms</td>
<td>The intrinsic microbes that reside in the host</td>
</tr>
<tr>
<td>Prebiotic</td>
<td>Non-digestible foods that have a beneficial effect on the microbiome for the host</td>
</tr>
<tr>
<td>Probiotic</td>
<td>Live microbes that have a positive effect on host health when ingested in adequate quantities</td>
</tr>
<tr>
<td>Germ free</td>
<td>A host without a microbiome; generally refers to mice and rats that were born and reared in a sterile environment to keep them from developing a microbiome</td>
</tr>
</tbody>
</table>

Early-Life Neurodevelopmental Plasticity and the Microbiota

Dramatic structural and functional changes in the brain are characteristic of the first years of life. This neurodevelopmental plasticity requires timely and adequate migration, division and differentiation of neuronal and glial precursors [9]. Neuronal migration and axonal guidance establish short- and long-range connections that enable the recruitment of multiple brain areas for the execution of complex behaviours [10, 11]. Differentiated oligodendrocytes insulate neuronal axons with a myelin sheath to guarantee proper conductance of neuronal signals [12]. A growing emphasis is now placed on the role of astrocytes and microglia in facilitating synaptic pruning during early life through adolescence, allowing later in life the fine tuning of complex circuits [13]. Plasticity is a key feature of the standard neurodevelopmental trajectory and modulates the dynamics of synaptic connections and neural circuitry formation. Deviations from the neurodevelopmental trajectory can account for increased susceptibility to brain diseases later in life.

There is a growing appreciation of the link between neurodevelopment and intestinal microbiota. Studies in germ-free mice have shown abnormal brain development, especially in male mice [14–16]. More recent studies in these microbiota-deficient mice have shown altered expression of genes implicated in neurophysiology processes, such as neurotransmission, neuronal plasticity, metabolism and morphology in the amygdala [17] and hippocampus [18]. Hypermyelination in the prefrontal cortex and abnormal microglia maturation characterize the glia profile of these animals [19–23]. Furthermore, they showed increased blood-brain barrier permeability [24]. Functionally, such changes translate to increased stress response [14, 16], changes in anxiety [25] and fear recall [26], cognitive deficits [27], social changes [21, 28] and visceral pain responses [29]. Thus, the complete absence of microbial colonization in early life has dramatic effects on offspring’s brain development and function.
**Dynamics of the Maternal Microbiota during Pregnancy**

Pregnancy is a unique period in human life, and both the gut and vaginal microbiome have evolved to follow an optimum trajectory to support the mother and the developing fetus and allow for the ideal handover of microbiome at birth, informing maternal and child health outcomes.

The human female gut microbiota undergoes dynamic compositional changes across gestation [30–32]. As pregnancy progresses, a reduction in the diversity of the intestinal microbiota takes place, characterized by an enrichment in Proteobacteria [30]. This natural shift in the bacterial populations is functional to the increased metabolic demands by the developing fetus. The Proteobacteria expansion can help the body with the increased energetic requirement that is characteristic of the third trimester [33]. Interestingly, when gut microbiota from this time period was transferred to microbiota-depleted rats, they showed increased adiposity, reduced glucose tolerance and inflammation, signs of metabolic syndrome [30]. This suggests that the changes in gut microbiota composition during pregnancy have an adaptive role for maternal and newborn health.

The vaginal microbiota composition also changes during pregnancy towards a less diverse configuration [34, 35]. As with gastrointestinal microbiota, the change in vaginal microbiota has a specific role during pregnancy. An increase in the presence of *Lactobacilli* helps maintain a low pH, limiting bacterial growth opportunity for other bacteria [35]. Furthermore, vaginal microbiota composition is critical in the context of vertical transmission of microbial populations [36]. Whether interventions in the physiological trajectory of maternal microbiota could alter the prenatal environment and, in turn, deviate normal brain development is a key question in neuroscience that is starting to be addressed both in preclinical and clinical areas.

**Preclinical Models of Early-Life Microbiota Trajectory**

Similar to humans, mice and rat intestinal and vaginal microbiota go through compositional changes during pregnancy, providing a robust preclinical model for studying the link between maternal gut environment and offspring brain development [37–40]. Early gestation is characterized by a transitional increase in the relative abundance of *Akkermansia* and *Bifidobacterium*, which in late pregnancy decrease to levels seen in non-pregnant mice. In contrast, *Bacteroides* remain relatively elevated throughout pregnancy [37]. Interestingly, microbiota compositional changes also occur post-partum. The relative abundance of Actinobacteria increases early post-partum, while the one of Bacteroidetes decreases [38].

The vaginal microbiota has its own trajectory in pregnant mice. After the first week of pregnancy, there is an increase in bacterial diversity characterized by a growth of the Firmicutes and Bacteroidetes phyla [40, 41]. The changes seen in mice gut microbiota during pregnancy and post-partum make it a solid approach to the study of interventions in the maternal microbiota and the impact on offspring’s neurodevelopment.

**External Challenges to Maternal Microbiota Dynamics**

Given the importance of early-life microbiota in neurodevelopment, any factor that affects its composition has the potential to influence brain health. Indeed, a variety of exogenous factors affect the trajectory of microbiota composition during pregnancy. Diet, drugs, infection, hospitalization, prematurity and stress are among the influences that divert maternal microbiota from its natural course and impact on offspring’s brain, immune system and the hypothalamic-pituitary-adrenal axis (HPA) development.

---

**Inadequate intake of macronutrients or micronutrients during pregnancy has been related to altered maternal microbiota and offspring’s poor neurocognitive outcome**

---

**Diet and Maternal Microbiota**

Diet is one of the major sculptors of the diversity and abundance of the intestinal microbiota [42]. Inadequate intake of macronutrients or micronutrients during pregnancy has been related to altered maternal microbiota [43] and offspring’s poor neurocognitive outcome (Table 2) [44]. This association suggests a role for the maternal microbiota in brain prenatal programming.

One of the most common macronutrient consumption imbalances during pregnancy is the consumption of high-fat diets. Maternal overweight has been associated in humans with increased risk of poor neurodevelopmental outcomes [45]. In rodents, consumption of a high-fat or Western diet prior and during pregnancy impacts the trajectory of maternal and offspring’s microbiota [37, 46]. This al-
teration was associated with a neuroinflammatory profile in the hippocampus and amygdala of the offspring, resulting in juvenile impaired social behaviour and anxiety-like phenotype [47]. Interestingly, a high-fat diet prior to and during pregnancy impairs maternal HPA axis plasticity and the offspring’s hypothalamic gene response to stress [48, 49]. However, caution is required when interpreting the literature on the neurobiological changes induced by diets rich in fat and sugar in rodents as the content of the control diets regarding fibre and other nutrients needs to be taken into account [50, 51]. Nevertheless, preclinical studies on maternal high-fat and Western diets (see [8] for an extensive review) support the idea of a role for diet-induced microbiota changes in brain programming.

During fetal development, micronutrients are required for neurological development. Deficiency in B vitamins, folate or ions, such as iron and zinc, exerts detrimental effects on neurocognitive development in humans and rodents [52, 53]. Folate deficiency is paradigmatic of the impact of micronutrient deficit on offspring neurodevelopment. Mammalian cells are unable to synthesize this vitamin; thus, humans depend on food or supplements to compensate for their requirement [54]. Failure to achieve normal serum folate levels during pregnancy has been associated with increased neural tube defects in the offspring [55]. Conveniently, bacteria residing in our colon can produce many vitamins of the B group, including folate. In mice, a loss-of-function mutation in an intestinal folate transporter can account for folate malabsorption, suggesting that bacterial produced folate plays a major role in host metabolism [56]. In humans, consumption of a vegetarian diet during early pregnancy was associated with a distinctive microbial composition rich in biosynthesis pathways for fatty acids, lipids and folate [57].

**Prebiotics and Probiotics**

Research on the effect of prebiotic and probiotic administration during pregnancy is at an early stage (Table 3). Current reports indicate that the administration of prebiotics or probiotics to pregnant women is not associated with an increase or decrease in the risk of preterm birth or other infant and maternal adverse pregnancy outcomes [58]. Researchers are beginning to shed light on their effects on offspring’s brain and immune development [58].

Prebiotics promote the growth of beneficial bacteria and include indigestible fibres that are fermented by colonic bacteria to produce short-chain fatty acids and provide a health benefit [59]. In humans, the effects of maternal intake of prebiotics on neurodevelopment have not been well studied, and there is uncertainty about their effects on allergy risk [60, 61]. Galacto-oligosaccharide (GOS) and inulin administration to pregnant mice modulated the gut microbiota and prevented immune activation and intestinal permeability in the offspring [62]. Moreover, it has recently been shown that the addition of inulin to a mouse maternal high-fat diet abrogated the negative metabolic effect of the high-fat diet on offspring [63].

Probiotics are beneficial strains of bacteria that confer a health benefit to the host [64]. There is lack of research on the prenatal impact of probiotics on neurodevelopment in humans and rodents. Administration of probiot-
ics to pregnant women impact on immunity, reducing the risk of atopy but not of asthma [65, 66]. More preclinical and clinical research must be conducted to determine the impact of prenatal probiotics on the maternal and offspring microbiota.

**Drugs**

**Antibiotics**

Antibiotics are widely used during pregnancy, but little is known about their effects on the trajectory of the maternal microbiome [67]. Preclinical models are starting to shed light on the effect of antibiotic exposure on offspring neurodevelopment. Administration of antibiotics to pregnant rats caused impairments in social behaviour and pre-pulse inhibition of the offspring [68]. In mice, administration of non-absorbable antibiotics during pregnancy reduced the exploratory behaviour in the offspring [69]. These results warrant further research on the effect of microbiota.

**Psychotropics**

Recently, Maier et al. [70] showed that a large amount of non-antibiotic human-targeted drugs have antimicrobial properties. Among them, drugs that can be prescribed during pregnancy, such as proton pump inhibitors, were found to disturb the growth of commensal bacteria (Table 2). Interestingly, psychotropic medications also influence the composition of gut bacteria in rodents [70, 71]. Selective serotonin uptake inhibitors, tricyclic antidepressants and antipsychotics negatively impact bacterial growth [71–73]. Looking at the effects on postnatal development, prenatal exposure to fluoxetine induces an anxiety-like phenotype in rats [74]. Also, in rodents, valproic acid administration during pregnancy disturbs the microbiome of the offspring and results in impairment of the social behaviour of the offspring [75, 76]. Owing to the prevalence of psychotropic administration during pregnancy, it is crucial to characterize the interaction between maternal health, microbiota and offspring neurodevelopment.

**Stress and the Maternal Microbiota**

In humans, prenatal and postnatal maternal stress has been associated with young adult offspring behavioural and depressive symptoms [77] and aberrant infant intestinal microbiota development (Table 2) [78, 79]. In rodents, prenatal stress shifts maternal gut and vaginal bacterial community and induces long-lasting alterations in the gut microbiota composition of the offspring [40, 80]. Moreover, this alteration was shown to occur in a sex-specific manner, and it correlates with hyper-reactivity of the HPA axis [40].

**The Microbiota in Transition: from Prenatal to Postnatal**

When the first contact with the microbiota occurs remains controversial. The sterility of the uterus during pregnancy is one of the paradigms that research on the microbiome is revisiting. Bacteria have been found in the placenta [81, 82], amniotic fluid and meconium of humans [83, 84]. Moreover, the presence of specific bacteria in utero has been associated with pregnancy risks, including higher rates of preterm delivery [85]. Nevertheless, the reliability of these findings is widely debated in the context of whether it is contamination or not [86, 87]. The existence of germ-free mice models further dismisses the idea of a prenatal microbiome [86]. It is generally accepted that the moment of birth is the first opportunity for large-scale bacterial colonization of the newborn. Thus, the mode of delivery has a tremendous impact on the establishment of the microbiota of infants.

| Table 3. Interventions that support microbiota development |
|---------------------------------|-----------------------------------------------------------------|---|
| **Factor** | **Effect on the microbiota** | **Ref.** |
| Diet | pregnancy | Diets high in fibre improve gut microbiota diversity | [152] |
| | early life | Due to its unique composition that includes prebiotics, breast milk supports early-life microbial development | [108] |
| Prebiotic | | Growth stimulation of specific bacteria populations that is associated with a health benefit | [153] |
| Probiotic | | Modulates microbiota functionality, intestinal immunity and epithelial responsiveness | [154] |
| | | In adequate amounts confers health benefits to the host |

Early-Life Microbiota and Birth Mode

A large number of studies associate the mode of delivery to a distinctive trajectory of microbiota development in the newborn [35, 36, 66, 88–99]. Unexposed to the birth canal, Caesarean section (C-section)-born babies elude mother–neonate vertical vaginal transmission of bacteria and viruses [36, 89, 100]. In turn, the microbiota resembles skin and environment microbiota, suggesting that C-section first colonizers come from diverse sources (Table 2) [35, 89].

That said it is worth reinforcing that mode of delivery-induced changes in microbiota composition are transitory. Vaginally delivered infants have significantly higher microbiota richness and diversity than C-section-born infants as early as 3 days after birth [88, 100–102]. Nevertheless, the early decline in Proteobacteria and the late Firmicutes expansion occur timely over the first year of life of C-section-born infants [101].

The time course of these microbiota alterations overlaps with a critical period for neuro- and immune development (see [103] for extensive review). It has been suggested that C-section-distinctive microbiota composition plays a functional role in predisposing these infants to a greater relative risk of neonatal infections, allergy, asthma, obesity and type 1 diabetes [35, 101, 104–108]. Preclinical models of C-section suggest that the mode of delivery could impact on early neuronal maturation [109, 110]. Whether modifying the initial colonizing microbiota induces directly or indirectly different trajectories in brain development has yet to be deciphered.

Epidemiology studies have shown that C-section-induced changes in terms of brain health and school performance later in life are subtle at best [111, 112] and, in the case of autism, do not withstand correcting for familial confounding [111].

Various strategies have been designed to restore the normal trajectory of the microbiota [113]. Although controversial, artificial vaginal microbiota transference was performed to C-section-born infants to mimic vertical transmission [114]. Other interventions, including supplementation with probiotics and prebiotics, were proposed to decrease the impact of delivery mode on the microbiota.

Mode of delivery-induced changes in microbiota composition are transitory

Early Postnatal Perturbations of the Microbiota

Early postnatal life entails an intrinsic sensitivity to environmental factors. As with the maternal microbiome, infant exposure to differences in diet, drugs and stress can interfere with the trajectory of the microbiota and neurodevelopment in a manner that is characteristic of this developmental period.

Mode of Nutritional Provision in Early Life

The stability and composition of the early-life gut microbiota community is also dependent on diet [115]. Accumulating evidence suggests that breastfeeding and formula-based nutrition leave a distinctive fingerprint in the intestinal microbiota (Table 2). Gut bacterial composition of infants exclusively breastfed is characterized by higher relative abundance of Bacteroides and Bifidobacterium compared to the one from formula-fed infants [108, 116]. Furthermore, breastfeeding had a positive effect on myelination and increased general, verbal and non-verbal cognitive abilities during childhood [117]. The implications of these findings are still unclear, but longitudinal studies are starting to shed light on the effect of early-life nutrition on the temporal course of microbiota maturation.

Human breast milk has a unique composition that interacts with the developing gut microbiota. Culture-dependent and -independent techniques revealed that it is a source of bacteria [118]. Interestingly, the human milk microbiome can be influenced by maternal body mass index and mode of delivery [119]. The other main components of breast milk are human milk oligosaccharides, which act as prebiotics [120, 121]. Supplementation of infant formula with GOS increases the abundance of Bifidobacteria and Lactobacilli to levels reported in breastfed infants [122, 123]. Both breast milk microbes and prebiotics play a role in the standard gut microbial developmental trajectory.

Later in life, feeding transitions drive important changes in composition and functionality of the intestinal microbiota [36, 89, 124]. From breastfeeding to solid food, the microbiome transitions from being enriched in genes associated with digestion of sugars from breast milk, vitamin production and iron transport to degradation of starch and high sugars [36]. Furthermore, the microbiota continues to undergo change; at 7–12 years of age, the composition and function of the microbiota remains significantly different from the one of adults [125], suggesting a role of the microbiome in the neurodevelopmental changes associated with adolescence.
Probiotics and Prebiotics

Most of the evidence available on the effect of early-life exposure to pre- and probiotics comes from preclinical studies. Early-life prebiotic administration in humans has shown effects on reducing the risk of atopy, an autoimmune disease [126], but neurodevelopmental outcomes have not been studied yet. In preclinical studies, oligosaccharides have been shown to modulate the gut-brain axis, highlighting the role of breastfeeding in neurodevelopment. Administration of the human milk oligosaccharides 3’Sialyllactose (3’SL) or 6’Sialyllactose (6’SL) to mice exposed to social disruption prevented stress-induced colonic microbial disruption and anxiety-like behavior [127]. Furthermore, fructo-oligosaccharide (FOS) and GOS administration attenuated corticosterone release in response to an acute stressor and protected the mice from the impact of chronic stress on the microbiota [128].

Preliminary clinical trials of probiotic interventions have yielded promising results with regard to reducing the risk for gastrointestinal problems, sepsis, allergies and even autism spectrum disorder and attention deficit hyperactivity disorder [129–134]. Several groups have now shown that early probiotic interventions mitigate the effects of early-life stress, maternal high-fat diet and maternal immune activation on infant outcomes [47, 135–138]. Oral administration at weaning of *Bifidobacterium fragilis* ameliorates the abnormal stereotyped and anxiety-like behaviours of the maternal immune activation mouse model of autism [136]. Probiotic administration during adolescence restores social interaction-induced long-term potentiation in an animal model of social impairment by maternal high-fat diet exposure [47]. In maternally separated rat pups, a combination of *Lactobacillus rhamnosus* and *Lactobacillus helveticus* reduced pup corticosterone responses to stress and normalized fear behaviour [135, 137, 138]. Another probiotic, *Bifidobacterium infantis*, normalized behavioural deficits in adult rats exposed to maternal separation [139].

Although clinical evidence on the role of pre- and probiotics for neurodevelopment is still lacking, preclinical research gives cause for a focus on early-life microbiota interventions.

**Drugs: Antibiotics and Beyond in a Paediatric Setting**

Antibiotics are commonly prescribed during the first years of life, yet the effect on brain health programming is unknown. Longitudinal clinical studies support the idea that early-life exposure to antibiotics perturbs the natural trajectory of the microbial communities by altering their stability [140]. Furthermore, neonatal exposure to antibiotics in rodents not only altered the microbiota but also induced increased visceral sensitivity and long-lasting changes in brain cytokines and behaviour [141, 142].

The interaction between early-life exposure to psychotropics, neurodevelopment and the microbiota is currently unknown. Not only exposure to psychotropics mediated by breastfeeding but direct administration of these drugs early in life could impact the developing microbiota. Serotonin uptake inhibitors and atypical antipsychotics indicated for the treatment of paediatric psychiatric disorders are among the non-antibiotic drugs known to change the microbiome composition [70, 71]. Atypical
antipsychotics indicated for the treatment of the irritability associated with autism spectrum disorders have been shown to inhibit gut bacteria [70]. At the same time, the composition of the microbiota of autistic patients was shown to be altered [143–147]. Whether there is an interaction between microbiota populations, psychotropic drugs and behaviour has yet to be determined.

Early-Life Stress
The impact of stress on the development of the HPA axis has been shown to contribute to the programming of brain health in later life [148]. Interestingly, evidence from preclinical studies shows that early-life stress also alters the microbiota. Maternal separation during early life disrupted the microbiota of the offspring of rhesus monkeys and rats [149, 150]. Interestingly, a diet containing prebiotics in combination with live Lactobacillus rhamnosus GG attenuated the effects of early-life maternal separation on anxiety-like behaviour and hippocampal-dependent learning [151]. Germ-free mice were more vulnerable to restraint stress, resulting in higher adrenocorticotropic hormone and corticosterone in plasma [14, 16], a reduction in glucocorticoid receptor mRNA and an increased stress response [14]. Remarkably, these effects were restored with microbiota transplantation during adolescence but not adulthood [14].

Future Perspectives
Pregnancy and the first years of life are unique stages of plasticity for the intestinal microbiota. In both cases, there is a dynamic trajectory of the intestinal microbiota composition that is functional to the requirements of the host. Although plasticity represents an opportunity for adaptation, it is also a vulnerable stage. As we have reviewed, clinical and preclinical studies suggest that diet, stress and drugs can interact with the natural trajectory of the microbiota and play a part in programming brain health (Fig. 1). However, the evidence is still scarce, and further research is needed to understand the functional implications of these interactions.

The nervous system and the microbiota show concurrent developmental trajectories, offering a unique opportunity for intervention. There is potential for the development of early-life-targeted interventions of the microbiome, aiming to reduce the risk of disease later in life. Further research is needed on the characterization of critical windows to modulate the microbiota and the consequences of early intervention.

Disclosure Statement
The writing of this article was supported by Nestlé Nutrition Institute. The APC Microbiome Institute is funded by Science Foundation Ireland (SFI), through the Irish Government’s National Development Plan. The APC Microbiome Institute has conducted research funded by many Pharmaceutical and Food Companies. M.G.C. is funded by the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 754535. J.F.C., T.G.D. and C.S. are supported by SFI (Grant 12/RC/2273). T.G.D. has been an invited speaker at meetings organized by Servier, Lundbeck, Janssen and AstraZeneca and has received research funding from Mead Johnson, Cremo, SunTory Wellness, Nutricia and 4D Pharma. J.F.C. has been an invited speaker at meetings organized by Mead Johnson, Yakult, Alkermes and Janssen and has received research funding from Mead Johnson, Cremo, SunTory Wellness, Nutricia, Dupont and 4D Pharma. M.G.C., S.M.O. and C.S. have no other conflicts of interest to declare.

References

Microbiota and Neurodevelopmental Trajectories

Reprinted with permission from:
Ann Nutr Metab 2019;74(suppl 2):16–27
DOI: 10.1159/000499144

DOI: 10.1159/000499144

Codagnone/Stanton/O’Mahony/Dinan/ Cryan


54 Kok DE, Steegenga WT, McKay JA. Folate and epigenetics: why we should not forget bacterial biosynthesis. Epigenomics. 2018 Sep;10(9):1147–1150.


Child eating behaviours manifest in the context of child characteristics, such as temperament, and broader developmental tasks, such as autonomy, separation, self-regulation and acquisition of motor skills.

Reprinted with permission from: Ann Nutr Metab 2019;74(suppl 2):29–42

Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness
by Lynne Allison Daniels

Key insights
Parent-child interactions related to feeding are central to the fabric of daily family life and contribute to all aspects of child development, health and well-being. Early parental feeding practices are a key determinant of food choices, eating habits and health outcomes in the child’s later life. The results from NOURISH, an early-life feeding intervention, indicate that educational interventions can be effective at shaping parental responses to their child’s eating behaviour. The success of the NOURISH intervention was largely due to an anticipatory guidance framework that provided parents with developmentally appropriate information on normal infant behaviours and constructive parental responses.

Current knowledge
Child eating behaviours are the product of complex interactions between genetics and the environment. Infants are born with predispositions that include the preference for sweet tastes and rejection of bitter/sour tastes and novel or unfamiliar foods. These preferences are no longer adaptive in our current food environment where the food supply is largely safe, energy-dense foods are readily available and childhood obesity is prevalent. Parental understanding and responses to these behaviours influence feeding practices, which in turn shapes the short- and long-term eating behaviour of the child.

Practical implications
Parents commonly misinterpret developmentally normal child eating behaviours (such as food refusal) as a cause for concern. They respond with coercive feeding practices, such as pressure, reward or restriction. Emotional feeding that uses food to calm or shape behaviour is also common. Such feeding practices are parent- rather than child-centred and are counterproductive. The end result is that the child learns to eat for reasons unrelated to appetite, leading to the consumption of more energy than they need. More widespread early feeding interventions are needed that help parents understand normal child eating behaviour, promote responsive feeding practices and effective food parenting.

Recommended reading
Feeding Practices and Parenting: A Pathway to Child Health and Family Happiness

Lynne Allison Daniels
School Exercise and Nutrition Sciences, Faculty of Health, Queensland University of Technology, Brisbane, QLD, Australia

Key Messages
- Feeding and parenting are inextricably linked. They shape the early feeding environment which interacts with genetics to influence the development of child eating patterns, which in turn are key determinants of life-long eating habits and associated health outcomes.
- Parents frequently misinterpret “normal” child eating behaviour as a cause for concern and respond with coercive, non-responsive feeding practices that are associated with adverse outcomes for child food preferences, appetite regulation and weight status. In addition, such practices may be a source of stress and distress for both parents and child.
- Parents respond positively to interventions designed to promote responsive feeding practices with positive outcomes for child eating behaviour and growth, stress and distress related to child feeding and broader parent-child interactions and family happiness and well-being.

Keywords
Child feeding behaviour · Parent feeding practices · Early feeding intervention · Responsive feeding practices · NOURISH RCT

Abstract
Feeding and parenting are inextricably linked. The complex bidirectional interactions between parent feeding practices and child eating behaviour shape the early feeding environment which in turn interacts with genetic predispositions to lay the foundation for life-long eating habits and health outcomes. Parent feeding and child (and parent) eating are central to the fabric of family life and are strongly rooted in culture and tradition. Yet, many parents experience stress and anxiety related to this ubiquitous parenting task and perceive their child as a “fussy eater” or a “difficult feeder.” Parents commonly misinterpret heritable and developmentally “normal” child eating behaviour, such as food refusal, as cause for concern. In an effort to get their child to “eat well” they respond with coercive feeding practices, such as pressure, reward and restriction. Emotional feeding that uses food to comfort, distract, calm or shape behaviour is also common. Although well intentioned, these non-responsive,
parent- rather than child-centred feeding practices are ineffective, even counterproductive. They teach children to eat for reasons unrelated to appetite and, hence, more than they need and fail to support development of healthy food preferences and appetite regulation. Early feeding interventions are needed that assist parents to understand normal child eating behaviour and promote responsive feeding practices and effective food parenting. The aim of this chapter is to review (1) "normal" eating behaviour of young children, (2) the range of feeding practices and strategies that parents use to respond to and try to shape these behaviours, (3) evidence for approaches to feeding young children that have potential to reduce conflict related to child feeding and promote life-long healthy eating patterns and (4) to provide an overview of an early feeding intervention, NOURISH, which demonstrated a positive impact on maternal feeding practices and potentially reduced parent anxiety and stress related to feeding.

Introduction

Feeding and parenting are inextricably linked, and infant feeding is central to the first maternal-child interactions [1]. Both feeding and parenting contribute to child physical, social, cognitive and behavioural development and well-being [2–4]. Consistent with the life course model [5], genetics and the early feeding environment interact to shape child food preferences, dietary intake and behaviours [6]. These lay the foundation for life-long eating habits and behaviours, which in turn are powerful predictors of long-term health outcomes, such as obesity, diabetes, cardiovascular disease and some cancers [7]. Parents are the gatekeepers of the early feeding environment which is shaped by complex parent-child interactions in the context of feeding and eating. These interactions have been termed “food parenting” [8]. In parallel with general parenting constructs, food parenting is considered to include feeding style and feeding practices. Feeding style is the broad emotional climate of the feeding dynamic, and feeding practices are the specific strategies and actions (the “when, what and how”) of child feeding [8]. In this paper, “feeding” refers to what parents do to nourish their child. “Eating” is what the child does and includes food preferences, dietary (nutrients and food) intake and eating behaviour. Increasingly, evidence suggests that food parenting involves bidirectional interactions whereby parent feeding practices can influence and/or respond to child eating behaviours [9–11].

Parent feeding and child eating are central to the fabric of family life and are strongly rooted in culture and tradition. Yet, many parents experience stress and anxiety related to this ubiquitous parenting task and perceive their young child as a “difficult feeder.” Tensions and battles related to feeding young children are common and have the potential to impact on the quality of family meal times, parent confidence and broader family dynamics and well-being [12]. The aim of this chapter is to review (1) our understanding of “normal” eating behaviour of young children, (2) the range of feeding practices and strategies that parents use to respond to and try to shape these behaviours, (3) evidence for approaches to feeding young children that have potential to reduce conflict related to child feeding and promote life-long healthy eating patterns and (4) to provide an overview of an early feeding intervention, NOURISH, which demonstrated a positive impact on and improved maternal feeding practices.

“Normal” Child Eating Behaviours and Appetite Traits

Child eating behaviours are a product of complex interactions between genetics and environment [13, 14]. Infants are born with predispositions that include a preference for sweet tastes and rejection of bitter/sour tastes and novel or unfamiliar foods. These genetic predispositions probably had evolutionary advantages whereby the child readily accepted sweet energy-dense foods (including breast milk) and avoided bitter (e.g., vegetables) and unfamiliar foods that were potentially toxic. These preferences are no longer adaptive in our current food environment where our food supply is largely safe, energy-dense foods are readily available and childhood obesity is prevalent [15–18]. Neophobia or rejection of novel foods is present from weaning and strengthens with child autonomy to peak at 2–5 years of age [17, 18]. These inborn heritable preferences can be modified by early feeding experiences, such as repeated neutral exposure to facilitate familiarity and acceptance [16–21]. It appears that food likes and dislikes are broadly established by 3–5 years of age and persist over time [18, 21]. Infants also have an inborn capacity to regulate their energy intake to need and operationalise this via cues of hunger and satiety. Parent recognition and responses to these cues are an integral component of food parenting and can either support or undermine this intrinsic self-regulation, which provides the foundation for healthy growth and long-term weight status [3, 4, 22, 23].
Eating behaviours in childhood (2–8 years) are widely described and assessed using the parent-report Children’s Eating Behaviour Questionnaire (CEBQ). The 8 behaviour/style scales (Table 1) have been broadly categorised into 4 food “approach” behaviours and 4 food “avoidance” behaviours [24]. The parallel Baby Eating Behaviour Questionnaire [25] has also been developed for use in infants. It includes 4 constructs in common with the CEBQ (Table 1), with items modified to account for milk feeding and an additional single item “my baby had a big appetite.” More recently, it has become clear that these behaviours have a strong genetic component and are now often referred to as “appetitive traits” [26, 27]. Children rated highly on the “food approach” or “food avoidance” scales have been described as having a “big” or “small” appetite, respectively, and these clusters of traits have been prospectively associated with weight status [13, 28]. Recent evidence indicates that, notwithstanding their heritability, these traits/behaviours are to some degree both responsive to and able to drive food parenting [9, 11, 29, 30, 31].

Food fussiness (FF) or “picky eating” is an eating behaviour reported by 10–50% of parents and a source of considerable concern and conflict in families [18, 32–35]. There is no consensus on the definitions of “fussy” or “picky” eating [33]. This umbrella label is attributed to a cluster of child behaviours that centre on food refusal, where anecdotally the child does not eat what or as much as their carer thinks they should. Parents want their child to be a “good eater” and praise them for eating all that is offered [36]. FF typically includes refusal of both familiar and unfamiliar foods [32–34]. Neophobia or refusal of unfamiliar foods is frequently labelled as FF but, as discussed above, is a normal developmental phase that may once have conferred evolutionary advantage [16, 18]. It is also heritable but varies with age, and some adults retain neophobic eating behaviours [34, 37]. Parents often also report concern about erratic appetite and seemingly “ad hoc” refusal of foods which their child both is familiar with and usually eats [32, 35]. Whilst often perceived as a “negative” eating behaviour, such refusal potentially signals satiety and the child’s intrinsic self-regulation in action. It may also be a means by which a toddler can assert their emerging need for autonomy [2, 3, 23, 32]. Quality prospective studies examining the impact of FF on objectively measured dietary intake and growth are scarce [33]. Consistent with the notion that FF is primarily a matter of parent perception of developmentally “normal” eating behaviour, there is very little evidence of an adverse impact of FF on growth and development in healthy children born at term [36]. However, there is evidence that there are bidirectional prospective relationships between maternal-reported FF and undesirable maternal food practices [11, 30]. Parent (fathers’ and mothers’) concern (how frequently they worried about 4 aspects of fussy eating) has been shown to fully mediate the cross-sectional relationships between FF and inappropriate parent feeding practices [38]. A recent study [36] reported that 30% of mothers perceived their child (age 14 months) as a “fussy eater.” This perception was associated with mothers reporting that their child mostly decided how much to eat and with a lower relative weight (researcher measured), but not with objectively assessed dietary intake or quality. Importantly,
all children were within the healthy weight range. The perception of their child as a fussy eater at 14 months, despite healthy weight status and no measurable relative reduction in dietary quality, was prospectively associated with less appropriate food parenting at 2 years of age [36]. In summary, it is the characterisation of developmentally normal food refusal in young children as “fussy eating” and a problematic non-compliant behaviour [35] that is more of an issue than the behaviour per se. Assisting parents to understand that these child eating behaviours commonly labelled as “fussy” or “picky” eating are influenced by genetics and developmental stage and, hence, are “normal” and, furthermore, could be important signals of satiety, may reduce anxiety and concern related to feeding and have a positive impact on food parenting.

Child eating behaviours manifest in the context of child characteristics, such as temperament, and broader developmental tasks, such as autonomy, separation, self-regulation and acquisition of motor skills [2]. From 12 to 24 months of age, growth and weight gain slow such that relative energy and hence food requirements/appetite decrease. In addition, neophobia escalates and separation/autonomy becomes a key developmental task [34, 35]. Suddenly, parents are faced with a baby who was a “good eater” transitioning to a toddler who has an erratic appetite and overall appears to eat less, insists on self-feeding despite limited fine motor skills and feeding competence, starts to show distinct likes and dislikes and refuses foods previously well accepted, needs to assert and test their emerging independence, is much more mobile and less willing to sit still for extended periods and is often frustrated with the many tasks of emotional, cognitive and physical development [39]. Feeding provides numerous opportunities every day for the parent and child to interact around these issues and, if not managed well, has great potential to induce stress and distress for both. It is impossible to “make” children eat. Efforts to do so are not only ineffective but can also be counterproductive in terms of developing healthy long-term eating patterns.

It is impossible to “make” children eat. Efforts to do so are not only ineffective but can also be counterproductive in terms of developing healthy long-term eating patterns.

...is bidirectional. Clearly, we cannot work directly with young children to influence their early eating behaviours. However, food parenting is modifiable [40–42]. Ensuring that parents have realistic expectations of the early feeding dynamic as well as the confidence and skills to respond appropriately to “normal” and changing child eating behaviour in the context of overall child development has great potential to reduce anxiety and conflict.

Parent Feeding Practices and Their Potential Relationship with Parent-Child Conflicts

Parents, particularly mothers, report considerable anxiety related to feeding, with a third to half of mothers reporting that their otherwise healthy child is difficult to feed or fussy [32, 33, 41]. There are a range of cultural, social and biological factors that contribute to the common notion that infants and particularly toddlers are “difficult to feed.” From an evolutionary perspective, a reliable, plentiful food supply is a very recent phenomenon. It is plausible that mothers are “hardwired” to feed their children as often and as much as possible to ensure survival. Child feeding is strongly embedded in culture and tradition, and feeding practices are passed from grandmother to mother to daughter [15]. Even in high-income countries, it is only 2–3 generations ago that feeding children occurred in the context of comparative food scarcity [43, 44]. The traditional approaches to child feeding in this context are likely to be ineffective, even counterproductive, in our current environment where food is widely available and relatively affordable, unhealthy foods are ever present and heavily marketed, particularly to children, and excess consumption is the “norm.” Furthermore, new approaches to child feeding are required that are adapted to shifts in economic and social factors (e.g., family structures, parent work patterns, eating out) [15].
From a sociological perspective, even in our contemporary societies, there are pervasive expectations that “good women” are “good mothers” and “good mothers” feed their children well. Adding to these pressures are well-intentioned but potentially misinformed and unhelpful advice from family and friends and an abundance of information of highly variable validity available on the internet. Despite good intentions, parents are likely to use traditional feeding practices advised and supported by family and friends without understanding the potential impact on child health in the context of the radically changed contemporary food supply [2, 15]. The “obesity epidemic” further adds to parent pressure. There is heightened awareness of the adverse short- and long-term outcomes of overweight/obesity. With around 25% of children and up to 70% of adults above the healthy weight range [45], this is a salient issue for many families. Up to three-quarters of women aged 25–45 years (and hence mothers), even those within the healthy weight range, report degrees of disordered eating or concern about their weight that interfere with their happiness [46]. Mothers plausibly wish to avoid passing their issues related to food and eating on to their children. There is evidence that maternal eating behaviours are associated with feeding practices [47] and child eating behaviour [48]. In addition, even in non-clinical samples, there is a relationship between child feeding and parental emotional and psychological well-being [49, 50]. It is no wonder parents find the “what, when, where and how” of food parenting a source of concern and conflict.

There are numerous conceptualisations and tools used to describe and measure parent feeding practices [51–53]. Table 2 summarises a variety of prevalent feeding practices with practical examples. In a recent review, Vaughn et al. [8] sought to rationalise food parenting constructs and terminology. They identified 3 overarching food parenting constructs: coercive control; structure; autonomy support of promotion. “Coercive control” includes pressure and authoritarian, overt restriction, both of which override the child’s hunger and satiety cues and undermine their capacity to self-regulate intake and hence are classified as non-responsive feeding practices [3, 4, 23]. Emotional or instrumental feeding practices (e.g., using food to calm; see Table 2) are also categorised as non-responsive [53]. These parent-centred, controlling feeding practices are prevalent and postulated to teach children to eat for reasons unrelated to appetite and to habitually eat more than they want or need [3, 4, 23, 32]. There is a substantial body of evidence which indicates that such non-responsive feeding practices are associated with poor outcomes in terms of child eating behaviour, diet quality and weight status [3, 4, 8, 15, 23, 31, 54, 55]. Consequently, interventions have generally sought to have parents avoid/reduce these behaviours. This “deficit” approach requires parents to “stop doing things” and has potential to contribute to parent guilt and anxiety.

“Structure” refers to practices that parents can use to organise and manage the eating environment such that child feeding competence and autonomy, enhanced food acceptance and intrinsic regulation of intake are encouraged. Examples are shown in Table 2 and include rules, limits and routines related to eating [8, 52, 56]. Hurley et al. [23] argue that structure provides a context in which the child can clearly express their hunger/satiety cues and parents are more able to appropriately recognise, interpret and respond to these cues. Structure practices, such as family meal times and routines, also provide important opportunities for socialisation to family food practices and traditions [8]. A recent study [56] demonstrated that structure operationalised via meal setting (where the child eats) and family meal setting (eats the same food as the family) were associated with parents reporting increased child ability to regulate food intake, based on an 8-item scale. Mealtime structure has also been associated with improved child FF, enjoyment of food and child and family well-being [56, 57]. Encouraging structure and limits related to eating offers a strengths-based approach to promoting positive feeding practices. Furthermore, the strategies are comparatively straightforward to understand and implement [56].

“Autonomy support” explicitly links food parenting practices to age-appropriate developmental milestones, such as emotional self-regulation, independence and cognitive capability [8]. It includes strategies that aim to develop food literacy (education, reasoning, involvement in preparation) and positively support (encourage, negotiate, praise) development of healthy eating habits. Promoting “autonomy support” strategies is also potentially a strength-based approach but requires explicit promo-
Table 2. Prevalent parent feeding practices that are associated with poor outcomes for child dietary quality, eating patterns, behaviour and weight status [3, 4, 8, 9, 15, 16, 23, 32, 37, 53, 54, 56]

<table>
<thead>
<tr>
<th>Feeding practices and outcomes</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coercive, non-responsive, authoritarian, parent-centred</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td></td>
</tr>
<tr>
<td>Active encouragement to eat more</td>
<td>Focus on portions size, decide how much child should eat</td>
</tr>
<tr>
<td>Overrides child satiety cues – usually expressed as food refusal</td>
<td>Game playing</td>
</tr>
<tr>
<td>→ Undermines capacity to self-regulate intake</td>
<td>Encourage “one more mouthful”</td>
</tr>
<tr>
<td></td>
<td>Praise for eating all that is given</td>
</tr>
<tr>
<td></td>
<td>Offer food reward for eating, e.g., dessert if eat vegetables</td>
</tr>
<tr>
<td></td>
<td>Offer non-food reward for eating, e.g., watch TV if eat vegetables</td>
</tr>
<tr>
<td></td>
<td>Threaten if child does not eat, e.g., withhold dessert or TV</td>
</tr>
<tr>
<td></td>
<td>Offer alternative liked food or drink – “as long as they eat something”</td>
</tr>
<tr>
<td></td>
<td>Insist that child eats, override self-feeding attempts</td>
</tr>
<tr>
<td><strong>Restriction</strong></td>
<td></td>
</tr>
<tr>
<td>Overtly limit access to unhealthy foods – child recognises restriction</td>
<td>Withhold dessert if child does not eat rest of the meal</td>
</tr>
<tr>
<td>Limited reasoning, choice</td>
<td>Do not allow child to have unhealthy foods even though they are overtly available to adults in the household</td>
</tr>
<tr>
<td>→ Increases desirability of restricted food</td>
<td>Allow no access to “treat” foods</td>
</tr>
<tr>
<td></td>
<td>Restrict on basis of “good” versus “bad” foods</td>
</tr>
<tr>
<td><strong>Emotional feeding</strong></td>
<td></td>
</tr>
<tr>
<td>Use food in response to negative emotions – comfort, calm, distract; shape behaviour</td>
<td>Offer food in return for good behaviour</td>
</tr>
<tr>
<td>→ Teaches child to eat for reasons unrelated to appetite</td>
<td>Withhold food to punish bad behaviour</td>
</tr>
<tr>
<td></td>
<td>Offer food to keep child quiet</td>
</tr>
<tr>
<td></td>
<td>Offer food when child is upset or hurt</td>
</tr>
<tr>
<td></td>
<td>Person praise (“good girl”) for desired eating behaviour</td>
</tr>
<tr>
<td><strong>Unstructured permissive/indulgent feeding</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Eating environment disorganised</strong></td>
<td></td>
</tr>
<tr>
<td>Few limits to what, where and when of eating occasions</td>
<td>Child given whatever food they ask for, whenever they ask</td>
</tr>
<tr>
<td>→ Fails to facilitate clear expression of appetite cues by child and recognition by parents</td>
<td>Variable and inconsistent meal frequency and location</td>
</tr>
<tr>
<td>→ Fails to facilitate feeding competence, support autonomy</td>
<td>Young child is not included in family meals</td>
</tr>
<tr>
<td></td>
<td>Child eats different food to the rest of the family, only liked foods are offered at mealtimes</td>
</tr>
<tr>
<td></td>
<td>No limits on range of foods from which child can choose – includes unhealthy options</td>
</tr>
<tr>
<td></td>
<td>Child allowed to eat wandering around</td>
</tr>
<tr>
<td></td>
<td>Distractions when eating, e.g., TV, access to toys</td>
</tr>
<tr>
<td><strong>Response to neophobia – rejection of unfamiliar foods</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Exposure to limited range of tastes and textures</strong></td>
<td></td>
</tr>
<tr>
<td>Only offer preferred, liked foods</td>
<td>When new food is rejected, assume that child does not like it and do not reoffer</td>
</tr>
<tr>
<td>→ Fails to maximise opportunities to become familiar with and learn to like and accept new foods</td>
<td>Offer new food &lt;6 times before deciding that child does not like</td>
</tr>
<tr>
<td></td>
<td>Disguise new foods</td>
</tr>
<tr>
<td></td>
<td>Insist/pressure on child to eat</td>
</tr>
<tr>
<td></td>
<td>Offer liked food instead</td>
</tr>
<tr>
<td></td>
<td>Reward for eating (rather than tasting)</td>
</tr>
<tr>
<td></td>
<td>Force feeding</td>
</tr>
</tbody>
</table>
tion of a nuanced emotional tone associated with implementation to ensure practices do not become coercive, e.g., encouragement versus pressure and “process” praise (e.g., “well done for trying new food”) versus “person” praise (e.g., “good girl for finishing your dinner”) as an emotional reward [8].

Recommendations that seek to promote child-centred responsive feeding that recognises and responds appropriately to child cues of hunger and satiety and, hence, supports rather than undermines the child’s inborn capacity to regulate intake are commonly based on the “trust” model [22]. This framework has also been termed the “Division of Responsibility” [39] (“parent provide, child decide”) and argues that parents are responsible for providing safe, developmentally appropriate, nutritious food, while the child is responsible for deciding whether and how much they eat. As such, this approach discourages coercive and controlling feeding practices (pressure, restriction, reward) and emphasises the feeding dynamic. It has also been described as authoritative feeding, analogous to an authoritative parenting style, where the carer responds warmly, consistently and predictably to child cues but also sets limits via structure [4]. Both authoritative feeding and parenting have been associated with a broad range of positive developmental outcomes [3, 4].

The food parenting practices discussed thus far have largely focussed on the “how” of feeding in the context of supporting the child’s intrinsic regulation of food (energy) intake. Food preferences are an important factor in food acceptance and choice (“what”), which in turn are key determinants of eating habits [17, 18]. As indicated above, infants are born predisposed to prefer sweet tastes and reject bitter/sour and unfamiliar foods (neophobia). Whilst these traits are heritable, they are also modified by early feeding experience. Table 2 gives some examples of common feeding practices used in response to neophobia. There is considerable evidence that repeated neutral (i.e., non-coercive) exposure to a wide variety of foods, particularly whilst neophobia is relatively low (4–10 months) [16, 37], can ameliorate these innate preferences and promote new food acceptance and improved dietary variety [19] and dietary quality [16–18]. Cooke argues that young children need repeated neutral exposure to become familiar with foods so that they can “learn to like and then like to eat” [17]. In our current food environment, there are plenty of opportunities for infants/toddlers to experience and learn to like unhealthy (high-sugar/fat, low-nutrient) foods. Indeed, early exposure to unhealthy foods is associated with enhanced preference and potentially increased intake of these foods [20, 21]. A recent prospective study [20] showed that the more variety of fruits and vegetables and the fewer non-core (high-fat/sugar, low-nutrient) foods a child had “tried” by 14 months of age predicted the number of foods within these food groups both liked and eaten, as well as improved diet quality at 3.7 years of age. Furthermore, children who had tried more vegetables by 14 months were also reported as less fussy at 3.7 years. These prospective associations were independent of maternal age, education, body mass index, duration of breast feeding, age of solid introduction and child fussiness at 14 months. Overall, repeated neutral exposure to healthy foods and limiting exposure to unhealthy foods are important food parenting practices to support the development of healthy food preferences and eating habits. It is critical that parents are supported to implement these strategies in conjunction with responsive feeding practices and structure to avoid counterproductive coercive controlling feeding practices.

In summary, effective food parenting practices have the capacity to positively influence the development of early taste preference, texture tolerance and appetite regulation that lay the foundation for life-long healthy food preferences and eating behaviours. However, studies suggest that sub-optimal feeding practices, including coercive, non-responsive feeding, that are characterised by excess maternal control and that teach children to eat for reasons unrelated to appetite are prevalent. Studies show that dietary quality is poor even in very young children and suggest that feeding practices related to early exposure are also sub-optimal [31, 32, 58]. Evidence and clinical experience suggest that food parenting is a source of considerable anxiety and conflict within families and that once an adverse feeding dynamic is established, it is very difficult to change. Interventions that promote positive feeding practices and increase the skills and confidence to support effective food parenting have the potential to positively influence health and well-being at the parent, child and family levels. Yet, there are very few food parenting interventions that have been well-described and evaluated in large robust clinical trials. One such trial will be discussed in the following section.

---

Parents are responsible for providing safe, developmentally appropriate, nutritious food, while the child is responsible for deciding whether and how much they eat.

---
The NOURISH Intervention and Randomised Controlled Trial

The NOURISH intervention was designed for first-time mothers with healthy term infants. The aim was to promote “protective” feeding practices that supported the development of healthy child eating behaviours, food intake and growth. The focus was on feeding practices from the start of solid feeding onwards. The intervention was evaluated by a randomised controlled trial designed and implemented according to standard recommendations. The protocol, intervention content and process and outcomes have been reported in detail [40–42, 59]. Briefly, first-time mothers of healthy term infants were initially approached on post-natal wards. Subsequently, 698

<table>
<thead>
<tr>
<th>Evidence-based strategies</th>
<th>Intervention principles</th>
<th>Parent concepts and strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure: promoting repeated neutral exposure to healthy foods; limiting exposure to unhealthy energy-dense nutrient-poor foods to support development of healthy food preferences [17]</td>
<td>The way we feed young children affects the food they will like and their health Habits are formed early and track to adulthood “Learning to like, liking to eat” [17]</td>
<td>Understand, expect neophobia, inborn taste preferences – salt and sweet Repeated neutral exposure: reoffer new healthy foods up to 10–15 times to develop familiarity and acceptance Limit exposure to sweet, salty foods – covert restriction, role modelling Same food presented a different way is a new food Tasting is important and spitting out is acceptable</td>
</tr>
<tr>
<td>Responsive feeding: recognising and responding appropriately to child cues of hunger and satiety to support and maintain the child’s innate capacity to self-regulate energy intake and avoid overfeeding [3, 4, 22]</td>
<td>Listen to and trust your child &quot;Parent provide, child decide&quot; [39]</td>
<td>Accept food refusal = not hungry or satiety Guide portion size but don’t focus on amounts Encourage autonomy – allow self-feeding to developmental stage; accept mess Neutral response to intake and refusal – No coercion, coaxing, games – No rewards, bribes, alternatives – Praise for tasting, self-feeding efforts – not for eating No emotional feeding to distract, comfort, shape behaviour No TV</td>
</tr>
<tr>
<td>Positive parenting (warmth, encourage autonomy, self-efficacy): operationalised via authoritative feeding characterised by behavioural limits (structure) and maternal sensitivity to cues; decreased over-control and protection [4, 61, 67]</td>
<td>Your relationship with your child is important “Feeding is parenting” Set good examples for your child “Be a good role model”</td>
<td>Set limits and rules Allow structured choice – choose from limited range of healthy foods based on what the family eats Establish meal/snack times and routines that ensure the child is hungry but not too hungry Make mealtimes pleasant for the whole family; some rules are important but don’t over-focus on manners Warmth, independence – responsive to child cues and skills – Avoid overpowering (authoritarian), e.g., pressure to clean plate – Avoid over-worrying (permissive or authoritarian), e.g., pressure to eat, overt restriction – Avoid being a “big softie” (permissive or unengaged) – “as long as they eat something”; don’t offer alternatives or be a “short-order cook” Feeding is a conversation – Allow the child to lead, wait until paying attention; pause for socialising – Allow self-feeding and touching food – Avoid intrusions/disruptions, e.g., cleaning face – Stop feeding when child loses interest – Talk quietly – about the food, encourage but don’t coerce, teach language for hunger and fullness</td>
</tr>
</tbody>
</table>

*Adapted and reprinted with permission from Nestec Ltd., Vevey and S. Karger AG, Basel. b As articulated to parents.*
mothers and infants (mean 4.3 months old) underwent baseline assessment and randomization. The intervention consisted of 2 modules of 6 group sessions of 1.5 h duration delivered fortnightly over 12 weeks. Sessions were facilitated at local child health clinics by study dietitians and psychologists using standardised facilitator and participant materials. The first module commenced immediately after baseline assessment at infants’ age 4 months. The second module commenced 6 months after completion of the first (9 months from baseline) when the children were 14 months old. An important aspect of the NOURISH intervention was the use of an anticipatory guidance framework to provide parents with developmentally appropriate information about “normal” infant behaviours and constructive responses, rather than waiting to seek advice on established problems. This dictated commencing the intervention when the infants were about 4 months old, just as mothers started complementary feeding, consistent with the evidence that suggests that the very early feeding experience (food parenting) lays the foundation for life-long eating patterns [15, 60].

The NOURISH intervention strategies, themes and corresponding parent messages are shown in Table 3, and a summary of module content is shown in Table 4. There were 3 content-targeted key domains of food parenting associated with positive outcomes in child eating behaviour, dietary quality and growth: (1) repeated neutral exposure to unfamiliar healthy foods and neutral limited exposure to unhealthy foods to promote healthy food preferences and acceptance of a wide range of tastes and textures [16, 17, 34]; (2) responsive feeding that attends to and responds appropriately to infant appetite cues to maintain and support self-regulation of intake to need and avoid overfeeding [3, 22, 23] and (3) positive parenting – warmth, encouragement of autonomy and self-efficacy [1, 4, 61]. Modules were designed to be consistent with developmental stage. Module 1 focussed on complementary feeding, whilst module 2 concentrated on managing toddler eating behaviour, particularly in the context of developmental needs for autonomy, and promoting feeding competence. The control group had self-directed access to parent resources and psychologists using standardised facilitator and participant materials. The first module commenced immediately after baseline assessment at infants’ age 4 months. The second module commenced 6 months after completion of the first (9 months from baseline) when the children were 14 months old. An important aspect of the NOURISH intervention was the use of an anticipatory guidance framework to provide parents with developmentally appropriate information about “normal” infant behaviours and constructive responses, rather than waiting to seek advice on established problems. This dictated commencing the intervention when the infants were about 4 months old, just as mothers started complementary feeding, consistent with the evidence that suggests that the very early feeding experience (food parenting) lays the foundation for life-long eating patterns [15, 60].

The NOURISH intervention strategies, themes and corresponding parent messages are shown in Table 3, and a summary of module content is shown in Table 4. There were 3 content-targeted key domains of food parenting associated with positive outcomes in child eating behaviour, dietary quality and growth: (1) repeated neutral exposure to unfamiliar healthy foods and neutral limited exposure to unhealthy foods to promote healthy food preferences and acceptance of a wide range of tastes and textures [16, 17, 34]; (2) responsive feeding that attends to and responds appropriately to infant appetite cues to maintain and support self-regulation of intake to need and avoid overfeeding [3, 22, 23] and (3) positive parenting – warmth, encouragement of autonomy and self-efficacy [1, 4, 61]. Modules were designed to be consistent with developmental stage. Module 1 focussed on complementary feeding, whilst module 2 concentrated on managing toddler eating behaviour, particularly in the context of developmental needs for autonomy, and promoting feeding competence. The control group had self-directed access to standard child health services which at the mothers’ initiative could include a telephone helpline and child weight measurement.

Outcomes were assessed 6 months and 2 and 3.5 years after completion of the intervention/module 2 and corresponding to child ages 2, 3.5 and 5 years, respectively [31, 41, 42, 55]. Validated maternal-report tools were used to assess child intake (24-h recall), food preferences and eating behaviours and maternal feeding practices, strategies to manage food refusal and parenting skills. Longitudinal analysis evaluated differences between the intervention and control groups at the 3 time points over the 3.5-year follow-up period [41, 42]. Mothers allocated to the intervention group demonstrated sustained and statistically significant improvements in feeding practices relative to those in the control group up to 3.5 years after intervention completion. Intervention mothers reported using less non-responsive feeding on 6/9 subscales [41, 42]. From 2 to 5 years of age, children in the intervention group were reported to have a small increase in satiety responsiveness and reduction in food responsiveness and fussiness, an overall pattern of appetite traits associated with healthier weight status [31]. The effect sizes were small, consistent with the heritability of these appetite traits as discussed above [26, 27], but provide evidence that increased use of responsive feeding practices may contribute to a reduction in “obesogenic” appetite traits consistent with healthy child eating behaviour [31]. These positive intervention effects on food parenting and child eating behaviour were associated with the body mass index Z-score at each follow-up assessment, being 16–17% lower (p = 0.06) for the intervention versus the control children. However, these positive intervention effects did not translate into measurable effects on food preferences or dietary intake or quality. There was no group effect on dietary intake assessed by a single 24-h recall. There were small positive intervention effects on food preferences (75 vs. 69% liked 16 fruits listed) and fruit and vegetable variety and frequency over 24 h and 7 days [31].

The NOURISH trial did not explicitly examine outcomes related to maternal happiness or parent conflict or distress related to feeding. However, there were a number of significant and relatively large differences at each of the follow-up assessments in the ways mothers managed food refusal (see Table 5) that support speculation that the intervention was potentially effective in reducing maternal anxiety related to food parenting. Intervention mothers were 1.7 times more likely to allow their child to take responsibility for how much to eat and less likely to be concerned about their child’s weight status [41]. Although at 2 years of age there were no group differences
Table 4. NOURISH intervention content [66]*

| Module 1 Sessionb | Introducing solids: commenced child age 4–7 months
| --- | --- |
| 1. Program introduction | Food preferences – innate likes and dislikes, neophobia
Parenting styles and feeding practices
Hunger and fullness cues |
| 2. Parenting styles and feeding practices | Parenting styles and attachment, relationship to feeding
Feeding practices to support “attached” feeding |
| 3. Healthy growth and feeding babies | Guide to healthy weight gain
Developmental readiness for solids
Process for introducing solids
Foods to avoid and how much |
| 4. The feeding relationship | “Normal” infant feeding behaviour – variable intake, prefer sweet and salt (limit these), support to try new things and learn to like new tastes
The feeding relationship – conversation, let the child lead |
| 5. Healthy and safe feeding skills | “Listen” to your child, recognise and respond to hunger/satiety cues, offer new foods, limit unhealthy foods
Rewards of attached feeding – increases child’s confidence and emotional grounding
Safe food, EBM and formula handling and preparation |
| 6. Planning for the future | Food refusal is “normal” – signals satiety – tips to manage; develop language to talk about hunger, fullness
Introduction to “division responsibility” [39]
Setting limits and allowing choice within limits |

| Module 2 Sessionb | Transition to family food, self-feeding; commenced child age 13–16 months
| --- | --- |
| 1. Introduction | Toddlers are different to babies – they want to be independent, increased neophobia
Toddlers don’t grow as quickly as babies
Small and highly variable appetites – trust your child to know how much they need to eat |
| 2. Healthy eating | Food groups – number and serve sizes, sample menus, don’t focus on amounts
Mealtime structure and strategies
No TV |
| 3. Parenting styles and feeding practices | Warmth – praise for trying new foods, not for eating
Independence – let the child decide how much to eat, self-feeding
Over-powering – force feeding, over-worrying – clean the plate
“Big softie” – as long as they eat something |
| 4. Feeding toddlers, understanding autonomy | Adult meals/foods, plan snacks
Provide choice within limits – parent decides “what and when”
Treat dessert as part of a meal, manage treats – “sometimes foods” – when, how often and portion sizes
Self-feeding and feeding competence |
| 5. Managing food refusal and fads | Food refusal is normal – satiety, autonomy
Regular meals/snacks
Realistic amounts, don’t offer preferred alternative, especially milk
Avoid coercive feeding and excess control
Don’t use food to shape behaviour; avoid emotional feeding (calm, distract, comfort) |
| 6. Overview, planning for the future | Division responsibility, authoritative feeding and parenting
Food away from home, food at child care |

EBM, expressed breast milk. * Adapted and reprinted with permission from Nestec Ltd., Vevey and S. Karger AG, Basel.

b Modules comprised fortnightly interactive group sessions (n = 10–15/group, duration 1.5 h). Modules 1 and 2 commenced when children were approximately 4 and 14 months of age, respectively.
in the proportion of children reported to often/very often refuse food (22%), intervention mothers were significantly more likely to report that their child was “easy to feed” and to report less FF. In response to food refusal, they were much less likely to insist that the child eats, offer alternate liked foods, use rewards, disguise foods or play games and more likely to accept that the child was not hungry, simply take the food away and offer no more food until the next usual snack/mealtime [31, 42, 55] (Table 5). The results consistently suggest that intervention mothers were more likely to use the “trust” [22] model and avoid using a range of coercive feeding practices that arguably contribute to conflict in the feeding dynamic. Process evaluation indicated that the intervention was well accepted, with 98% of participants indicating they would recommend NOURISH, and 99% found the information to be very useful/useful. 85% of participants reported that the intervention helped them “a lot” to feel more confident about child feeding, and 95% reported that it helped them to trust their child eats enough [62].

Overall, these results show that mothers (first-time at least) welcome and respond to anticipatory guidance on food parenting and that such guidance not only enhances maternal confidence but is able to modify maternal feeding practices with positive child outcomes. It is plausible that the intervention was associated with reduced anxiety and conflict and enhanced maternal confidence and well-being.

Further Considerations
With changes to the gender-based divisions of responsibilities for employment and parenting within families and society at large, fathers have an increasingly important role in early feeding. However, to date research into parental feeding practices has largely focussed on mothers [63]. Our unpublished data comparing feeding practices (using the Child Feeding Questionnaire [51]) in 70 parent pairs indicated that, compared to mothers, although fathers feel less responsible for child feeding, they are more concerned about child weight status and appear to more frequently use relatively controlling and, hence, suboptimal feeding practices. Other studies suggest that fathers of pre-schoolers more often used “insistence on...

**Table 5. NOURISH intervention effects on maternal response to child food refusal [41, 42]**

<table>
<thead>
<tr>
<th>Response</th>
<th>2 years old (n = 467)</th>
<th>5 years old (n = 392)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Intervention</td>
</tr>
<tr>
<td>Refusal of familial foods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-responsive/coercive: overrides satiety cuesa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insist child eats</td>
<td>37</td>
<td>18</td>
</tr>
<tr>
<td>Offer milk drink instead</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Offer liked food instead</td>
<td>78</td>
<td>63</td>
</tr>
<tr>
<td>Encourage/pressure to eat by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Playing games</td>
<td>57</td>
<td>21</td>
</tr>
<tr>
<td>Offering food reward for eating</td>
<td>31</td>
<td>9</td>
</tr>
<tr>
<td>Offering non-food reward for eating</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>Feeding with spoon</td>
<td>not asked</td>
<td>53</td>
</tr>
<tr>
<td>Responsive: respond appropriately to satiety cuesa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accept that child is not hungry, take food away</td>
<td>91</td>
<td>96</td>
</tr>
<tr>
<td>Offer no food until next usual meal/snack time</td>
<td>48</td>
<td>67</td>
</tr>
<tr>
<td>Mother mostly responsible for what child eats</td>
<td>76</td>
<td>72ns</td>
</tr>
<tr>
<td>Child mostly responsible for how much to eat</td>
<td>49</td>
<td>82</td>
</tr>
<tr>
<td>Neophobia: refusal of unfamiliar foodsa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assume child does not like and do not reoffer</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Neutral offer ≥6 times before deciding child dislikes</td>
<td>35</td>
<td>72</td>
</tr>
<tr>
<td>Disguise the food</td>
<td>65</td>
<td>45</td>
</tr>
<tr>
<td>Offer with liked food</td>
<td>94</td>
<td>94ns</td>
</tr>
</tbody>
</table>

Frequency (%) of strategies (explicitly addressed in intervention content) used. ns, not significant. a Response options: 1 = never to 5 = most of the time OR 1 = never to 4 = often dichotomised to 1, 2 versus 3, 4, 5 and 1, 2 versus 3, 4, respectively.
eating” and food to reward good behaviour, while mothers more often used “positive persuasion” to eat and a range of strategies to enhance dietary quality (e.g., “snack limits”) [64, 65]. This discordance in food parenting has potential to contribute to parental conflict and stress. Whilst the importance of fathers in child feeding must not be forgotten, it is critical that interventions do not exacerbate conflict related to feeding and are explicitly designed to support parents to work together to achieve positive intervention outcomes. Cultural and ethnic background and a range of socio-demographic factors are likely to influence the roles of mothers and fathers in child rearing and feeding, and ensuring diversity in parents participating in interventions will be critical to building a robust evidence base for the role of early feeding practices of both parents.

**Conclusion**

Parent-child interactions related to feeding are central to the fabric of daily family life and contribute to all aspects of child development, health and well-being. Child eating behaviours are in part heritable, are influenced by a range of child characteristics and reflect normal developmental stages. They are both responsive to and drive parent feeding style and practices. Parents frequently misinterpret developmentally normal child eating behaviours, such as food refusal, as cause for concern and anxiety and respond with coercive feeding practices (pressure, restriction, emotional feeding). Clinical experience indicates that parents, in an attempt to just get a few more mouthfuls of food into their toddler, can resort to quite bizarre feeding practices that are a source of stress and distress for both parent and child. These parent-centred authoritarian practices may be well intentioned but are both counterproductive and associated with poor outcomes for child health, including development of food preferences and appetite regulation, which lay the foundation for life-long healthy eating habits and chronic disease risk. Furthermore, it is plausible that stress and conflict around feeding may generalise to the broader parent-child interactions and family dynamic and impact on family happiness.

Overall, there is evidence that food parenting can be improved with a potential to positively influence child eating behaviour, diet quality and weight status and, in the longer term, reduce chronic disease risk. It is important that interventions take a strengths-based approach and explicitly support parents to cooperate rather than exacerbate any discordance in feeding practices. Furthermore, given the central role that feeding and eating play in the parent-child interactions (particularly in young children), and indeed within the broader family and cultural contexts, it could be argued that effective food parenting contributes to healthy and happy children and families.

**Acknowledgements**

We acknowledge the NOURISH investigators, staff, students and participants. NOURISH was funded from 2008 to 2014 by 2 consecutive grants from the Australian National Health Medical Research Council. Additional funding was provided by H.J. Heinz, Meat & Livestock Australia, Department of Health South Australia, Food Standards Australia New Zealand and Queensland University of Technology. We thank Dr Rebecca Perry for her contribution to the development of the NOURISH intervention content and materials.

**Disclosure Statement**

The writing of this article was supported by Nestlé Nutrition Institute and the author declares no other conflicts of interest.

**References**


In addition to how we consume foods, the environment we eat in may influence food’s impact on our well-being

Key insights
Higher well-being is associated with many health benefits, including improved immune function, better personal relationships and career success, and increased longevity. Researchers exploring the factors and interventions that affect well-being have revealed a common thread: that food consumption can enhance well-being. In particular, there is a consistent correlation between the consumption of fruits and vegetables and well-being. However, it is not only the quantity and quality of food consumed that influence positive mood and well-being but also the manner and conditions under which the food is eaten.

Current knowledge
The link between food intake and well-being has been investigated using different methods across populations from different countries, ages, and cultures. Interestingly, the studies have also identified differences in various aspects of food consumption across cultures. For example, people from some cultures spend more time preparing food and eating, and less time eating alone, compared to others. Furthermore, the relationship between food intake and well-being is bidirectional: experimentally elevating positive moods can increase an individual’s choice of healthy foods. These findings underscore the fact that food and eating are multi-dimensional constructs which have an impact on the biological, psychological, and social aspects of health.

Practical implications
Individuals who believe that they are in control of their own well-being have a more elevated and positive mood and are more likely to make healthier food and lifestyle choices. If food consumption is shown to increase well-being, this knowledge can enhance positive psychology interventions known to increase positive mood and help people understand that their food choices can impact their well-being. Thus, the consumption of fruits and vegetables in a mindful way in the company of others may represent a daily activity that people can engage in to increase their well-being.

Recommended reading
The Contribution of Food Consumption to Well-Being

Mark D. Holder
The University of British Columbia, Kelowna, BC, Canada

Key Messages
- High well-being is associated with many benefits, including increased longevity, improved immune functioning, better personal relationships, and increased career success.
- Correlational, longitudinal, and experimental studies link the consumption of fruits and vegetables with enhanced well-being.
- The mechanisms for why food intake may enhance well-being are not yet clear.

Keywords
Happiness · Life satisfaction · Positive psychology · Well-being · Positive affect · Negative affect · Food intake · Health · Fruits and vegetables · Fast food

Abstract
The newly emerging field of positive psychology focuses on the positive facets of life, including happiness, life satisfaction, personal strengths, and flourishing. Research in this field has empirically identified many important benefits of enhanced well-being, including improvements in blood pressure, immune competence, longevity, career success, and satisfaction with personal relationships. Recognizing these benefits hasmotivated researchers to identify the correlates and causes of well-being to inform them in the development and testing of strategies and interventions to elevate well-being. As positive psychology researchers throughout the world have turned their attention toward facets of food intake, a consensus is developing that the consumption of healthy foods can enhance well-being in a dose-response fashion. The link between unhealthy foods and well-being is less clear. Some studies suggest that under certain conditions, fast food may increase happiness, though other studies demonstrate that fast food can indirectly undermine happiness. The positive impact of food consumption on well-being is not limited to what people consume but extends to how they consume it and social factors related to eating. Though the research suggests that our food intake, particularly fruits and vegetables, increases our well-being, this research is in its infancy. Research specifically focused on subpopulations, including infants and pregnant mothers, is mostly lacking, and the mechanisms that underlie the relationship between food consumption and well-being remain to be elucidated.
The Emergence of Positive Psychology

Research in many health-related fields, including medicine, neuroscience, and psychology, has adopted the medical model and focused on deficits, disease, and dysfunction. This focus has been pivotal in understanding and alleviating ill-being, but it has also led to a limited conceptualization of health and health care as primarily a reduction or absence of ill-being [1, 2]. Relatively recently, the concept of health has been expanded to include the promotion of well-being, which includes happiness, life satisfaction, and flourishing. The World Health Organization [3] has endorsed this expansion as its mandate now reaches beyond only eradicating disease or infirmity, to include promoting well-being.

This expansion is at the core of a complementary approach to psychology referred to as positive psychology. Positive psychology places well-being at the center of its field of study by elevating the importance of empirically understanding and promoting happiness, satisfaction, strengths, positive experiences, positive traits, and other facets of human thriving [4–6]. The aim of positive psychology is not to replace traditional psychology or view the focus of traditional psychology as exclusively negative. Rather, positive psychology’s mandate is to expand traditional psychology’s focus on what is wrong with people and how we address these problems, with a complementary focus on what is right with people and what evidence-based interventions we can employ to assist people to thrive and flourish [1].

The importance of positive psychology’s mandate is supported by research that empirically demonstrates many benefits associated with high levels of well-being as summarized in Table 1. For example, increasing positive feelings may play a role in improving health [7, 8], as enhanced well-being is associated with lower blood pressure [9], increased immune functioning [10, 11], and increased telomere length [12], though not all studies report this increase in telomere length [13]. Additionally, longevity is positively correlated with well-being [14, 15], and self-reports of high levels of well-being are associated with exceptional longevity [16] and reduced mortality [17]. In addition to health, well-being is associated with improved social relationships. This association may be bidirectional [18, 19]. Happier people report that their relationships are of higher quality [20], more satisfying [11], and stronger [21]. In addition to health and relationships, work and school success are linked to well-being. For example, happier people are more likely to enjoy greater career [11] and academic success [22]. Research suggests that well-being often precedes greater career performance [23]. The increased work and career success may be attributable to increased cognitive functioning [24] including enhanced creativity in problem solving [25] following increases in well-being.

The Relationship between the Consumption of Healthy Food and Well-Being

Given the many important possible benefits of well-being, and the finding that across cultures and countries people desire happiness [26], researchers have begun to explore factors and interventions that can enhance happiness, life satisfaction, and flourishing. As summarized in Table 2, research from across continents has shown an emerging pattern that factors related to food consumption can enhance well-being. For example, university students self-reported their well-being along with aspects of their eating habits [27]. The results showed that eating

---

**Table 1. Benefits associated with high levels of well-being and its components**

<table>
<thead>
<tr>
<th>Component of well-being</th>
<th>Benefit</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater positive emotions</td>
<td>Lower blood pressure</td>
<td>[9]</td>
</tr>
<tr>
<td>Increased vigor and optimism</td>
<td>Improved immune functioning</td>
<td>[10, 11]</td>
</tr>
<tr>
<td>Increased positive affect, life satisfaction, optimism</td>
<td>Increased longevity</td>
<td>[14–16]</td>
</tr>
<tr>
<td>Increased overall well-being, positive affect, life satisfaction, happiness, optimism</td>
<td>Enhanced career success</td>
<td>[21, 24]</td>
</tr>
<tr>
<td>Happiness, life satisfaction</td>
<td>Improved social relationships</td>
<td>[18–22]</td>
</tr>
<tr>
<td>Increased happiness, resilience, overall well-being, positive affect</td>
<td>Improved romantic relationships</td>
<td>[52]</td>
</tr>
</tbody>
</table>
breakfast regularly, consuming more meals and snacks, and eating more fruits and vegetables were all associated with greater well-being. Though the authors reported that food intake was linked to happiness, they employed the Oxford Happiness Questionnaire which has been criticized as a measure of happiness [28]. The Oxford Happiness Questionnaire consists of 29 items that assess much more than happiness. Thus, these findings can be better understood as showing the link between food intake and aspects of overall well-being. Similarly, in a large cross-sectional study in Britain, increased consumption of fruits and vegetables was associated with increased self-reports of life satisfaction, happiness, and well-being [29]. The relationship between fruit and vegetable intake and positive mental states was maintained even after controlling for demographic and economic factors, and the relationship appeared to follow a dose-response function. In a complementary study of American university students, fruit and vegetable consumption was correlated with positive affect, though not life satisfaction [30]. This relationship remained significant even after controlling for demographic variables, health-related behaviors (sleep, smoking, and exercise), and the consumption of other foods (sugar drinks, fats, tea, and coffee). However, given these studies used correlational methods, the causal direction of the relationship between the intake of fruits and vegetables and levels of well-being is unclear. Participants who experience high well-being may be more prone to eat fruits and vegetables rather than the intake increasing well-being.

Many of the studies of the contribution of fruit and vegetable consumption to well-being have focused on hedonia. Hedonia is related to the pleasure gained from high levels of positive affect and low levels of negative affect and is typically assessed with measures of happiness (an affective rating of one’s life) and life satisfaction (a cognitive rating of one’s life). Though research in positive psychology has tended to focus more on hedonia, assessing eudaimonia is important to attain a more comprehensive understanding of well-being [31]. Eudaimonia is conceptualized as related to realizing one’s full capacity by acting in concert with one’s virtues, strengths, and potential. To examine whether food intake contributed to eudaimonia, in one study young adults recorded their intake (fruits, vegetables, sweets, and chips), their hedonia (positive and negative affect), and their eudaimonia (eudaimonic well-being, curiosity, and creativity) for 13 consecutive days [32]. As reported by other studies, positive affect and consumption of fruits and vegetables were positively correlated. Importantly, this study also showed that fruit and vegetable consumption was positively correlated with eudaimonic well-being, increased intensity of feelings of curiosity, and higher levels of creativity. On those days when consumption of fruits and vegetables was greater, the participants reported greater eudaimonic well-being, curiosity, and creativity. However, similar to the studies described above, the correlational method used in this study does not allow one to ascertain the causal direction of the relationship.

Though the conclusions that may be reached from these cross-sectional studies are limited given the correlational methodology they employed, other research designs point to similar conclusions. Based on their longitudinal study of the food intake diaries of over 12,000 Australians, Mujcic and Oswald [33] reported that as fruit and vegetable consumption increased from 0 to 8 portions per day, self-reports of life satisfaction and the percentage of time people reported feeling happy increased

| Table 2. Examples of relationships between food consumption and well-being |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| **Food consumed or environment** | **Component of well-being** | **Methodology** | **Reference** |
| Eating breakfast, meals, and snacks | Overall well-being | Correlational | [28] |
| Fruits and vegetables | Life satisfaction, happiness and overall well-being | Correlational | [30] |
| | Positive affect but not life satisfaction | Correlational | [31] |
| | Overall well-being, positive affect, feelings of curiosity and higher creativity | Correlational | [33] |
| | Life satisfaction and happiness | Longitudinal | [34] |
| | Vitality, flourishing, motivation | Experimental | [48] |
| Apple and chocolate bar | Increased positive mood | Experimental | [35] |
| Eating dinner with family | Increased well-being | Correlational | [44] |
as well. However, the increase in well-being may not be a direct and specific result of the fruit and vegetable consumption. Perhaps participating in any behaviors thought to be healthy and productive promotes components of well-being.

Although an experimental research design using random assignment and double-blind safeguards is generally considered the gold standard of research design, this design does not lend itself well to food intake studies with humans in part because it is impossible to have people consume fruits and vegetables in a normal fashion without them knowing it. One study that did employ an experimental method required participants to report their mood states twice each day for a week following eating an apple, a chocolate bar, or nothing [34]. Relative to eating nothing, participants reported an increase in positive mood following eating the apple, and an even greater increase after eating the chocolate. There was no difference in the level of satiation reported after consuming the chocolate and apple.

As described above, a developing literature reports that food intake, particularly that of fruits and vegetables, is associated with higher levels of components of well-being (Table 2). The conclusions reached from these studies are bolstered by the findings that increased fruit and vegetable intake results in increased well-being in a dose-response fashion. Additionally, recent research suggests that the reverse relationship is also present; levels of well-being can influence our responses to food. In a series of 3 studies, happy Japanese undergraduates showed greater emotional responses to food and pictures of food than their less happy counterparts [35]. These studies used the Subjective Happiness Scale to assess happiness. However, when Item Response Theory was applied to this scale to evaluate each of the scale’s 4 items individually, the fourth item was identified as problematic [36]. If this item had been eliminated from the analyses, the relationship between food and emotional reactions, which was influenced by prior levels of happiness, might have been even stronger than the authors report.

**The conclusions reached from these studies are bolstered by the findings that increased fruit and vegetable intake results in increased well-being in a dose-response fashion**

**The Relationship between the Consumption of Unhealthy Food and Well-Being**

A growing literature indicates that increased consumption of healthy foods, particularly fruits and vegetables, is associated with higher levels of subjective well-being. Additional research has examined how unhealthy food may be linked to well-being. Researchers used a nationwide survey of 2- to 12-year-old Taiwanese children to explore the relationship between happiness and the consumption of fast food and soft drinks [37]. Though fast food and soft drinks are associated with a greater risk of obesity, the study reported that they were also associated with a decrease in unhappiness. However, we need to view these results as preliminary given that unhappiness was assessed with a single question (“How often does your child feel unhappy, sad or depressed?”) with only 3 response options (“often,” “seldom,” or “never”), which was completed by the children’s mothers. Children’s self-reports of their own well-being and parental reports of their children’s well-being are only modestly correlated [38], and happiness is not simply the opposite of negative affect.

A series of experiments concluded that the packaging used by the fast food industry can have an indirect effect on happiness [39]. American adults were recruited online to view photographs of food (coffee, burger, and fries) either served in ordinary ceramic tableware or in McDonald’s fast food packaging. There was no difference in levels of self-reported happiness following the 2 sets of photographs; however, there was an indirect effect. Following the viewing of the food pictures, participants viewed beautiful photos of nature that had been previously shown to increase happiness. The increase in happiness that typically follows viewing beauty in nature was more pronounced for the participants who previously viewed photos of food served in the ceramic tableware. This suggested that the capacity of participants to savor the beauty of nature was undercut by the fast food packaging images. In a companion study, a similar procedure was used, but beautiful music replaced the nature photos. Those participants who had viewed the fast food images first, reported more impatience and felt that the music lasted longer (time passed slower) than those who had viewed the ceramic tableware images. Together, these studies suggest that fast food images can indirectly lower our well-being and increase our impatience by undermining our ability to savor positive events in our lives. However, this conclusion is perhaps premature given that the researchers did not include a neutral control group (e.g., a group that viewed nonfood photos of geometric...
shapes) to serve as a comparison to the 2 food image groups. It is possible that ceramic tableware images promoted savoring rather than fast food images undermined savoring.

The ability to savor small positive events is critical to one’s well-being. Though we tend to believe that major life events deliver happiness [40], these events actually account for only a small amount of the variance in our happiness [41]. Smaller positive experiences may be better predictors of happiness because they occur more often and are less vulnerable to adaptation and shrinking marginal utility [42]. Thus, the finding that fast food images can dampen our ability to savor the small pleasures of life may be impactful on our overall and enduring happiness.

**Fast food images can indirectly lower our well-being and increase our impatience by undermining our ability to savor positive events in our lives**

The Context of Food Intake and Well-Being

It is not only the quality and quantity of food consumed that influences positive mood and well-being, the manner and the conditions under which the food is eaten matter. For example, practicing mindfulness can increase the beneficial impact of food intake on well-being. Mindfulness involves a heightened awareness that may result from meditation or specific instructions designed to increase one’s focus and attention. In one study, participants were given either a cracker or a chocolate and instructed to consume the food in a mindful or nonmindful way [43]. The instructions that were designed to increase mindfulness directed participants to focus their attention on the sensory qualities of the food as opposed to eating the food with little awareness. Participants reported an increase in positive mood following the mindful consumption of the chocolate compared to those who ate the chocolate nonmindfully or those who ate the cracker either mindfully or nonmindfully.

In addition to how we consume foods, the environment we eat in may influence food’s impact on our well-being. In a large community sample of over 26,000 Canadians aged 11–15 years, the relationship between family dinners and well-being was explored [44]. Participants who reported eating more dinners with their family also reported greater emotional well-being and life satisfaction, as well as more prosocial behaviors. The positive dose-response relationship between the frequency of family dinners and enhanced well-being was noted across gender, grade level, and family income. However, the causal direction of the relationship between family dinners and well-being is unclear. Rather than family dinners promoting well-being, it is possible that family members who enjoy high levels of well-being are more prone to eat together. If family dinners actually promote well-being, which facet of the dinners is responsible for the relationship is not clear though social relationships are a likely candidate. Social relationships are known to be strongly linked to well-being, including in children [19], so this component of family dinners may help explain why family dinners contributed to the children’s well-being. In fact, parent-adolescent communication explained 13–30% of the variance in the relationship between frequency of family dinner and well-being [44].

**Food Intake Viewed as a Positive Psychology Intervention**

Positive psychology has focused on the development and testing of interventions to enhance well-being. Studies have reported that a variety of interventions, including those focused on kindness, gratitude, and best possible self, can increase happiness. Two prominent meta-analyses concluded that positive psychology interventions can have a modest impact on increasing well-being and decreasing ill-being [45, 46]. However, when the methodological shortcomings of these analyses are addressed (e.g., small sample size bias), positive psychology interventions seem to have no effect or at most a small impact on ill-being and well-being [47]. In particular, the effect sizes approach zero when small sample size bias is accounted for. As a result, there is a need to revisit the development and testing of interventions designed to increase well-being and to incorporate new approaches. Included in these new approaches may be ones that focus on the role of factors related to food consumption in promoting well-being. In fact, in a study already described, the benefit of fruit and vegetable consumption on positive affect was substantial [30]. When comparing participants who consumed no fruits and vegetables each day to those who consumed 8 or more servings, the effect size was moderate.

When fruit and vegetable consumption was tested as a psychological intervention, the results were encouraging [48]. Participants were randomly assigned to 1 of 3 groups: normal diet, encouragement diet (text messages were sent to participants reminding them to eat more fruits and vegetables and a voucher was provided to purchase these...
foods), and enhanced diet (in addition to their normal diet, participants were given 2 extra servings of fruits and vegetables each day). Only participants in the enhanced diet group showed increases in well-being (vitality, flourishing, and motivation). Measures of ill-being (depression, anxiety, and mood) were not impacted.

It is well established that a diet rich in levels of fruits, vegetables, and fiber is linked to many physical health advantages. For example, the increased consumption of fruits and fiber is associated with the reduction of a number of health issues, including type 2 diabetes, colorectal and lung cancer, asthma, and pulmonary disease [49]. This increased consumption also seems to contribute to promoting several healthy facets of life, including successful aging and increased bone density. However, the health benefits of eating a healthy diet are only realized in the long term and, thus, may not be as motivating for people, particularly children and adolescents, who are more impacted by immediate results. Research that shows that healthy food consumption is linked to enhanced well-being is important because it demonstrates an almost immediate benefit of this diet choice.

**Strength of the Findings**

Collectively, one can have confidence in the external validity of the research demonstrating a link between food intake and well-being because it has been investigated using different methodologies and has sampled from differently aged populations from many countries and cultures. This broad sampling is particularly important in studies of food intake because research has identified differences in components of food consumption across cultures. For example, compared to a city in the USA, citizens of a city in France spend more time preparing food and eating, and less time eating alone, and these differences were linked to aspects of their well-being [50].

The validity of this research is further strengthened because studies of the links between food intake and well-being have assessed multiple components of well-being, including happiness, life satisfaction, overall well-being, and flourishing. This is important because well-being is a multi-dimensional construct, and the correlates and causes of each dimension differ [51]. Conclusions that can be drawn from research on well-being are often limited because only one or a few domains of well-being are assessed. Kahneman et al. [51] found that life satisfaction and experienced happiness were only modestly correlated ($r = 0.36$), and this relationship notably weakened ($r = 0.21$) when depression was controlled for. To support the conceptualization that the components of well-being are somewhat independent, research has shown that the conditions of one’s life (income, education, having a partner, living with children) account for greater variance in life satisfaction than happiness. Positive conditions accounted for 20% of one’s life satisfaction but less than 2% of one’s experienced happiness. In short, the different dimensions of well-being are independent, and to attain a comprehensive understanding of well-being multiple dimensions need to be measured.

However, the research linking food intake to well-being is incomplete. For example, the mechanisms underlying the relationship still need to be elucidated. One possible mechanism involves social factors. It is clear that the quality of social relationships, both friendships [19] and romantic relationships [52], is associated with increases in well-being. Eating is often a social activity, and eating in the company of others is associated with elevated positive well-being [50]. Another possible mechanism involves biological factors. For example, fruit and vegetable consumption may increase levels of vitamin C, B vitamins, and antioxidants, which may lead to increased synthesis of dopamine, serotonin, and oxytocin, which have been linked to eudaimonia [53].

The association between fruit and vegetable consumption may be indirect as well. For example, increased fruit and vegetable consumption may lead to better health, which in turn leads to greater well-being. Research has not strongly supported this indirect relationship. The link between well-being and fruit and vegetable consumption is still apparent even after physical health and daily exercise are accounted for [29, 30, 54].

The relationship between food intake and well-being may be largely in the reverse direction or bidirectional. Higher well-being may prompt people to select more fruits and vegetables.

---

The relationship between food intake and well-being may be largely in the reverse direction or bidirectional. Higher well-being may prompt people to select more fruits and vegetables.
Conclusion

Research has identified many important benefits of increasing well-being. Using multiple methods and measures of well-being, and sampling from a wide range of populations, research demonstrates that food consumption, particularly of fruits and vegetables, is associated with increased well-being. Recent work has shown that the more strongly we adopt a view that our well-being is under our control and can be changed, the greater is our hedonic and eudaimonic well-being [56, 57]. Participants who were experimentally led to believe that they can make choices to change their well-being endorsed activities thought to enhance well-being more than those led to believe that their well-being was fixed and could not be changed [56]. If food consumption is shown to increase well-being, this knowledge can add to positive psychology interventions known to increase well-being and help people believe that their choices can impact their well-being. Adopting this view can increase well-being and perhaps increase people’s adherence to these interventions. Thus, the consumption of fruits and vegetables in a mindful way with others may represent a daily activity that people can engage in to increase their well-being and help them adopt a view that they can change their well-being. In turn, the subsequent increase in well-being may provide a host of benefits to the most important aspects of living, including better health, longevity, personal relationships, and career success.

Disclosure Statement

The writing of this article was supported by Nestlé Nutrition Institute and the author declares no other conflicts of interest.

References


Reprinted with permission from: Ann Nutr Metab 2019;74(suppl 2):44–51
DOI: 10.1159/000499147

Holder
34 Macht M, Dettmer D. Everyday mood and emotions after eating a chocolate bar or an apple. Appetite. 2006 May;46(3):332–6.