Clinical Nutrition Experimental 6 (2016) 25–38

Contents lists available at ScienceDirect

Clinical Nutrition Experimental

journal homepage: http://www.clinicalnutritionexperimental.com

Food for thought: The role of nutrition in the microbiota-gut–brain axis

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ARTICLE INFO

Article history:
Received 12 October 2015
Received in revised form 4 January 2016
Accepted 4 January 2016
Available online 21 January 2016

Keywords:
Diet
Psychobiotics
Gut microbiota
Gut–brain axis
Psychiatric disorders

SUMMARY

Recent research has provided strong evidence for the role of the commensal gut microbiota in brain function and behaviour. Many potential pathways are involved in this bidirectional communication between the gut microbiota and the brain such as immune mechanisms, the vagus nerve and microbial neurometabolite production. Dysbiosis of gut microbial function has been associated with behavioural and neurophysical deficits, therefore research focused on developing novel therapeutic strategies to treat psychiatric disorders by targeting the gut microbiota is rapidly growing. Numerous factors can influence the gut microbiota composition such as health status, mode of birth delivery and genetics, but diet is considered among the most crucial factors impacting on the human gut microbiota from infancy to old age. Thus, dietary interventions may have the potential to modulate psychiatric symptoms associated with gut–brain axis dysfunction. Further clinical and *in vivo* studies are needed to better understand the mechanisms underlying the link between nutrition, gut microbiota and control of behaviour and mental health.

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http://dx.doi.org/10.1016/j.yclnex.2016.01.003

Contents

1. Introduction

The microbial population residing in the small and large intestine represents the largest microbial population of the human microbiota. Estimates suggest that bacterial cells within the gut microbiota outnumber human eukaryotic cells by ten to one [1]. Moreover, the genes encoded by the gut microbiota, the gut microbiome, outnumber the human genome by one hundred to one [2]. This complex ecosystem is formed mainly by bacteria, but also viruses, archae, protozoa and fungi. Due to the advances in genomic technologies it has been possible to unravel around 75% of the adult gut microbiota bacterial composition, which is predominantly composed of the Firmicutes and Bacteroidetes phyla [3].

Furthermore, the gut microbiota plays a major role in host health by shaping the development of the immune system, metabolizing dietary nutrients (such as fatty acids, glucose and bile acids) and drugs, digesting complex indigestible polysaccharides and synthesizing vitamins and bioactive molecules [4].

Throughout different life stages, various changes occur in the microbial diversity of humans. Early studies suggested that the foetus first came in contact with microbes during birth. However, it has been posited that as early as the prenatal period, an initial inoculum of microbes may be translocated via the bloodstream and placenta from the mother to the foetus, thus contradicting the “sterile womb” hypothesis [5].

After birth, the first colonizers of the gut are facultative anaerobes such as *Streptococcus*, *Enterobacteriaceae* and *Staphylococcus*. These colonizers consume oxygen, creating an anaerobic environment leading to an increase of *Clostridium*, *Bacteroides* and *Bifidobacteria*, which are strict anaerobes. During this early post-natal period, diet (breast milk/formula feeding) plays a key role in shaping the gut microbiota composition [6]. This unstable infant gut microbiota with low diversity goes through a number of compositional changes during the first two years of life. From the second year of life onward, the microbial composition undergoes an important shift toward the stable gut microbiota profile of the adult, which is composed mainly of *Bacteroidetes* and *Firmicutes*. During healthy adulthood the gut microbiota remains relatively stable until ageing, when considerable changes occur [7].

The intestinal microbes are markedly affected by numerous factors such as host genetics, mode of delivery, lifestyle (urbanization and global mobility), medical interventions (use of antibiotics, vaccinations and hygiene) and health status [8]. Furthermore, diet has repeatedly shown to be one of the most important factors affecting gut microbiota establishment and composition throughout the lifespan [4]. Indeed, more than 50% of the variation of gut microbiota has been related to dietary changes [9] and major changes in diet during adulthood can modify the microbiota in a matter of days [10].