Gut Online First, published on June 9, 2014 as 10.1136/gutjnl-2014-307305

The gut microbiota, dietary extremes and exercise

Georgina L Hold

The GI tract is colonised by trillions of bacteria in a complex community collectively referred to as the gut microbiota. This metabolically active 'foreign' body contributes to host metabolism and immune system development and changes in its composition have been implicated in many chronic diseases including obesity and diabetes. Under normal conditions, this metabolically active 'foreign' body exists in a state of symbiotic tolerance (eubiosis) with its host and remains relatively stable over time. One of the major influences on the gut microbiota, at least in terms of our ability to modulate it, is diet. There is growing awareness that diet and lifestyle choices have a profound impact on the gut microbiota.[1]

The relationship between gut microbes and nutritional status is complex and has been a long-standing subject of intense debate. The composition of the gut microbiota is known to determine the efficacy of energy harvest from food.[2] In turn, the composition of the diet we consume is known to affect the microbial community composition.[3] To date, most attention has focused on the impact of dietary excess and obesity-related disorders and their effect on the microbiota. The relationship among the gut microbiota, exercise and related dietary changes has received much less attention. Loss of community richness/biodiversity has been demonstrated in obesity studies while increased diversity, which has been advocated to promote stability and improved ecosystem performance, is associated with increased health in certain populations.[4] This has led to the suggestion that microbiota diversity could become a new biomarker for health status. It has been suggested that monitoring the gut microbiota annually to determine changes in the composition and stability could be sufficient to detect health status changes.[5]

Studies that have examined changes in the gut microbiota in obesity almost unanimously demonstrate that obese individuals have altered levels of certain bacterial groups with a loss of biodiversity being the consistent outcome. These studies have highlighted the impact of weight loss on microbial diversity and the changes in metabolism and immune response associated with the weight loss. All studies to date however have focused on assessing changes in overweight individuals; no studies have attempted to assess changes in relation to exercise in healthy individuals. When considering the dietary extremes associated with intense exercise, the intention is usually reduced caloric intake achieved through high protein intake with low fat/carbohydrate intake. The amount, type and balance of the three main dietary components, that is, protein, carbohydrates and fat, have a profound impact on the gut microbiota. Low carbohydrate diets in which carbohydrates are largely replaced by increasing dietary protein and/or fat have proved a popular weight loss strategy although they remain controversial among nutritionists. Reduced dietary carbohydrate intake by overweight adults has been shown to impact on the gut microbial composition and activity.[6] Short chain fatty acids, primarily butyrate, propionate and acetate, are the main end products from microbial degradation of carbohydrates in the gut. The range of end products generated by protein digestion is broader than that of carbohydrates. Exercise alone can also influence the gut microbiota composition although impact of exercise on gut motility and transit time must also be considered. Matsumoto *et al*[7] showed that non-obese rats that participated in voluntary running exercise had increased colonic butyrate concentrations compared with sedentary rats. It has also been demonstrated that physical activity increases expression of IgA and cytokines such as interleukin-6 and TNF-α which may lead to alterations in host–microbial interactions and ultimately impose selective pressure on bacterial selection.[8]

In the first study of its kind, Clarke *et al* demonstrated the impact of exercise and associated dietary changes on the gut microbiota by studying a professional rugby team during a regulated environment of preseason training.[9] This pioneering approach demonstrated that gut microbiota diversity was significantly higher in the athletes compared with size matched (high Body Mass Index (BMI ~30)) and age/gender matched (lower BMI <25) control groups, with few differences seen between the two control cohorts. As well as differences in microbial diversity, athletes had lower inflammatory and improved metabolic markers compared with controls, in particular the high BMI controls. Dietary consumption by the athlete group was significantly different to the controls. They consumed more calories, with increased protein, fat and carbohydrate per day consumed than both control groups. Microbiota diversity measures positively correlated with protein intake and plasma creatine kinase levels (a marker of extreme exercise), which suggested that both diet and exercise were driving the changes in microbial diversity. The article is the first report that exercise increases gut microbiota richness/diversity and highlights that exercise is another important factor in the complex relationship among the host, host immunity and the microbiota.

The overall aim of the studies of the gut microbiota in health and disease is to find associations between lifestyle changes and functional consequences of alterations in the gut microbiota. By being able to identify the impact of such activities, we can aim to reproduce the positive impacts through manipulation of the gut microbiota. Through review of the amassed literature, various microbial taxonomic changes in the gut, in varying nutritional statuses have been reported but these are not reflected by significant changes in function. Comparatively rare species however can have potentially profound effects on host physiology and may explain the link between gut microbiota shifts and physiology changes. But it must be remembered that any changes are transient and only persist while the defined dietary/exercise regimen is followed.

As life expectancy continues to increase, it is important that we understand how best to maintain good health. Never has this been more relevant than in respect of our resident microbiota. Understanding the complex relationship among what we choose to eat, activity levels and gut microbiota richness is essential. Our diet and exercise patterns are continuing to change as a knee-jerk response to keep pace with our increasingly hectic lifestyles. The fact remains though that our gut microbiota is not programmed to keep pace with the demands that modern life throws at us. Research focused on sustaining health rather than restoring health is urgently needed. Understanding the impact of exercise and the nutritional value of foods in terms of relevance to

Correspondence to Dr Georgina L Hold, Institute of Medical Sciences, Aberdeen University, Foresterhill, Aberdeen AB25 2ZD, UK; g.l.hold@abdn.ac.uk

our microbiota is essential. Developing new ways to manipulate the beneficial properties of our microbiota by finding ways to integrate health-promoting properties into modern living should be the goal.

Acknowledgements The author would like to gratefully acknowledge the critical review of the article by Dr Sylvia Duncan.

Contributors GLH developed the outline for the commentary, reviewed the literature, drafted and edited the article.

Competing interests None.

Provenance and peer review Commissioned; internally peer reviewed.

To cite Hold GL. *Gut* Published Online First: [*please include* Day Month Year] doi:10.1136/gutjnl-2014-307305
Received 2 May 2014
Revised 7 May 2014
Accepted 9 May 2014

▶ http://dx.doi.org/10.1136/gutjnl-2013-306541

Gut 2014;**0**:1–2. doi:10.1136/gutjnl-2014-307305

REFERENCES

1 Claesson MJ, Jeffery IB, Conde S, *et al*. Gut microbiota composition correlates with diet and health in the elderly. *Nature* 2012;488:178–84.
2 Turnbaugh PJ, Ley RE, Mahowald MA, *et al*. An obesity-associated gut microbiome with increased capacity for energy harvest. *Nature* 2006;444:1027–131.
3 David LA, Maurice CF, Carmody RN, *et al*. Diet rapidly and reproducibly alters the human gut microbiome. *Nature* 2014;505:559–63.
4 Le Chatelier E, Nielsen T, Qin J, *et al*. Richness of human gut microbiome correlates with metabolic markers. *Nature* 2013;500:541–6.
5 Faith JJ, Guruge JL, Charbonneau M, *et al*. The long-term stability of the human gut microbiota. *Science* 2013;341:1237439.
6 Duncan SH, Belenguer A, Holtrop G, *et al*. Reduced dietary intake of carbohydrates by obese subjects results in decreased concentrations of butyrate and butyrate-producing bacteria in feces. *Appl Environ Microbiol* 2007;73:1073–8.
7 Matsumoto M, Inoue R, Tsukahara T, *et al*. Voluntary running exercise alters microbiota composition and increases n-butyrate concentration in the rat cecum. *Biosci, Biotechnol Biochem* 2008; 72:572–6.
8 Viloria M, Lara-Padilla E, Campos-Rodríguez R, *et al*. Effect of moderate exercise on IgA levels and lymphocyte count in mouse intestine. *Immunol Invest* 2011;40:640–56.
9 Clarke S, Murphy E, O'Sullivan O, *et al*. Exercise and associated dietary extremes impact on gut microbial diversity. *Gut* 2014. doi:10.1136/gutjnl-2013-306541

The gut microbiota, dietary extremes and exercise

Georgina L Hold

Gut published online June 9, 2014
doi: 10.1136/gutjnl-2014-307305