

Title	Gut microbiota: implications for sports and exercise medicine
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Publication date	2017-01-11
Original citation	Cronin, O., O'Sullivan, O., Barton, W., Cotter, P.D., Molloy, M.G. and Shanahan, F. (2017) 'Gut microbiota: implications for sports and exercise medicine', British Journal of Sports Medicine. doi: 10.1136/bjsports-2016-097225
Type of publication	Other
Link to publisher's version	http://dx.doi.org/10.1136/bjsports-2016-097225 Access to the full text of the published version may require a subscription.
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Item downloaded from	http://hdl.handle.net/10468/3792

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1 **Title:**

2 Gut Microbiota: Implications for Sports and Exercise Medicine.

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21 **Word Count:** 783

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26 **INTRODUCING THE GUT MICROBIOTA**

27 Technological progress in high-throughput sequencing and advanced bioinformatic
28 techniques, have facilitated a deeper understanding of the gut microbial influence on
29 human health. Collectively known as the gut microbiota, the trillions of microbes
30 including bacteria, viruses and fungi, which reside within the gut, are now recognized
31 as significant contributors to human (host) health. Patients with non-communicable
32 diseases such as metabolic syndrome, obesity and inflammatory bowel disease,
33 demonstrate distinct microbial alterations. This has prompted vigorous pursuit of the
34 mechanisms by which this microbial “organ” influences host health. This branch of
35 medicine has already revealed exciting avenues for disease treatment, from the
36 discovery of novel antibiotics to the treatment of recurrent *Clostridium difficile*
37 infection.¹

38 The scale and spectrum of microbial influence is substantial and elegant
39 studies have linked the presence or absence of specific microbes with immunity,²
40 neuro-development, and even behavioral disturbances.³ The potential impact of
41 microbiome science extends to the specialties of Sports Medicine and particularly to
42 Exercise Medicine.

43

44 **EXERCISING YOUR MICROBIOTA**

45 The development of a mature enteric microbiota is subject to modifiable and non-
46 modifiable factors, including diet and host genetics.⁴ The gut microbiota is perturbed
47 by antibiotic usage and is influenced by short- and long-term dietary trends. Recently,
48 the interaction between exercise and the gut microbiota has been highlighted
49 following identification of correlations between cardio-respiratory fitness and health-
50 associated gut microbial parameters such as taxonomic diversity and richness.^{5,6} It is

51 unknown whether improvements in cardio-respiratory fitness achieved during
52 adulthood can shift the gut microbiota toward a more healthy compositional profile.
53 Evidence suggests that physical activity in childhood and adolescence supports the
54 development of a diverse core microbiota that promotes psychological and metabolic
55 health.⁷ However, longitudinal studies are required to establish or challenge this
56 hypothesis.

57 In determining the true or specific effect of exercise on the composition and
58 activity of the gut microbiota, significant impediments must be addressed. First, there
59 is the confounding influence of subconscious or intentional dietary and lifestyle
60 changes, which commonly accompany changes in physical activity. Secondly, there
61 are the uncertain effects of fitness-industry targeted dietary supplements, including
62 energy bars, caffeine, and whey protein, on gut microbiota status and on human health
63 and performance. These effects are of particular interest to elite sport, where attention
64 to detail and marginal gains are perceived as pivotal to competitive success.

65

66 **MICROBIAL LESSONS FOR THE ELITE ATHLETE**

67 Recognition of the need to prevent illness in athletes has heightened, with emphasis
68 on nutrition and workload monitoring central to illness prevention strategies.

69 Microbes in the gut transduce functional nutritional signals to enhance not only
70 energy input but also immune and metabolic welfare. Simply stated, athletes need to
71 know that when they eat and drink, they are feeding not only themselves, but also
72 their microbes! Dietary supplementation, although commonplace, is generally
73 adopted with poor understanding of how supplements influence gut microbial health
74 and performance. Furthermore, knowledge of the impact of sports drinks on the oral
75 microbiota of athletes is limited, yet may be significant considering the high

76 prevalence of dental caries and periodontal disease witnessed in this population, and
77 the potential for oral microbiota to affect both systemic and oral health.

78 As microbiome science advances, there is likely to be improved
79 standardization and dietary design with due regard for host-microbe interactions
80 under varying levels of physical activity. Previously, we characterized the microbiota
81 of a professional international rugby union squad demonstrating a distinct
82 compositional profile compared to non-athletes.⁶ The elite athlete microbiota is
83 diverse and its characteristics are associated with positive health indicators, including
84 favorable metabolic and inflammatory profiles. The compositional and functional
85 characteristics of the elite athlete microbiota are likely the cumulative result of years
86 of optimized nutrition and high-degrees of physical conditioning, through youth,
87 adolescence and into the professional sporting milieu. Athletes' microbial potential
88 may also be shaped by their own genotype.⁸ However, longitudinal studies are needed
89 to resolve many gaps in knowledge, as most of the available data on exercise and the
90 microbiota are cross-sectional.

91 In summary, there is significant potential for microbiota research to contribute
92 to the specialty of Sports and Exercise Medicine. In addition, Sports and Exercise
93 Medicine represents a model or platform to facilitate studies of the interplay between
94 human physiology, host and microbial genetics, and diet. The gut microbiota is
95 implicated in areas vital to elite sport; these include immunity, defence against gastro-
96 intestinal infections, and energy provision. Microbiome science even embraces
97 cerebral function, cognition and behavior. To exploit the microbial contribution to
98 athlete performance, prospective studies are required to bridge the gap between
99 correlation and causation, and the interactions among biological co-variables and the
100 microbiota.⁴ Athletes of the future will continue to measure many parameters of

101 fitness and amongst these will be microbial indicators of health and nutritional
102 welfare.

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104 **Conflicts of interest:**

105 FS is a founder shareholder in Atlantia Food Clinical Trials, Tucana Health Ltd and
106 Alimentary Health Ltd.

107

108 **Funding:**

109 OC is funded by the Irish Centre for Arthritis Research and Education (ICARE). FS is
110 director of the *APC Microbiome Institute*, a research centre funded in part by Science
111 Foundation Ireland (SFI) (APC/SFI/12/RC/2273) and which is/has recently been in
112 receipt of research grants from Abbvie, Alimentary Health, Cremo, Danone, Janssen,
113 Friesland Campina, General Mills, Kerry, MeadJohnson, Nutricia, 4D pharma and
114 Second Genome, Sigmoid pharma. Research in the Cotter laboratory is funded by SFI
115 through the PI award, “Obesibiotics” (11/PI/1137). Orla O’Sullivan and Wiley Barton
116 are funded by Science Foundation Ireland through a Starting Investigator Research
117 Grant award (13/SIRG/2160).

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