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1 **Title:**

2 Gut Microbiota: Implications for Sports and Exercise Medicine.

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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.<sup>1</sup>

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,<sup>2</sup>  
40 neuro-development, and even behavioral disturbances.<sup>3</sup> 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.<sup>4</sup> 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.<sup>5,6</sup> 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.<sup>7</sup> 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.<sup>6</sup> 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.<sup>8</sup> 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.<sup>4</sup> 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.

103

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107

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