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• Review

Exercise and gut microbiota: clinical implications for the feasibility of Tai Chi

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ABSTRACT

Recent studies have shown exercise is associated with changes in the gut microbiota in humans as well as in experimental animals. Tai Chi is an exercise that integrates a martial art, deep breathing and mediation, and has various beneficial effects for health. This review summarizes current knowledge and recent literature on the association between exercise and gut microbiota, and explores the feasibility of Tai Chi for improving gut microbiota composition and function. PubMed/MEDLINE was used to search the English literature for the keywords exercise and gut microbiota. Fourteen relevant studies were identified. In humans, exercise increases the gut microbial diversity. However, the evidence for this association is weak, as previous studies were small-scale, non-controlled studies of short duration or cross-sectional design. In animals, exercise alters the composition of gut microbiota, with some studies suggesting exercise increases the Bacteroidetes/Firmicutes ratio. However, these results are controversial, partly because host genetics and physical fitness also influence gut microbiota. Furthermore, the intensity of exercise may play a key role in how exercise affects gut microbiota. Tai Chi is a moderate-intensity exercise that improves immune function and inflammation of the gut. Tai Chi may also affect gut microbiota through vagal modulation and mediating the hypothalamic-pituitary-adrenal axis. However, no studies have investigated the association between Tai Chi and gut microbiota. Well designed studies exploring the effects of Tai Chi on gut microbiota are needed.

Keywords: exercise; Tai Chi; gut microbiota; intestinal bacteria; Bacteroidetes; Firmicutes; complementary medicine; alternative medicine

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1 Introduction

Exercise is a structured and repetitive physical activity that increases metabolic activity via contraction of skeletal muscles. Exercise therapy is beneficial for obesity,[1] cardiovascular risk factors,[2] prevention of colon cancer,[3] depression[4] and chronic fatigue syndrome (CFS).[5] Regular exercise also has extensive benefits for human cardiovascular, immunological and neural systems.[6] Recently, Clark et al.[7] reported that exercise increased the diversity of gut microbiota in humans. The human gut microbiota comprises approximately 100 trillion microbes.[8] Firmicutes (60%–65%), Bacteroidetes (20%–25%) and Proteobacteria (5%–10%) comprise the majority of human gut microbiota, though there is considerable inter-individual variability in microbial composition.[9] Microbiota can be clustered into enterotypes, characterized as a ratio of *Bacteroides*, *Prevotella* or *Ruminococcus*, and are affected by long-term diet.[10] Exercise may affect gut microbiota, though evidence for this association is limited. Moderate intensity exercise can improve immune function,[11] oxidative stress and inflammation.[12] Exercise

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also modulates the autonomic nervous system (vagal nerve activity), which is sometimes referred to as the "brain-gut axis."[13] Dysregulation of vagal nerve activity influences the development of depression,[14] inflammatory bowel disease[15] and irritable bowel syndrome.[16] Recently, an experimental study has shown that prebiotic treatment can have antidepressant and anxiolytic effects.[17] Further, mucosal inflammation in inflammatory bowel disease was associated with the reduction in gut microbiota diversity.[18] Growing evidence suggests that alterations in gut microbiota are associated with the condition of irritable bowel syndrome.[19] In patients with type 2 diabetes, long-term (12 months) moderate- to high-intensity aerobic and resistance exercise decreased inflammatory cytokines, such as interleukin (IL)-1β, IL-6, tumor necrosis factor-α (TNF-α), interferon-γ, and high-sensitivity C-reactive protein, and increased anti-inflammatory cytokines (e.g., IL-4 and IL-10).[20] Exercise may modulate gut microbiota by regulating intestinal immune function and vagal tone; however, the underlying mechanism is not clear.

Tai Chi is an ancient Chinese martial art, characterized by slow, smooth and fluid movements. All sorts of people can practice Tai Chi as exercise which is defined as a planned, structured and repetitive physical activity with the objective to improve physical fitness and overall health.[21] The health effects of Tai Chi have been investigated, and Tai Chi is considered safe and effective for the management of metabolic diseases.[22] Previous studies reported that Tai Chi had a favorable effect on immune function and oxidative stress.[23,24] However, no studies have investigated the association between Tai Chi and gut microbiota.

This review summarizes current knowledge and discusses recent literature on the association between exercise and gut microbiota. The focus is on clinical research in humans and experimental animals that explore the underlying mechanisms by which exercise beneficially affects gastrointestinal function. In addition, the feasibility of Tai Chi in improving gut microbiota composition and function is discussed.

2 Methods

The English language literature was searched for exercise and gut microbiota using PubMed/MEDLINE, using the search terms "exercise OR physical activity," "gut microbiota" and "intestinal flora." The search returned 136 published articles, including human and experimental animal studies. Inclusion criteria for study selection were: (1) the subjects in human studies were adults aged from 20 to 60 years; (2) the animal study was a controlled trial; (3) aerobic exercise was the intervention; and (4) the study duration was more than 6 d. The titles and abstracts of identified articles were reviewed to determine their relevance. In total, 14 studies met the inclusion criteria.

3 Association between exercise and gut microbiota in humans

Evidence for the association between exercise and gut microbiota in humans is sparse. A study by Ehrenpreis et al.[25] was the first study to indicate a positive association between exercise and gut microbiota, though this was not a direct relationship. That study included 12 participants (6 men and 6 women), and examined whether short-duration moderate-intensity exercise increased hydrogen production after lactulose consumption. Exercise sessions lasted 5 min and used a treadmill set to 10 km/h with a 20% incline. Participants performed exercise sessions 180 min after ingesting 10 g of lactulose. All participants completed resting and exercise trials, and breath hydrogen levels were measured. The areas under the curve for breath hydrogen concentration for time periods of 0–420 min and 180–420 min were compared between resting and exercise sessions. The mean area under the curve for breath hydrogen concentration from 0–420 min increased by 37% in the exercise trial compared with the resting trial, whereas no difference was observed between resting and exercise trials for 0–180 min. The mean area under the curve for breath hydrogen concentration from 180–420 min increased by 61% in the exercise trial compared with the resting trial. Those authors suggested that exercise enhanced lactulose catabolism by colonic bacteria due to induced motion of the colonic contents. They reported that exercise, in part, had a beneficial effect on colonic mucosa. Alterations in colonic microbiota are associated with chronic constipation. Some probiotics may be beneficial for constipation,[26] suggesting that colonic motility is important for maintaining normal intestinal flora. Short-duration (5 min) moderate-intensity exercise may therefore benefit gut microbiota. Conversely, long-distance endurance exercise may cause mucosal erosions and ischemic colitis by reducing intestinal blood flow.[27,28] However, there may be a threshold in the duration and intensity of exercise whereby colonic function can be improved.

Shukla et al.[29] examined microbiomes in blood and stool samples collected before and after (15 min, 48 h, and 72 h) a maximal exercise challenge in patients with myalgic encephalomyelitis (ME)/CFS. Participants included 10 patients with ME/CFS and 10 healthy controls. They performed a maximal exercise test on a cycle ergometer, keeping the pedal rate at 60–70 revolutions per min during the exercise test. Participants started exercise with a 3-minute warm-up at 25 W; the work rate was then increased by 5 W per 20 s. The exercise test was finished