

AstaPure® Arava Natural Astaxanthin Whole Algae Product Supports Immune Function and Improves Subjective Well-Being

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Abstract

We evaluated the effects of dietary supplementation with a full-spectrum microalgae extract on upper-respiratory tract complaints (URTCs) and psychological mood state. Thirty-two male (15) and female (17) runners consumed AstaPure® Arava a whole algae supplement (*Haematococcus pluvialis* microalgae) containing 8 mg of Astaxanthin or a placebo daily during a 4-week supplementation period (3 weeks before and 1 week following a marathon or half-marathon competition). We collected subjective and objective measures before and after supplementation. Subjects completed the profile of mood state (POMS) psychological assessment and a health log questionnaire assessing health status and URTCs (subjective measures), as well as provided saliva samples and fecal samples for measurement of cortisol and microbiome balance, respectively (objective measures). Subjects in the microalgae supplement group reported significantly fewer URTCs and better overall well-being, as well as lower cortisol and superior microbiome indices, compared to placebo. These results suggest that microalgae concentrate may improve immune system vigilance and overall well-being following the stress of endurance training and competition, possibly via improvements in the microbiome and Gut-Immune-Brain-Axis.

Keywords: *AstaPure® Arava; Astaxanthin; Immune Function; Microbiome; Gut-Immune-Brain-Axis*

Introduction

The immune system is traditionally thought of as the body's primary defense against external pathogens such as viruses. Increasingly, research is demonstrating an expanded role of the immune system as both a "shield" against viruses and also as a "communication organ" via its contribution to psychological mood state and overall well-being.

Numerous studies have shown the close links between psychological factors such as stress, sleep deprivation, and immune suppression leading to poor vaccine responses and increased upper-respiratory tract infections (URTIs) and non-infection upper-respiratory tract complaints (URTCs) such as chest heaviness, cough, dry/sore throat, etc. Athletes in particular, because of the mental and physical stress of their heavy exercise and intense training regimen, tend to have increased susceptibility to URTI and URTC [1-4]. Exercise has been demonstrated both a physical and psychological stressor that can have significant negative impacts on immune system components such as neutrophils, natural killer cells, T cells and B cells [5-7]. The one-to-two-week period following intense endurance competition represents a period of particularly elevated susceptibility, during which athletes often present with a range of upper-respiratory tract complaints

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(URTC), such as cough, stuffy nose, sore throat, headaches, and others. These complaints may be related to temporary elevations in hormones such as cortisol and inflammatory cytokines that coordinate the stress response [8,9]. The chronic impact of continuous heavy endurance training (without adequate recovery) may be categorized as overtraining or overreaching syndrome and eventually athlete burnout, which is characterized by a weakened immune system, increased risk of URTIs/URTCs and negative outcomes for psychological mood state (e.g. higher stress, poor sleep quality, increased risk for depression, among others).

Like psychological stress, exercise stress is known to suppress immune system vigilance and increase susceptibility to many disease states, including URTIs/URTCs [10]. Habitual exercise is widely regarded as a buffer against many detrimental health effects of stress, but chronic overload (in the absence of adequate recovery), which can be common in motivated recreational athletes building up for an endurance competition such as a half-marathon or marathon, can also lead to psychological stress and deteriorations in mood state [11]. Individual ability to cope with daily stressors is known to influence the immune response to exercise, with over-stress associated with reductions in immune cell populations, lowered antibody production and altered cytokine response [12,13].

A wide range of dietary supplements have shown varying levels of effectiveness in balancing the relationship between exercise stress and immune vigilance. For example, various vitamins and minerals (C, D, zinc), yeast beta-glucans, and mushroom alpha-glucans have shown promising benefits in endurance runners [14-22] via their ability to enhance the innate immune response, helping to prime immune system function during and following various forms of chronic stress.

Astaxanthin is one of the most powerful antioxidants known. It is bioavailable in many organs and can cross the blood-brain barrier and blood-retinal barriers, bonds with muscle cells and enters skin cells - thus achieving a multitude of health-related benefits.

Natural microalgae-derived astaxanthin (a dark red carotenoid from *Haematococcus pluvialis*) has been clinically evaluated for its antioxidant, anti-inflammatory, cardioprotective, neuroprotective, and immune-modulatory activities, while pre-clinical studies have further shown astaxanthin to modulate cellular stress pathways, including nuclear factor kB (NFkB), nuclear factor E2 related factor 2 (Nrf2), and nitric oxide [23]. In addition to the implication of cellular stress pathways in various neurological disorders including Alzheimer's, Parkinson's, and age-related dementia, astaxanthin may also play a role in psychological mood states (e.g. depression and anxiety) through its involvement in neurotransmitter balance, including within the serotonergic system [24]. Previous studies of astaxanthin supplementation have shown a variety of physical and psychological benefits, including attenuation of exercise-induced muscle damage, delayed physical exhaustion, improved endurance performance and elevated immunoglobulin levels - as well as anti-depressive, anti-anxiety, and mood-balancing effects [23-25]. Recently, natural astaxanthin supplementation was shown to support the psychophysiological "Heart-Brain-Axis" with simultaneous improvements in both physical performance and mental wellness - suggesting a potential ergogenic aid for endurance athletes (e.g. marathon runners, triathletes, cyclists, etc.), where both physiological endurance and psychological balance are simultaneously stressed and where support of both may be a novel approach to improving physical/mental performance [25].

Haematococcus pluvialis algae is the most concentrated natural form of astaxanthin.

In addition to astaxanthin, more than half of the *Haematococcus pluvialis* cell is comprised of carbohydrates including polysaccharides and dietary fibers - each of which represent plant structures that have been shown in multiple studies to have an important role in the normal function of the gastrointestinal tract, mitochondrial energy production, and the incidence of respiratory illnesses. In recent (unpublished) *in-vitro* experiments, the whole microalgae powder shows significant activity, even at low concentrations, to positively modulate immune responses as well as inflammatory biomarkers involved in reparative and regenerative functions. These preliminary results are suggestive of a synergistic effect from the combination of astaxanthin, polysaccharides, lipids and other natural components found in a "full-spectrum" microalgae powder. Indeed, recent clinical and pre-clinical studies have evaluated the effects of dietary

supplementation with “whole” *Haematococcus pluvialis* powder - finding dramatic improvements in markers of cellular stress (total antioxidant capacity, superoxide dismutase, and glutathione S-transferase) and activation of immune-vigilance genes [26-29].

Stress-related immune alterations, including dysbiosis at the level of the gut microbiome, can represent significant and meaningful challenges for not only the exercise performance of athletes, but also their overall health and well-being. In this study, we used the “exercise stress” of endurance running (training and competition) to activate the athlete’s stress response system (cortisol) and both challenge gut microbiome resilience and temporarily suppress immune vigilance and psychological mood state. We have used this exercise stress model in a number of previous investigations of immune system function and mood state [8] - and apply it here to elucidate the potential benefits of whole microalgae complex in supporting the Gut-Immune-Axis.

Materials and Methods

This study was done in accordance with the Helsinki Declaration, for clinical research involving human subjects and was reviewed and approved by an external advisory board (WCG-IRB, Puyallup, WA; Protocol #20202070).

The objective of this study was to investigate the effects of dietary supplementation for one-month with AstaPure® Arava whole microalgae complex containing 8 mg of Astaxanthin. Our hypothesis was that this unique complex may be immunomodulatory for improving both immune system vigilance and psychological stress. We recruited 40 healthy volunteers to receive the Supplement or a Placebo (maltodextrin). The supplement provided 8mg of “full-spectrum” microalgae complex as (Arava; *Haematococcus pluvialis*, AlgaTech, Israel), providing 3% astaxanthin, 50% polysaccharides and dietary fibers, 28% lipids, 14% proteins, and a variety of B-complex vitamins and trace minerals.

Subjects

We recruited healthy, fit, recreational runners who were experienced in training and competing for half-marathon to marathon-distance events. Our subject pool completing all phases of baseline pre-supplementation measurements, training, competition, and final post-supplementation measurements included 32 subjects (Table 1). Four subjects in the Supplement group and four subjects in the Placebo group were lost to follow up (did not complete all measures). There were no adverse events reported for either group.

Group	Average Age	Men	Women	Total
Supplement	41 ± 6	6	10	16
Placebo	46 ± 4	9	7	16

Table 1: Subject demographics.

Health log

Subjects completed a physical health questionnaire [8] at baseline (pre-supplementation) and 4-weeks (post-supplementation). The health log was a daily health perception log containing questions related to overall health status and specific upper-respiratory tract complaints (URTCs). The URTC-related symptoms measured included nasal congestion, runny nose, sore throat, sneezing, cough, fatigue, headache, general malaise and body aches. Reported symptoms were totaled for each assessment period.

Mood assessment

Changes in psychological mood state were assessed using the research-validated Profile of Mood States (POMS) questionnaire to measure 6 primary psychological factors (tension, depression, anger, fatigue, vigor, and confusion) plus the combined global mood state

as an indication of subjective well-being. The POMS methodology has been used in ~3,000 studies, and its validity is well established [30]. The POMS profile uses 65 adjective-based intensity scales scored on a 0 - 4 hedonic scale (e.g. “not at all” to “extremely”). The 65 adjective responses are categorized into the 6 mood factors (tension, depression, anger, fatigue, vigor, or confusion), tabulated, scored, and analyzed. The output of the POMS questionnaire is an assessment of the positive and negative moods of each subject at baseline and post-supplementation.

Salivary cortisol

Cortisol is the major glucocorticosteroid stress hormone produced in the adrenal cortex and is actively involved in regulating many aspects of metabolism related to sports performance, including blood pressure, anti-inflammatory function, gluconeogenesis, and immune function. Cortisol production has a circadian rhythm, with peak levels in the early morning and nadir levels at night during deep sleep. Levels rise independently of circadian rhythm in response to stress. Salivary cortisol represents a simple and accurate method for assessing unbound active cortisol levels as an index of overall stress exposure. Each subject provided “first morning” saliva samples (upon awakening) for analysis of free cortisol at baseline (pre-supplementation) and 4-weeks (post-supplementation).

Microbiome assessment

Volunteers were provided with a take-home kit to obtain fecal samples in the privacy of their home for analysis. The kit included detailed instructions and postage paid packaging for return directly to the lab. Each kit was numerically coded so that samples were blinded to the lab. Microbiome analysis of fecal samples was carried out using the complete BiomeTracker system (Wasatch Scientific, Murray, UT). Briefly, fecal samples were obtained by nylon swab and placed into preservative binding buffer to lock the composition of bacteria in place. DNA was then purified using DNA columns and ~20 ng of DNA from each sample was added to the reaction mixtures. Samples were processed on an ABI 7500 Fast (Applied Biosystems) instrument in duplicate. A “microbiome composite score” was generated as an overall average of many different aspects of microbiome balance, including *Bifidobacterium*, *Lactobacillus*, *Akkermansia*, *S. thermophilus*, *Firmicutes/Bacteroidetes* (F/B) ratio and others.

Data management and analysis

All questionnaires were hand-delivered or mailed to a central location and transcribed to a central database. Subjects who did not complete the questionnaires or who submitted incomplete questionnaires were dropped from the study and not included in the study analysis (8 subjects: 4 from the Supplement group and 4 from the Placebo group). Data were identified by subject number and examined for accuracy and completeness. Tabulated data were analyzed with JMP 14.0 (JMP Statistical Discovery, Cary, NC) using standard parametric paired t tests and significance was assessed with a 2-tailed alpha level set at 0.05. Data are presented as average values for each group (Placebo and Supplement) before and after supplementation.

Results

Following 4 weeks of supplementation with AstaPure® Arava whole microalgae complex, (3 weeks before and 1 week following an intense endurance run), we observed the following differences between the Supplement and Placebo groups.

Subjective measures

As expected, both groups reported a dramatically greater number of self-reported upper-respiratory tract complaints (URTCs) following the endurance run compared with before (Figure 1). However, the total number of URTC symptoms reported such as cough, sore throat, sniffles, stuffiness, etc., were 78% lower in the Supplement group compared to Placebo (Figure 1).

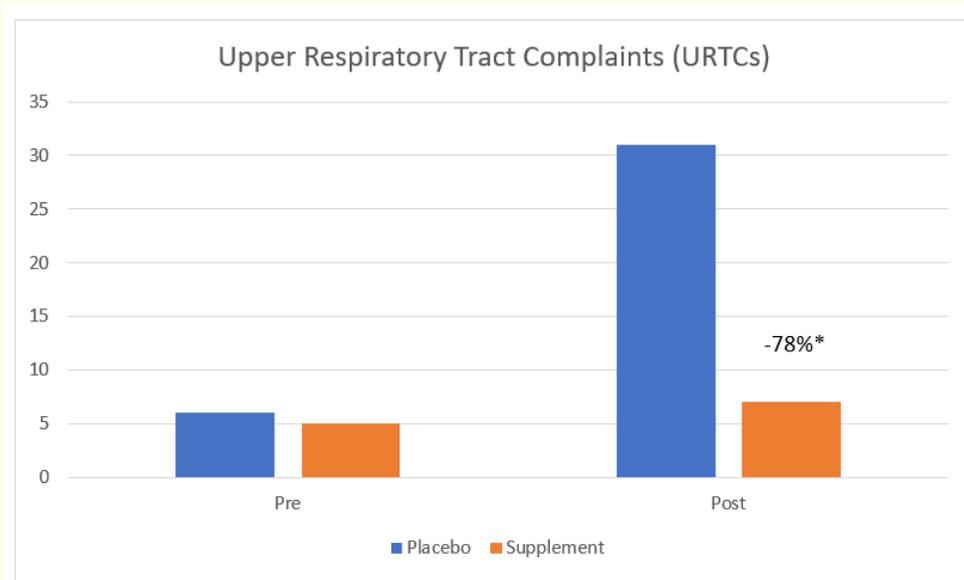


Figure 1: Subjects in the supplement group had significantly fewer self-reported upper respiratory tract complaints (URTCs) compared to placebo (*Significantly different from post-supplementation placebo value, $p < 0.05$).

There was no significant change in Global Mood State (e.g. “overall well-being”), following the endurance run in the Placebo group (Figure 2), while the Supplement group demonstrated an 14% improvement (a lower number indicates a less negative psychological mood state - and thus a better overall well-being index).

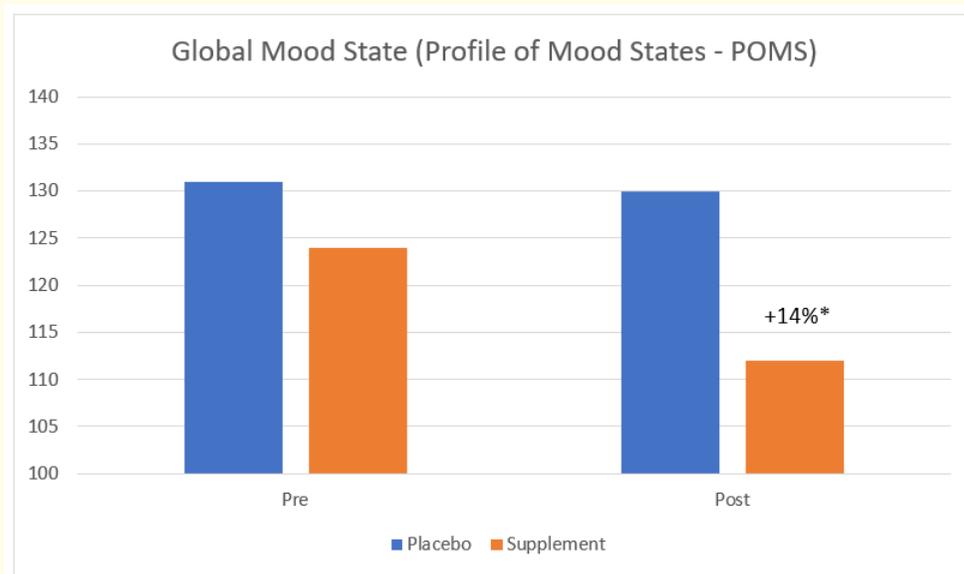


Figure 2: Subjects in the supplement group had significantly better global mood state compared to placebo (lower score indicates higher well-being index) (*Significantly different from post-supplementation placebo value, $p < 0.05$).

Objective measures

There was no significant difference in overall microbiome indices following the endurance run. However, following supplementation, *Streptococcus thermophilus* values were 72% higher in the Supplement group, suggesting improved immune system regulation (Figure 3).

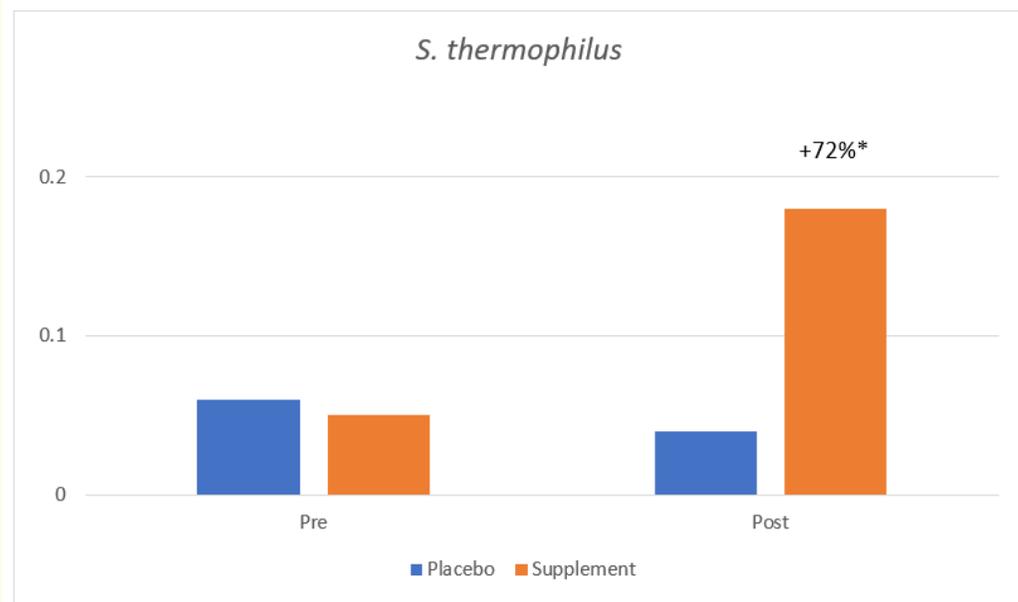


Figure 3: Subjects in the supplement group had significantly higher relative abundance of *Streptococcus thermophilus* bacteria compared to placebo (*Significantly different from post-supplementation placebo value, $p < 0.05$).

Cortisol, the primary stress hormone related to both mood and immune function, was slightly but not significantly elevated in the Placebo group following the endurance run, but was 25% lower in the Supplement group post-supplementation compared to Placebo (Figure 4).

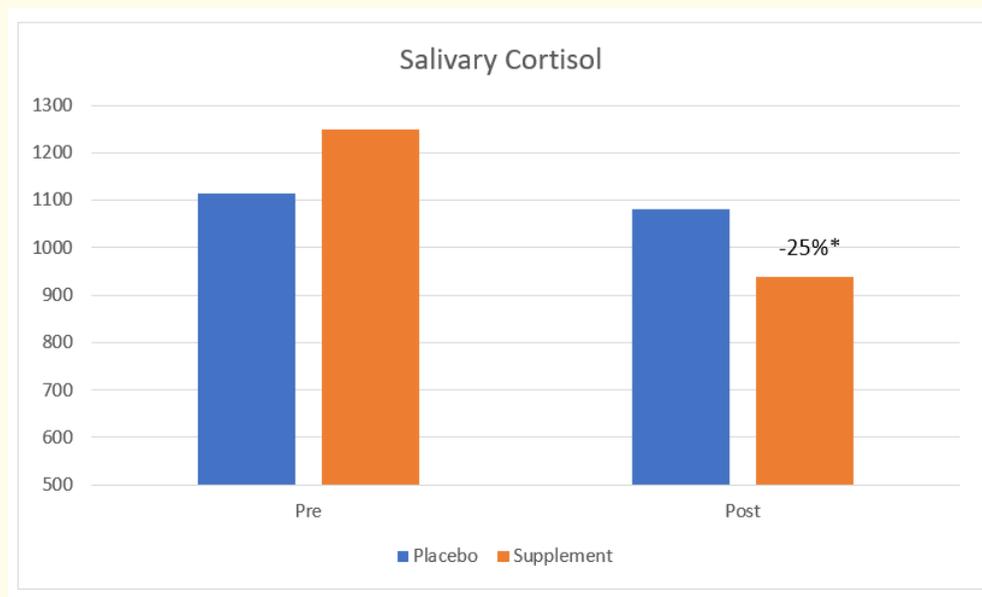


Figure 4: Subjects in the supplement group had significantly lower salivary cortisol (ng/ml) compared to placebo (*Significantly different from post-supplementation placebo value, $p < 0.05$).

Discussion

These results demonstrate a range of novel benefits associated with supplementation with AstaPure® Arava whole microalgae complex for supporting the immune system as both a “shield” (protection from upper-respiratory complaints) and as a “communication organ” (signaling well-being between body and mind and resulting in superior psychological mood state). This linkage between body and mind across the “Gut-Immune-Axis” [31] involves many aspects of a coordinated and interconnected communication system linking the gut microbiome (*S. thermophilus*) to the brain (psychological mood state) across the axis (immune and stress response pathways). When the entire system is balanced, as evidenced here in the Supplement group, there is a noticeable benefit for physical health and mental wellness.

In order to “stress and suppress” the immune system of volunteers in our study, participants trained for and completed a strenuous endurance running event (half-marathon to marathon distance) to induce both physical and mental stress, as well as to create a temporary one-to-two week “susceptibility window” whereby a higher risk for upper-respiratory tract complaints (URTCs) is more likely to be observed following intense endurance competition. Our hypothesis was that the group supplementing with whole microalgae complex as a natural immune modulator would demonstrate fewer URTC symptoms and lower indices of mental/physical stress.

Rather than being an “immune-booster” to stimulate immune system activity, AstaPure® Arava whole microalgae complex may be considered as natural “immune-modulators” that can help to balance overall immune system activity. Such natural substances represent an emerging approach to immunotherapy that either elevates a suppressed immune system “up” to optimal - or calms an over-activated immune system “down” to optimal. We refer to this paradigm as “priming” the immune system - a concept that is analogous to how traditional medicine practitioners and herbalists often refer to the balancing “adaptogenic” effect of certain plants such as ashwagandha, shatavari, cordyceps and rhodiola (collectively referred to as “adaptogens” for their ability to help the body/mind adapt to stressful conditions). In this fashion, a properly primed immune system “pays attention” better to factors that it should fight (e.g. viruses, bacteria, cancer, etc), while “ignoring” factors that should be considered non-harmful (e.g. pollen, mucus membranes, joint cartilage, etc).

The majority of both the microbiome and the immune system reside in the gut - forming a symbiotic relationship and ensuring that the human body is protected from harmful pathogens entering the body via the gut from ingested foods and liquids. Over time, our immune system shapes the diversity of our microbiome, and our gut influences the development and vigilance of our immune system. For example, the gut microbiome acts as a gatekeeper, and a trainer, and increasingly as a communication organ - educating immune cells and orchestrating overall immune system function. In addition, the gut microbiome interacts with the brain in multi-directional ways that involve the immune system using neural, inflammatory, and hormonal signaling pathways [31]. These immune-mediated signals from gut to brain have been implicated in many aspects of mental health and well-being, including depression, anxiety, stress reactivity, and overall psychological mood states [31].

In this study, we report the effect of supplementing with a whole microalgae complex (AstaPure® Arava) for 4 weeks on the physical and psychological well-being of long-distance runners. The current study employed a series of subjective self-assessment questionnaires that addressed overall health status and URTC. In addition to our evaluation of subjects for physical health, a psychological assessment known as the Profile of Mood States (POMS) was conducted to assess overall mood state. We also collected objective markers of microbiome balance (*Streptococcus thermophilus*) and stress hormones (salivary cortisol), both of which are associated with immune system vigilance and psychological stress response and which may represent a possible mechanism by which immune function and psychological mood state are related.

During the course of the 4-week treatment period (3 weeks before and 1 week after an intense endurance run), subjects in the Supplement group reported fewer URTCs, better overall health and a more positive mood state compared to Placebo. In addition,

supplemented runners also showed higher levels of *Streptococcus thermophilus* (*S. thermophilus*) and lower stress hormone exposure (cortisol) - both of which are objective markers related to stress response, immune vigilance and psychological mood state across the gut-immune-brain-axis.

Runners and other athletes, whose athletic activities cause significant levels of both physical and mental stress, are more susceptible to URTI (infections) and URTC (complaints). Previous research has reported that athletes training for a marathon experience a deterioration in global mood state [1,2,4-7,10,11,13,31], and several studies have reported that nutritional supplementation can modulate their health status [5,8,9,14-22].

Physical and psychological factors of subjects undergoing stressful situations are reported to increase URTI and URTC [12,13]. In all cases, the subjects supplemented with the whole microalgae complex experienced better physical health and improved psychological status (Global Mood State), than those in the placebo group. Supplemented subjects reported both fewer URTC symptoms and a better overall health status. The URTC symptoms reported by subjects are typical of cold and flu symptoms, and analogous to symptoms reported in other studies [5,12,13].

The POMS assessment for psychological health strongly supported and mirrored the physical health assessment. Illness and stress impact the immune system in both physical and psychological ways [13,26]. The POMS methodology has been used in more than 3,000 studies [26]; thus it has well-established validity and is sensitive to changes in psychological states pre/post-intervention - particularly in assessing the overall global mood state of subjects - analogous to a measurement of overall well-being and mental resilience.

Conclusion

In this study, supplementation with AstaPure® Arava whole microalgae complex significantly decreased upper-respiratory tract complaints (URTCs) and improved psychological mood state (global well-being) following intense endurance training and competition. These findings support a strong link for physical and mental benefits of AstaPure® Arava whole microalgae complex following the stress of endurance exercise. Additionally, subjects in the Supplement group had lower cortisol and superior microbiome parameters, suggesting that immune vigilance and mental well-being is linked through the microbiome and stress response pathways (e.g. the “Gut-Immune-Brain-Axis”). These results add to the growing scientific literature and natural armamentarium for immune-modulation to both reduce upper-respiratory symptoms and improve psychological mood state in “stressed” individuals (endurance athletes in this study).

Conflicts of Interest and Funding Statement

This study was funded by Algatechnologies Ltd., which manufactures and sells AstaPure® Arava microalgae powder. The study was designed and conducted by 3Waves Wellness, which was compensated to carry out the trial. ST is an employee of Amare Global, which sells dietary supplements that include microalgae extracts. ST and JT are owners of 3Waves Wellness, an independent research organization.

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