Translational Sports Medicine

Effect of ThymoQuin Black Cumin Seed Oil as a Natural Immune Modulator of Upper-Respiratory Tract Complaints and Psychological Mood State

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Abstract

This was a placebo-controlled, double-blind study designed to evaluate the effect of a commercially available dietary supplement on upper-respiratory tract complaints (URTCs) and psychological mood state. Thirty-seven marathon and half-marathon runners consumed 500mg of black cumin seed oil extract (commercial name ThymoQuin®3%) or placebo daily during the 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 questionnaire style health log measuring 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 ThymoQuin supplementation group (500mg black cumin seed oil extract) reported significantly fewer upper-respiratory tract complaints (URTCs) and better overall well-being, as well as lower cortisol and superior microbiome diversity compared to placebo. These results suggest that ThymoQuin black cumin seed oil extract may improve immune system vigilance and overall well-being following the stress of endurance training and competition.

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). For example, in athletes, heavy exercise or intense training may lead to increased

susceptibility to URTI (Nieman et al., 1990; Peters and Bateman, 1983; Spence et al., 2007). Intense exercise is a physical stressor that results in measurable immune challenges with reductions in key immune system components such as neutrophils, natural killer cells, T cells and B cells (Mackinnon and Hooper, 1994; Nieman et al., 1995; Ostrowski et al., 1998). Athletes are particularly susceptible in the one to two-week recovery period after competitive endurance events, partially due to elevations in hormones such as cortisol that coordinate the stress response (Peters and Bateman, 1983). The net effect of an ongoing immune challenge is a weakened immune system, which often results in URTIs/URTCs as well as detrimental effects on psychological mood state.

Exercise stress is similar in certain ways to other stressors, such as psychological stress, which can lead to a weakened immune system and increased susceptibility to URTI/URTC and other disease states (Mackinnon, 1997). Although regular exercise is generally regarded as a buffer against many detrimental effects of stress, psychological stress can also result from prolonged training and competition – in both elite and recreational athletes – with noticeable deteriorations in mood state during intense training periods, and before and after endurance events (Achten et al., 2004; Hassmen and Blomstrand, 1991). Lifestyle factors, such as coping with daily stress, may influence the immune response to exercise (Konig et al., 2000). Reductions in immune cell populations, lowered antibody production and altered cytokine response have been observed due to psychological stress (Cohen et al., 1999; Glaser et al., 1999).

A variety of intervention techniques can be used to ameliorate psychological and physical stress, such as administering selective dietary supplements containing immune modulating compounds (Akerstrom and Pedersen, 2007; Nieman and Bishop, 2006; Peters et al., 1993). In ultra-marathon runners, 600mg of vitamin C, taken 21 days before and 14 days after a 90 km race, reduced URTI symptoms (Peters et al., 1993). Biological response modifiers such as beta-glucan, enhance the innate immune response (Luhm et al., 2006; Niederman et al., 2002), helping to prime immune system function during and following various forms of chronic stress.

Black cumin seed (*Nigella sativa*) oil is widely used in various traditional Eastern and Ayurvedic systems of medicine as a therapeutic tool for many different ailments and conditions. Nigella sativa seeds have been used medicinally in the Middle East and Southeast Asia for over 2,000 years. Black cumin seeds are mentioned in the Bible and the Koran where they are referred to as "the blessing seed," created by God in order to relieve difficult medical conditions. Black seeds were also buried with Egyptian pharaohs to aid in the afterlife journey.

Extensive preclinical, animal, and clinical research has been conducted on N. sativa's properties and it is among the top ranked evidence-based herbal medicines. Most of the therapeutic properties of this plant are attributed to its essential oil constituent, ThymoQuinone (TQ), and modern black seed extracts can be standardized for TQ content (e.g. ThymoQuin, 3% TQ; TriNutra, Israel). A number of laboratory and animal studies have demonstrated immune modulation of black cumin seed via effects on hematopoietic stem cells, lymphocytes, macrophages, T cells, dendritic cells (DCs), natural killer (NK) cells, and a variety of cytokines (IFN, IL-2, TNF-alpha, IL-6, and others).

Approximately 500 clinical trials have evaluated the efficacy of black seed preparations for a variety of conditions. ThymoQuin (black cumin seed oil standardized to 3% ThymoQuinone) is known to have broad-spectrum antimicrobial effects (including anti-viral, anti-bacterial, and anti-fungal) as well as for benefits related to longevity and overall well-being.

Stress-related immune alterations can be consequential for health; they can enhance susceptibility to infectious agents and influence the severity of infectious disease, diminish the strength of immune responses to vaccines, reactivate latent viruses, and slow wound healing.

Materials and Methods

This study was done in accordance with the Helsinki Declaration, as revised in 1983, for clinical research involving humans and was reviewed and approved by an external advisory board (WCG-IRB, Puyallup, WA; Protocol #20202070).

The objective of this study was to recruit 40 healthy volunteers to participate in a research study investigating the effects of dietary supplementation for one-month with black cumin seed oil extract (500mg ThymoQuin 3% ThymoQuinone and 1.8 Free Fatty Acid, TriNutra, Israel; N=20) that may be immunomodulatory for improving immune system vigilance and psychological stress versus Placebo (500mg Maltodextrin; N=20).

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 37 subjects (Table 1). One subject in the ThymoQuin group and two subjects in the Placebo group were lost to follow up. There were no adverse events reported for either group.

Health log

Subjects completed a physical health questionnaire 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. 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. Levels peak in the early morning and drop to the lowest concentration at night. Levels rise independently of circadian rhythm in response to stress. In the blood only 1 to 15% of cortisol is in its unbound or biologically active form, with the remaining cortisol bound to serum proteins. Unbound serum cortisol enters the saliva via intracellular mechanisms, and in saliva the majority of cortisol remains unbound to protein where it can be easily collected and assayed as an index of overall stress exposure and recovery. 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 ~20ng 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, 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 (3 subjects; 1 from the Supplement group and 2 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 ThymoQuin) before and after supplementation.

Table 1. Subject Demographics

Group	Average Age	Men	Women
ThymoQuin	35±6	10	9
Placebo	36±5	10	8

Results

Following 4 weeks of supplementation with ThymoQuin, (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 dramatically more self-reported upper-respiratory tract complaints (URTCs) following the endurance run compared with before (**Figure 1**). However, URTCs, including the total number of symptoms reported such as cough, sore throat, sniffles, stuffiness, etc., were 62% lower in the ThymoQuin group compared to placebo (**Figure 1**).

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 ThymoQuin group demonstrated a 11% improvement (a lower number indicates a less negative psychological mood state).

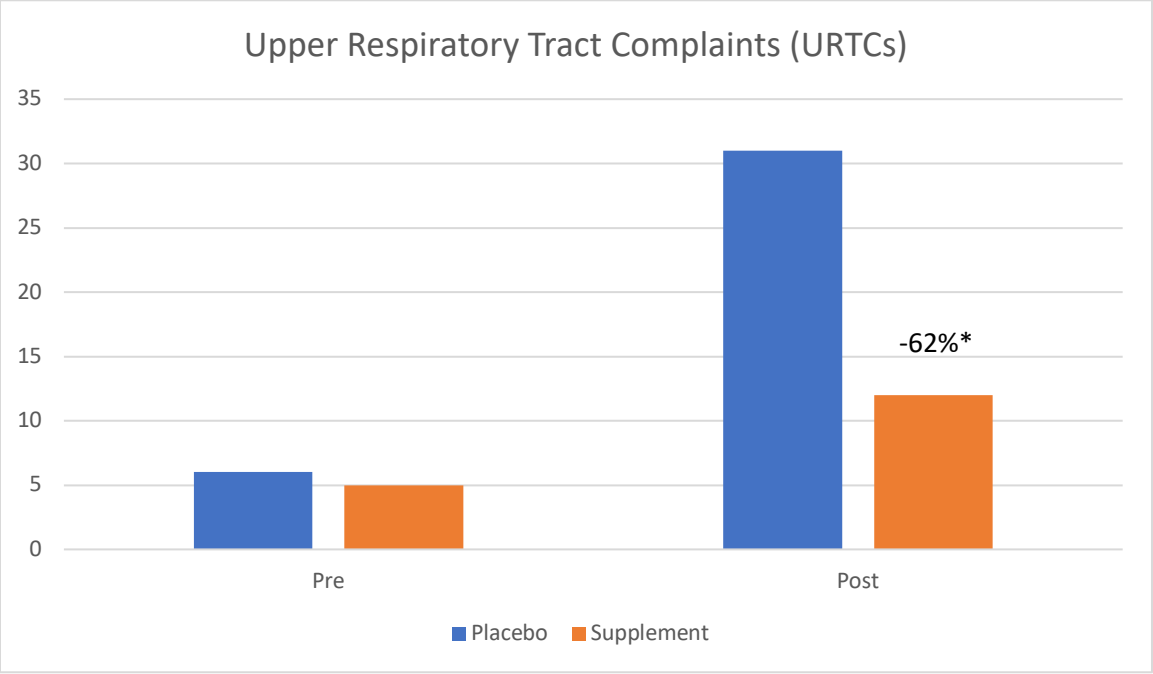

Figure 1. Subjects in the ThymoQuin group had significantly fewer self-reported upper respiratory tract complaints (URTCs) compared to Placebo. (*significantly different from post-supplementation placebo value, $p<0.05$).

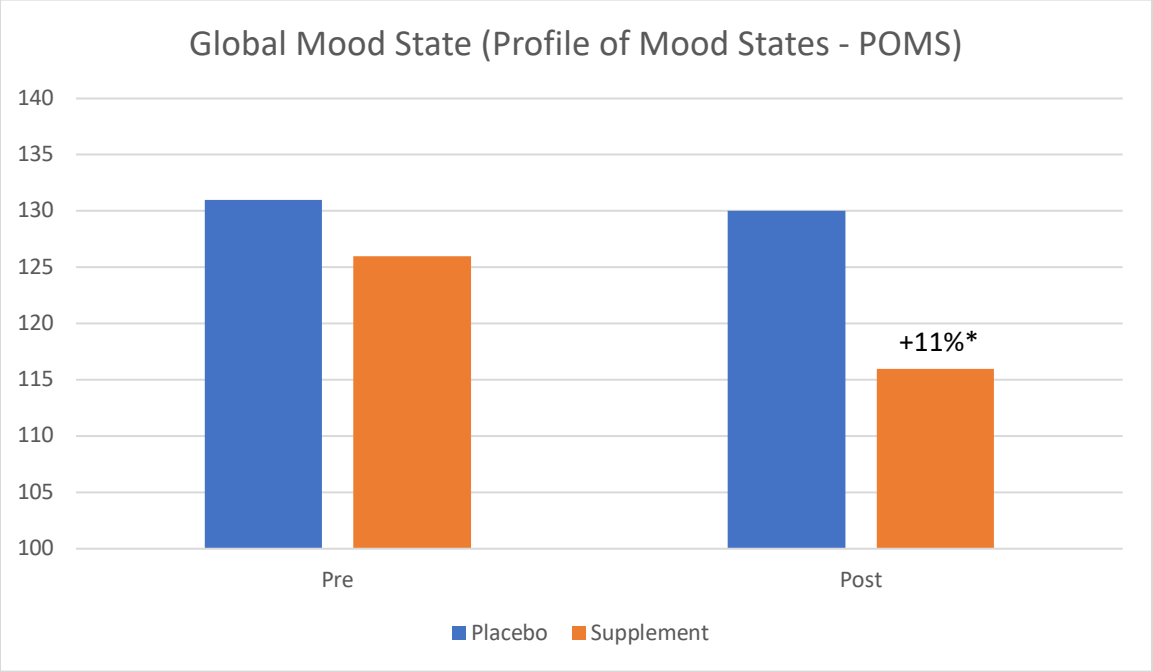

Figure 2. Subjects in the ThymoQuin group had significantly better Global Mood State compared to Placebo (lower score indicates higher well-being index). (*significantly different from post-supplementation placebo value, $p<0.05$).

Objective Measures

There was no significant difference in microbiome indices following the endurance run. However, following supplementation, *Streptococcus thermophilus* values were 66% higher in the ThymoQuin group, suggesting improved immune system regulation (**Figure 3**) and overall microbiome composite score was 8% higher, indicating improved microbiome diversity (**Figure 4**).

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 44% lower in the ThymoQuin group post-supplementation compared to Placebo (**Figure 5**).

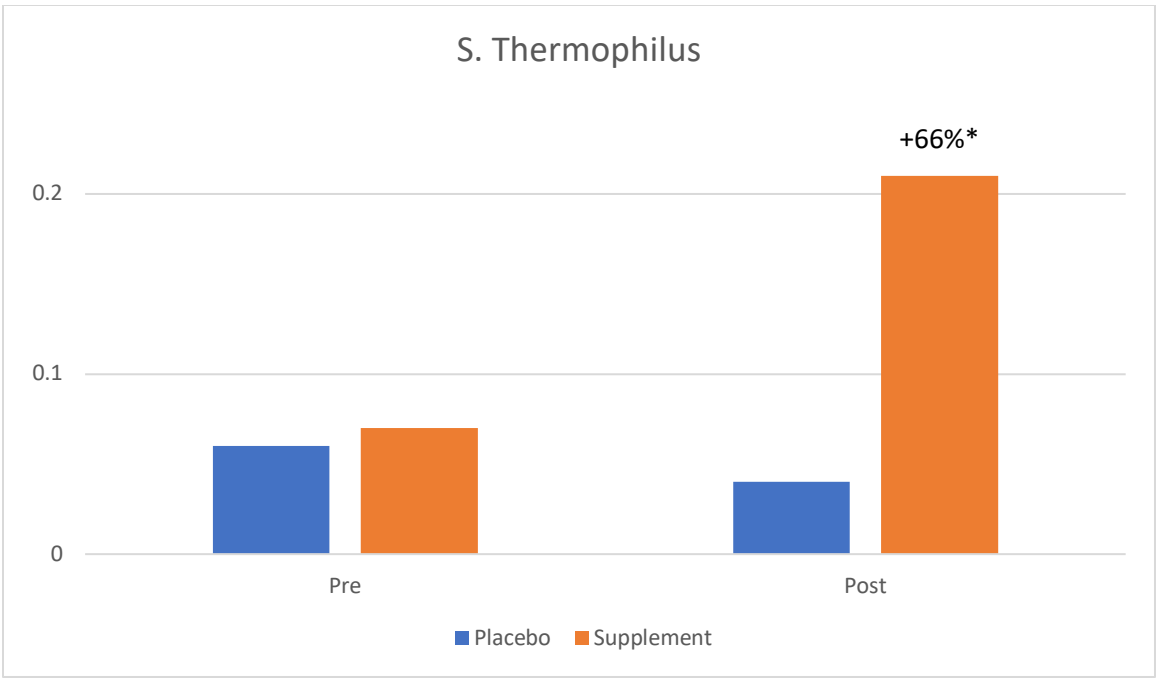

Figure 3. Subjects in the ThymoQuin group had significantly higher relative abundance of *Streptococcus thermophiluis* bacteria compared to Placebo. (*significantly different from post-supplementation placebo value, $p<0.05$).

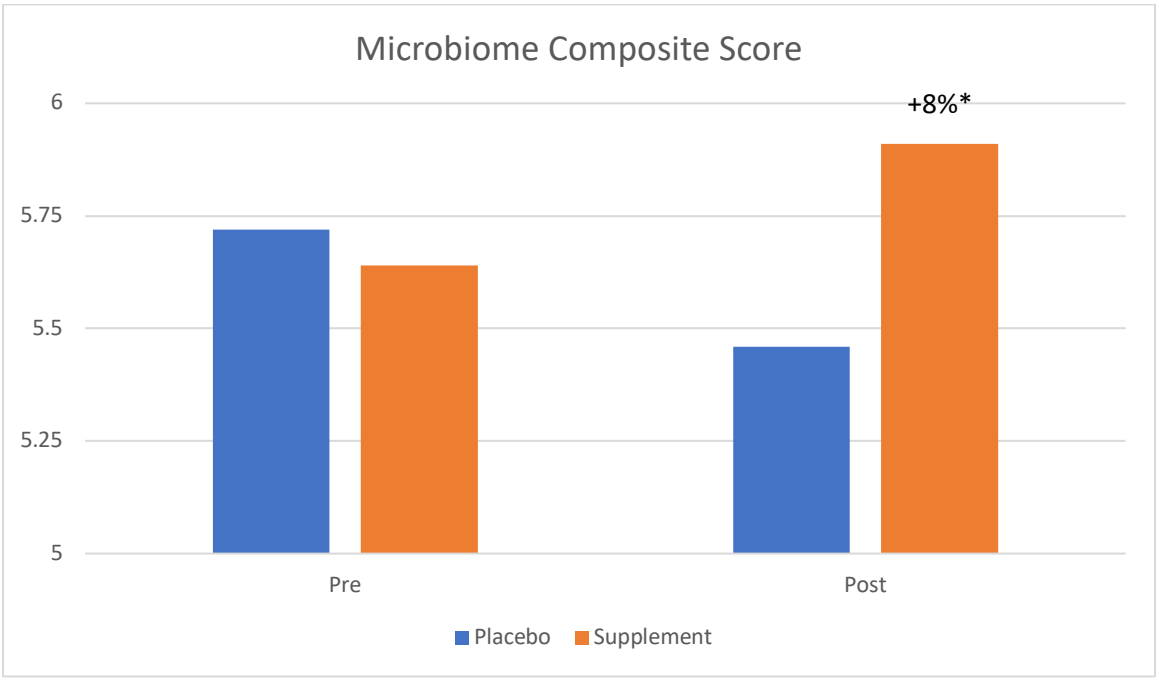

Figure 4. Subjects in the ThymoQuin group had significantly higher Microbiome Composite Score compared to Placebo. (*significantly different from post-supplementation placebo value, $p<0.05$).

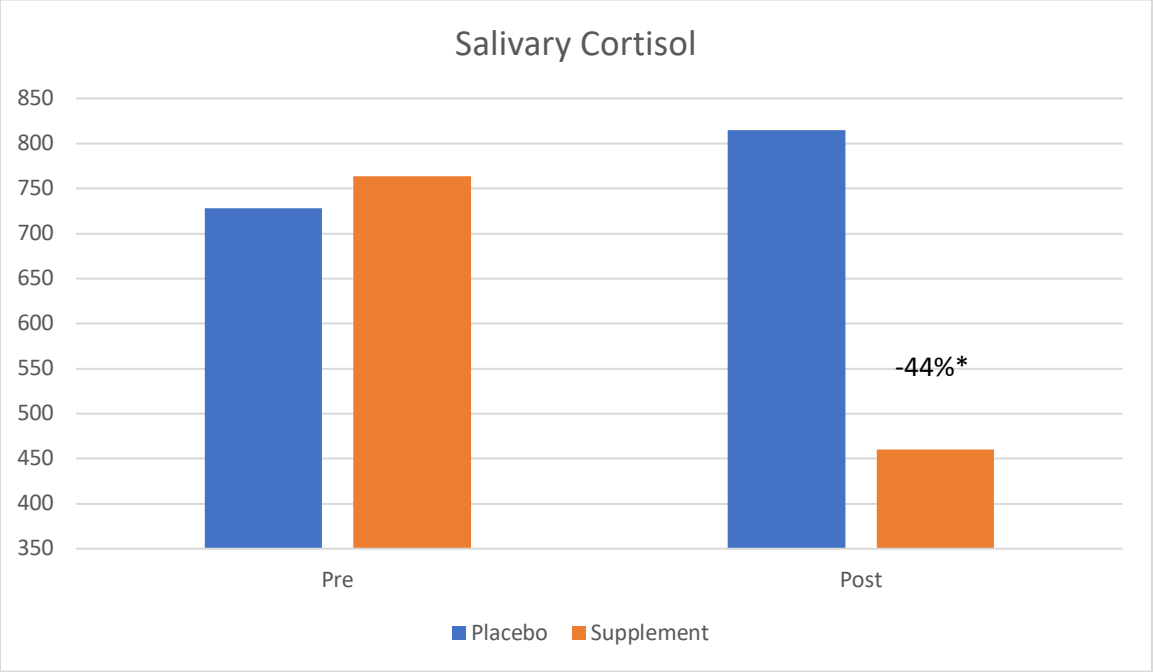

Figure 5. Subjects in the ThymoQuin group had significantly lower Salivary Cortisol (ng//ml) compared to Placebo. (*significantly different from post-supplementation placebo value, $p<0.05$).

Discussion

These results demonstrate a significant and meaningful benefit of ThymoQuin supplementation for 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-Brain-Axis 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 ThymoQuin 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 "susceptibility window" whereby a higher risk for upper-respiratory tract complaints (URTCs) is more likely to be observed in the control/Placebo group. Our hypothesis was that the group supplementing with ThymoQuin 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, ThymoQuin may be considered as a natural "immune-modulator" 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 – in a paradigm that we refer to as "priming" the immune system. A properly primed immune system "pays attention" better to factors that it should fight (e.g. viruses, bacteria, cancer cells, 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. 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. 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 (Margolis et al., 2021). These immune-mediated signals from gut to brain have been implicated in many aspects of mental health and well-being, including depression, anxiety, and overall psychological mood states (Margolis et al., 2021).

In this study, we report the effect of supplementing with ThymoQuin 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 URTCs. In addition to evaluation of subjects for physical health, a psychological assessment known as the Profile of Mood States (POMS) was conducted to assess 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 ThymoQuin 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 being associated with immune vigilance and psychological mood state.

Runners and other athletes, whose athletic activities cause significant physical 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 (Achten et al., 2004; Hassmen and Blomstrand, 1991), and a number of studies have reported that nutritional supplementation can modulate their health status (Nieman et al., 1990; Nieman and Bishop, 2006; Peters and Bateman, 1983; Peters et al., 1993; Spence et al., 2007).

Physical and psychological factors of subjects undergoing stressful situations are reported to increase URTI and URTC (Cohen et al., 1999; Konig et al., 2000). In all cases, the subjects supplemented with ThymoQuin experienced better physical health and a significantly improved psychological status (Global Mood State), than those in the placebo group. ThymoQuin participants 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 (Cohen et al., 1999; Konig et al., 2000).

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 (Konig et al., 2000; Strasner et al., 2001). The POMS methodology has been used in more that 2,900 studies (McNair et al., 1971); thus it has well-established validity. The survey instrument employs 65 adjective based scales that are scored by subjects without knowledge of how the scale scoring will be analyzed. The POMS survey instrument assesses the overall global mood state of subjects – analogous to a measurement of overall well-being and mental resilience.

Previous work has shown benefits of beta-glucan for improving overall immune function, including following intense endurance exercise (Hetland et al., 1998; Hong et al., 2004; Kernodle et al., 1998; Vetvicka et al., 2002; 2008), and a range of other dietary supplements may help reduce URTI symptoms in athletes (Cox et al., 2008; Kekkonen et al., 2007; Peters et al., 1993), i.e., zinc treatment reduced duration and severity of cold symptoms (Prasad et al., 2000); probiotics (Lactobacillus fermentum) reduced the severity and duration of URTI in athletes (Cox et al., 2008); and vitamin C supplementation in ultramarathoners reduced the duration and severity of URTI when taken 21 days before an ultramarathon (90 km) (Peters et al., 1993).

Conclusion

In this study, ThymoQuin significantly decreased upper-respiratory tract complaints and improved psychological mood state following intense endurance training and competition. Additionally, ThymoQuin subjects had lower cortisol and superior microbiome parameters, suggesting that immune vigilance and mental well-being is linked through the microbiome and stress response pathways. These results add to the growing scientific literature and natural armamentarium for immune-modulation to both reduce URTI/URTC 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 TriNutra, which manufactures and sells ThymoQuin black cumin seed oil, and conducted by 3Waves Wellness, which was compensated to carry out the trial. ST is an employee of Amare Global, which sells a multi-ingredient dietary supplement that includes black cumin seed oil. ST and JT are owners of 3Waves Wellness, an independent research organization.

References

1. Akerstrom, T.C. and Pedersen, B.K. (2007) Strategies to enhance immune function for marathon runners: what can be done? Sports Medicine 37, 416-419.
2. Babineau, T.J., Hackford, A., Kenler, A., Bistrian, B., Forse, R.A., Fairchild, P.G., Heard, S., Keroack, M., Caushaj, P. and Benotti, P. (1994a) A phase II multicenter, double-blind, randomized, placebo-controlled study of three dosages of an immunomodulator (PGG-glucan) in high-risk surgical patients. Archives of Surgery 129, 1204-1210.

3. Babineau, T.J., Marcello, P., Swails, W., Kenler, A., Bistrian, B.,and Forse, R.A. (1994b) Randomized phase I/II trial of a macro- phage-specific immunomodulator (PGG-glucan) in high-risk surgical patients. Annals of Surgery 220, 601-609.
4. Bedirli, A., Kerem, M., Pasaoglu, H., Akyurek, N., Tezcaner, T., Elbeg, S., Memis, L. and Sakrak, O.(2007) Beta-glucan attenuates inflammatory cytokine release and prevents acute lung injury in an experimental model of sepsis. Shock 27, 397-401.
5. Cohen, S., Doyle, W.J. and Skoner, D.P. (1999) Psychological stress, cytokine production, and severity of upper respiratory illness Psychosomatic Medicine 61, 175-180.
6. Cox, A.J., Pyne, D.B., Saunders, P.U. and Fricker, P.A. (2008) Oral administration of the probiotic Lactobacillus fermentum VRI- 003 and mucosal immunity in endurance athletes. British Journal of Sports Medicine, in press
7. Davis, J.M., Murphy, E.A., Brown, A.S., Carmichael, M.D., Ghaffar, A. and Mayer, E.P. (2004) Effects of oat beta-glucan on innate immunity and infection after exercise stress Medicine and Science in Sports and Exercise 36, 1321-1327.
8. Hassmen, P. and Blomstrand, E. (1991) Mood change and marathon running: a pilot study using a Swedish version of the POMS test. Scandinavian Journal of Psychology 32, 225-232.
9. Kekkonen, R. A., Vasankari, T. J., Vuorimaa, T., Haahtela, T., Julkunen, I. and Korpela, R. (2007) The effect of probiotics on respiratory infections and gastrointestinal symptoms during training in marathon runners. International Journal of Sport Nutrition and Exercise Metabolism 17, 352-363.
10. Konig, D., Grathwohl, D., Weinstock, C., Northoff, H. and Berg, A. (2000) Upper respiratory tract infection in athletes: influence of lifestyle, type of sport, training effort, and immunostimulant intake. Exercise Immunology Review 6, 102-120.
11. Mackinnon, L.T. (1997) Immunity in athletes. International Journal of Sports Medicine 18, S62-S68.
12. Mackinnon, L.T. and Hooper, S. (1994) Mucosal (secretory) immune system responses to exercise of varying intensity and during overtraining. International Journal of Sports Medicine 15, S179-S183.
13. Margolis, K.G., Cryan, J.F., and Mayer, E.A. (2021) The Microbiota-Gut-Brain Axis: From Motility to Mood. Gastroenterology, Volume 160, Issue 5, 1486-1501.
14. McNair, D., Heuchert, J. and Shilony, E. (2003) Profile of mood states bibliography 1964-2002. Available from URL: http://www.mhs.com
15. Nieman, D.C. and Bishop, N C. (2006) Nutritional strategies to counter stress to the immune system in athletes, with special reference to football. Journal of Sports Science 24(7), 763-772.
16. Nieman, D.C., Henson, D.A., McMahon, M., Wrieden, J.L., Davis, J.M., Murphy, E.A., Gross, S.J., McAnulty, L.S. and Dumke, C.L. (2008) Beta-glucan, immune function, and upper respiratory tract infections in athletes. Medicine and Science in Sports and Exercise 40, 1463-1471.
17. Nieman, D.C., Johanssen, L.M., Lee, J.W. and Arabatzis, K. (1990) Infectious episodes in runners before and after the Los Angeles Marathon. Journal of Sports Medicine and Physical Fitness 30, 316-328.
18. Nieman, D.C., Simandle, S., Henson, D.A., Warren, B.J., Suttles, J., Davis, J.M., Buckley, K.S., Ahle, J.C., Butterworth, D.E. and Fagoaga, O.R. (1995) Lymphocyte

proliferative response to 2.5 hours of running. International Journal of Sports Medicine 16, 404-409.
19. Ostrowski, K., Hermann, C., Bangash, A., Schjerling, P., Nielsen, J.N. and Pedersen, B.K. (1998) A trauma-like elevation of plasma cytokines in humans in response to treadmill running. Journal of Physiology 513, 889-894.
20. Peters, E.M. and Bateman, E.D. (1983) Ultramarathon running and upper respiratory tract infections. An epidemiological survey, South African Medical Journal 64, 582-584.
21. Peters, E.M., Goetzsche, J.M., Grobbelaar, B. and Noakes, T.D. (1993) Vitamin C supplementation reduces the incidence of postrace symptoms of upper-respiratory-tract infection in ultramarathon runners. American Journal of Clinical Nutrition 57, 170-174.
22. Prasad, A.S., Fitzgerald, J.T., Bao, B., Beck, F.W. and Chandrasekar, P.H. (2000) Duration of symptoms and plasma cytokine levels in patients with the common cold treated with zinc acetate. A randomized, double-blind, placebo-controlled trial. Annals of Internal Medicine 133, 245-252.
23. Spence, L., Brown, W.J., Pyne, D.B., Nissen, M.D., Sloots, T. P., McCormack, J.G., Locke, A.S. and Fricker, P.A. (2007) Incidence, etiology, and symptomatology of upper respiratory illness in elite athletes. Medicine and Science in Sports Exercise 39, 577-586.
24. Strasner, A., Barlow, C., Kampert, J. and Dunn, A. (2001) Impact of physical activity on URTI symptoms in Project PRIME participants. Medicine and Science in Sports Exercise 33, S301.
25. Vetvicka, V., Terayma, K., Mandeville, R., Brousseau, P., Kournakakis, B. and Ostroff, G. (2002) Pilot study: Orally-administered yeast beta 1-3-glucan prophylactically protects against anthrax infection and cancer in mice. Journal of the American Nutraceutical Association 5, 5-9.
26. Vetvicka, V., Vashishta, A., Saraswat-Ohri, S. and Vetvickova, J. (2008) Immunological effects of yeast- and mushroom-derived beta- glucans. Journal of Medicinal Food 11, 615-622.