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Effects of Fiber Supplementation for Four Weeks on Athletic Performance in Japanese College Athletes: A Case Study—Measurement of the Athletic Performance, Salivary Biomarkers of Stress, and Mood, Affect Balance

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Abstract

Aim: In this study, we explored the effects of dietary fiber on athletic performance. **Methods:** Twenty healthy college athletes (male/female, 1/1) consumed 6 grams of dietary fiber (Fiberpro, Taiyo Lab Inc., Tokyo) daily for four weeks and were evaluated for their athletic performance, salivary biomarkers of stress (α-amylase activity pre-post exercise, cortisol, melatonin, and secretory immunoglobulin A (SIgA) levels), and mood/affect using the Profile of Mood State 2nd edition (POMS 2®). Measurements were taken at baseline (before supplementation), at Week 4 (after 4 weeks of supplementation), and at Week 8 (4 weeks after the completion of supplementation). **Results:** Results showed that athletic performance and exercise-induced elevation in salivary α-amylase activity improved with Fiberpro supplementation in both men and women. Further, the Anger-Hostility scale in POMS was significantly elevated in men; in women, an increase in Vigor-Activity score, a single index of positive mood, was noted. These findings suggest that Fiberpro may induce differential affective responses in men and women. Meanwhile, Fiberpro did not affect the normal diurnal changes in salivary melatonin and SIgA levels, but it appeared to augment the normal circadian patterns of cortisol, an effect that persisted for a month without Fiberpro intake. We propose that boosting fiber intake in young, healthy athletes may improve gut microbiota and confer resilience against stress.

Keywords

Athletic Performance, Dietary Fiber, Salivary Assay, Stress

1. Introduction

Dietary fiber is defined as the "indigestible portions of plants which are not hydrolyzed by endogenous enzymes in the small intestine", and for this reason, it has been long disregarded as a nutritive element in "traditional" nutrition. Since 1970, however, dietary fiber has been catapulted to a new status as "the sixth nutritive substance" for its physiological effects that defy explanation from a nutritional perspective, and for its role as a "nutritive element" in maintaining optimal health. Fiber is now widely recognized for its beneficial role in the prevention of various lifestyle diseases.

Modern life and dietary habits have been associated with reduced intake of dietary fiber in both adults and children. Although the Japanese Ministry of Health, Labour and Welfare recommended in 2015 that men and women consumed more than 20 grams and more than 18 grams of fiber each day, respectively, the actual average daily intake reported was 12.3 - 16.3 grams for men and 11.8 - 16.1 grams for women [1].

Meanwhile, nutritional support for athletes has garnered serious attention in recent years in preparation for the 2020 Tokyo Olympic and Paralympic Games. In Japan, the "Nutrition Guidelines for Athletes" serves as a reference for sports nutrition, but the range and standards of evaluable nutritional elements described in this reference for individual nutritional support are deemed insufficient. Asami *et al.* have conducted interviews among male and female student athletes to establish dietary reference intakes for this population as an attempt to fill in the gaps for the dearth of research on sports nutrition [2].

The aim of this study was to assess whether fiber supplementation would affect athletic performance, mood/affect, and salivary biomarkers of stress. Male and female college athletes ingested 6 grams of fiber each day (Fiberpro, Taiyo Lab Inc., Tokyo, Japan) for four weeks and their physical and mental status was evaluated. The effects of Fiberpro on athletic performance were determined by the maximum number of repetitions of sit-ups and repeating side-to-side jumps performed under circuit training-induced fatigue. The effects of Fiberpro on affect were assessed by self-reported mood states using the Profiles of Mood States 2nd edition (POMS 2®) as well as diurnal changes in salivary cortisol, melatonin, and SIgA levels. Salivary α-amylase activity was measured as an index of physical stress level.

2. Participants and Methods

2.1. Participants

Twenty college athletes (male/female, 1/1) aged 20 - 23, the most physically fit men and women, enrolled in Chuo University Tennis Club who provided written consent participated in the study. We limited our participants to those who had no health condition and actively played tennis or engaged in athletic training at least 2 - 3 times a week. Here, we defined "athletes" as people who were healthy and did exercise constantly at least two hours per time. This study was approved by the Ethics Committee at Shiba Palace Clinic (Tokyo, Japan).

2.2. Study Design

2.2.1. Fiber Supplementation

Fiberpro (100 g) contains 0 - 1 g of protein, 0 g of fat, 8.9 g of carbohydrate, 84.7 g of dietary, and 50 - 150 mg of sodium chloride.

Participants consumed 6 g/day, which supply a deficiency of daily dietary fiber of men and women, of Fiberpro dissolved in water or any other liquid for four weeks, which is the period positive effect was reported by manufacturer. The following outcome measures were assessed:

1. Maximum repetitions of sit-ups and repeating side-to-side jumps completed under extreme (circuit training-induced) fatigue,
2. Mood states (POMS 2®),
3. Salivary biomarkers (cortisol levels, melatonin levels, SIgA levels, and *α*-amylase activity).

Meals were standardized for all participants throughout the study.

2.2.2. Assessment of Athletic Performance

(1) Sit-ups and Repeating Side-to-Side Jumps

All participants performed the "super circuit training" to induce exhaustion. Under this condition, participants performed maximum repetitions of sit-ups for 30 seconds followed by maximum repetitions of repeating side-to-side jumps (100 cm to each side) for 20 seconds to evaluate their athletic performance. Testing was conducted between 18:00 and 20:00.

(2) Super Circuit Training

Participants were instructed to perform the following 12 exercises at maximal power for 15 seconds each in a sequential manner (front lunges, crossover sit-ups, side lunges, back extensions, side crossover lunges, arm curls using tubes, butterfly, side leg raises, rowing, push-away, calf raises, and ball gripping). Between each exercise, 20 seconds of jumping rope at the speed of running was also performed. One round of circuit training lasted approximately 7 min. In total, two rounds of circuit training were performed. Athletic performance was evaluated at baseline (before Fiberpro supplementation) and at week 4 (after 4 weeks of Fiberpro supplementation).

2.2.3. Questionnaire on Mood States

The Japanese version of POMS 2® instrument was used to assess the subjective mood states of the participants. The full-length version is comprised of 65 self-report items using the 5-point Likert Scale [3]. The POMS 2® questionnaire measures six different dimensions of mood swings over a period of time, including anger or hostility, confusion or bewilderment, depression or dejection, fatigue or inertia, tension or anxiety, and vigor or activity. Total mood disturbance is a function of these six subscale scores. The Friendliness subscale is scored separately.

Negative mood states:

- Anger-Hostility score reflects the extent to which the subject felt anger or antipathy toward others.

- Confusion-Bewilderment score indicates the extent to which the subject felt confused, disorganized, or perplexed.
- Depression-Dejection score indicates the extent to which the subject experienced depression accompanied by a sense of personal inadequacy.
- Fatigue-Inertia score reflects the extent to which the subject felt weary and/or listless.
- Tension-Anxiety score reflects the extent to which the subject experienced heightened anxiety and musculoskeletal tension (as observable somatic tension and/or psychomotor manifestations).

Positive mood states:

- Vigor-Activity score indicates the extent to which the subject felt vigorous and/or energetic.
- Friendliness score measures the extent to which the subject experienced positive feelings toward others.

Participants completed the POMS 2® questionnaire at baseline, Week 4, and Week 8 (4 weeks after completion of 4 weeks of Fiberpro supplementation).

2.2.4. Salivary Assays and Collection Methods

Salivary samples were collected at fixed times (upon waking, before lunch, before dinner, and before bedtime) using the Saliva Collection Aid (SCA) (Salimetrics LLC, USA). Participants were instructed to allow saliva to pool in the mouth and gently force it through the SCA tube into a collection vial. Samples were stored at −20˚C until analysis. Salivary cortisol, melatonin, and SIgA levels were measured at baseline and at weeks 4 and 8 using the following kits, respectively: Salivary Cortisol Enzyme Immunoassay Kit, Salivary Melatonin Enzyme Immunoassay Kit, and Secretory Immunoglobulin A Salivary Immunoassay Kit (Salimetrics LLC, USA) [4].

2.2.5. Salivary Amylase Analysis

Pre-post exercise samples were collected using a sublingual test paper held in the mouth for 30 seconds. Salivary amylase monitor (NIPRO, Osaka, Japan) was used to measure the α-amylase activity. Samples were collected at baseline and before and after the assessment of athletic performance in Week 4.

2.3. Statistical Analysis

All data are expressed as Mean ± SE. The student's t-test was used to analyze the difference between the outcome measures obtained before and after Fiberpro intake. P values less than 0.05 were considered statistically significant for all analysis. Statistical analysis was performed using the StatView J5.0 software.

3. Results

3.1. Effects of Fiberpro on Athletic Performance

Figure 1 shows the effects of Fiberpro on athletic performance (maximum repetitions of sit-ups and repeat side-to-side jumps performed under extreme fatigue induced by "super circuit training"). At Week 4, the overall mean number of

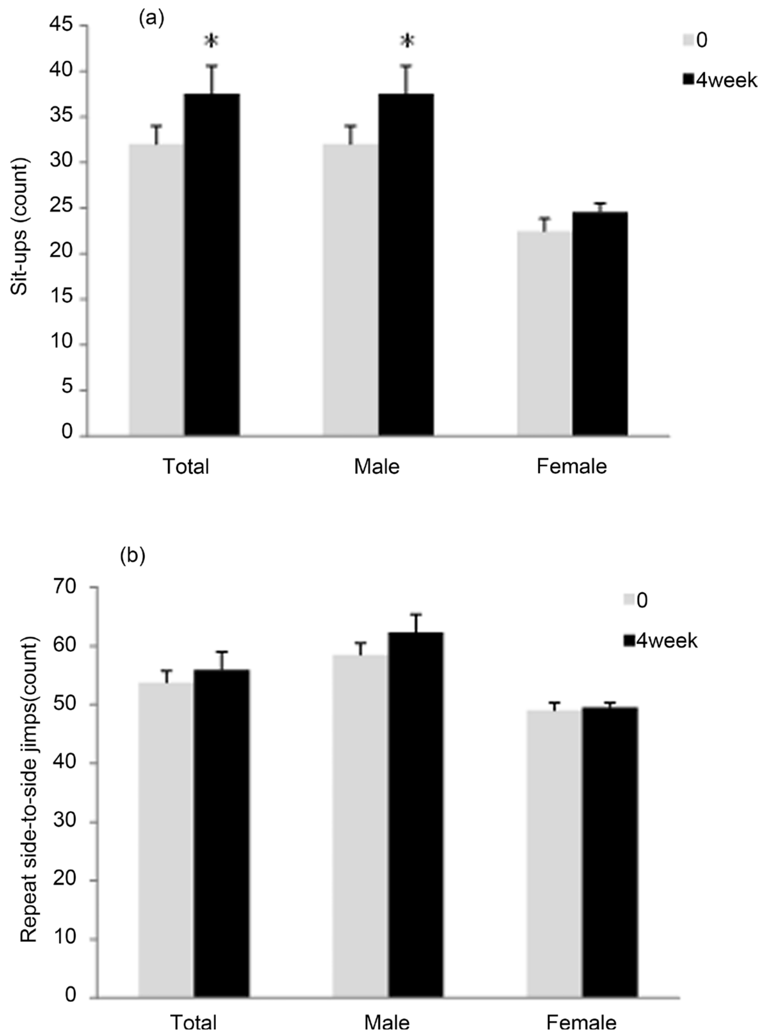

Figure 1. Effects of Fiberpro on athletic performance. (a) Sit-ups, (b) Repeat side-to-side jumps. (Mean ± SE) *: $p < 0.05$ vs. 0.

sit-ups increased significantly from 27.3 ± 1.6 to 31.1 ± 2.2 ($p < 0.05$). The mean number of repeat side-to-side jumps increased from 53.8 ± 1.5 to 55.9 ± 1.9.

The mean number of sit-ups performed by female athletes at baseline was 22.5 ± 1.3, which increased significantly to 24.6 ± 0.9 at week 4 ($p < 0.05$). The differences between the mean number of repeat side-to-side jumps at baseline and Week 4 were unremarkable.

The mean number of sit-ups performed by male athletes at baseline was 32.0 ± 2.0, which increased significantly to 37.5 ± 3.1 at Week 4 ($p < 0.05$). The mean number of repeat side-to-side jumps also increased from baseline to Week 4 (58.5 ± 1.6 vs. 62.3 ± 1 .8).

3.2. Effects of Fiberpro on Salivary α-Amylase Activity under Physical Stress

Figure 2 shows the effects of Fiberpro on pre-post exercise salivary α-amylase activity. Pre-exercise salivary α-amylase activity at baseline was 24.9 ± 11.9 kIU/L, which increased markedly to 49.7 ± 10.0 kIU/L post-exercise. Pre- and

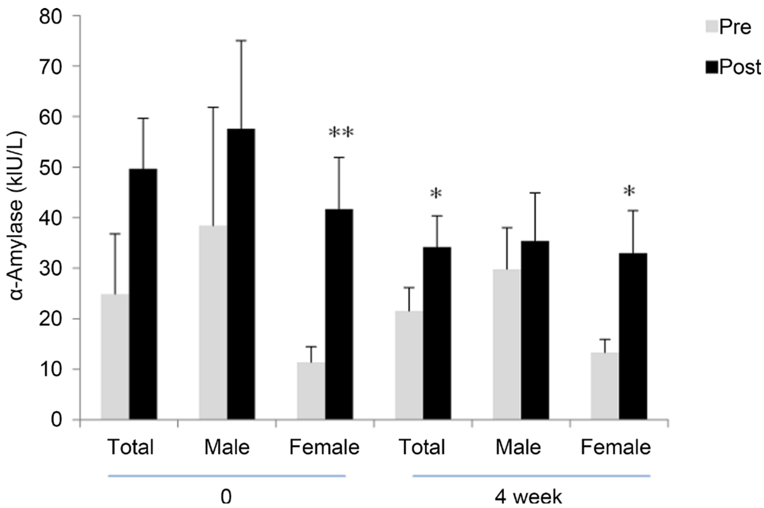

Figure 2. Effects of Fiberpro on salivary *α*-amylase activity. (Mean ± SE) *: p < 0.05, **: p < 0.01 vs. pre.

post-exercise *α*-amylase levels at Week 4 were 21.6 ± 4.6 kIU/L and 34.2 ± 6.2 kIU/L (p < 0.05), respectively, indicating that a rise in *α*-amylase activity in week 4 was lower than that of the baseline.

Among female athletes, the pre-post exercise increase in *α*-amylase activity at baseline was significant (24.9 ± 11.9 kIU/L vs 49.7 ± 10.0 kIU/L, p < 0.01). At Week 4, there was still a significant increase in activity (13.3 ± 2.6 kIU/L vs. 33.0 ± 8.4 kIU/L, p < 0.05); however, the increase observed in week 4 was lower than that of the baseline.

Among male athletes, the pre-post exercise increase in *α*-amylase activity at baseline was also significant (38.4 ± 23.4 kIU/L vs. 57.6 ± 17.4 kIU/L, p < 0.01). At Week 4, the activity increased (29.8 ± 8.2 kIU/L vs. 35.4 ± 9.5 kIU/L, p < 0.05), but this was lower relative to the increase observed at baseline.

3.3. Effects of Fiberpro on Mood States

Table 1 shows the effects of Fiberpro on mood as assessed by POMS 2[*]. Overall, our results indicate that the Anger-Hostility score (negative mood) increased significantly after Fiberpro supplementation, yet other scores remained unchanged.

In women, the scores on negative mood including Anger-Hostility, Confusion-Bewilderment, Depression-Dejection, Fatigue-Inertia, Tension-Anxiety were unaffected. However, the Vitality-Activity scale of the positive mood state increased at week 4 which persisted until Week 8.

In men, the Anger-Hostility and Depression-Dejection scores increased significantly after Fiberpro supplementation (p < 0.01). The Vitality-Activity and Friendliness scores (positive mood) remained unaltered.

3.4. Effects of Fiberpro on Salivary Biomarkers of Stress

3.4.1. Salivary Cortisol Levels

Figure 3 shows the effects of Fiberpro on circadian cortisol patterns. Overall, Fiberpro restored the normal diurnal fluctuations of cortisol at Weeks 4 and 8,

Table 1. Effects of Fiberpro on mood states.

Total	0	4 weeks	8 weeks
AH	50.5 ± 1.9	57.4 ± 2.5**	56.6 ± 3.1
CB	57.0 ± 2.6	59.5 ± 1.8	59.0 ± 1.6
DD	53.3 ± 2.0	59.9 ± 2.4	55.9 ± +2.4
FI	56.1 ± 1.8	55.8 ± 2.1	56.6 ± 1.8
TA	56.2 ± 2.3	59.2 ± 1.8	58.6 ± 1.6
VA	55.4 ± 2.0	57.4 ± 1.8	58.6 ± 2.0
F	60.6 ± 2.3	60.6 ± 1.9	60.7 ± 2.2
Male			
AH	50.8 ± 1.9	60.5 ± 2.8**	65.1 ± 5.1*
CB	52.4 ± 3.2	58.8 ± 2.6	58.4 ± 2.4
DD	51.2 ± 2.1	62.7 ± 3.2*	62.0 ± 4.2
FI	56.6 ± 2.5	55.0 ± 2.8	58.9 ± 2.1
TA	51.7 ± 2.5	59.9 ± 2.8	59.3 ± 2.9
VA	56.9 ± 3.1	59.4 ± 2.4	57.6 ± 2.5
F	61.8 ± 3.1	61.9 ± 2.1	59.5 ± 2.2
Female			
AH	50.2 ± 3.4	54.2 ± 4.0	49.7 ± 2.4
CB	61.6 ± 3.8	60.1 ± 2.6	59.5 ± 2.2
DD	55.4 ± 3.5	57.1 ± 3.5	51.0 ± 1.7
FI	55.6 ± 3.1	56.6 ± 3.4	54.8 ± 2.7
TA	60.7 ± 3.5	58.4 ± 2.2	58.0 ± 1.9
VA	53.9 ± 2.7	55.3 ± 2.6	59.9 ± 3.2
F	59.4 ± 3.4	59.9 ± 3.2	61.7 ± 3.6

AH: Anger-Hostility, CB: Confusion-Bewilderment, DD: Depression-Dejection, FI: Fatigue-Inertia, TA: Tension-Anxiety, VA: Vitality-Activity, F: Friendliness, (Mean ± SE) *: $p < 0.05$, **: $p < 0.01$ vs. 0.

i.e., peaking upon waking and dropping at bedtime.

Female athletes demonstrated ideal diurnal cortisol fluctuations naturally at baseline and weeks 4 and 8, with peaks in the morning and troughs at bedtime. In this study, Fiberpro did not induce any changes in this pattern in women.

By contrast, diurnal cortisol levels in male athletes remained constant upon waking, before lunch, and before dinner. At week 4, the levels peaked before noon and dropped before dinner or bedtime. At week 8, cortisol levels peaked in the morning upon waking and gradually decreased over the course of the day.

3.4.2. Salivary Melatonin Levels

Figure 4 shows the effects of Fiberpro on circadian melatonin patterns. We did not observe any effects of Fiberpro on melatonin levels.

Melatonin levels in female athletes decreased from morning to noontime, then gradually increased until bedtime at all three time points (baseline, Week 4, and

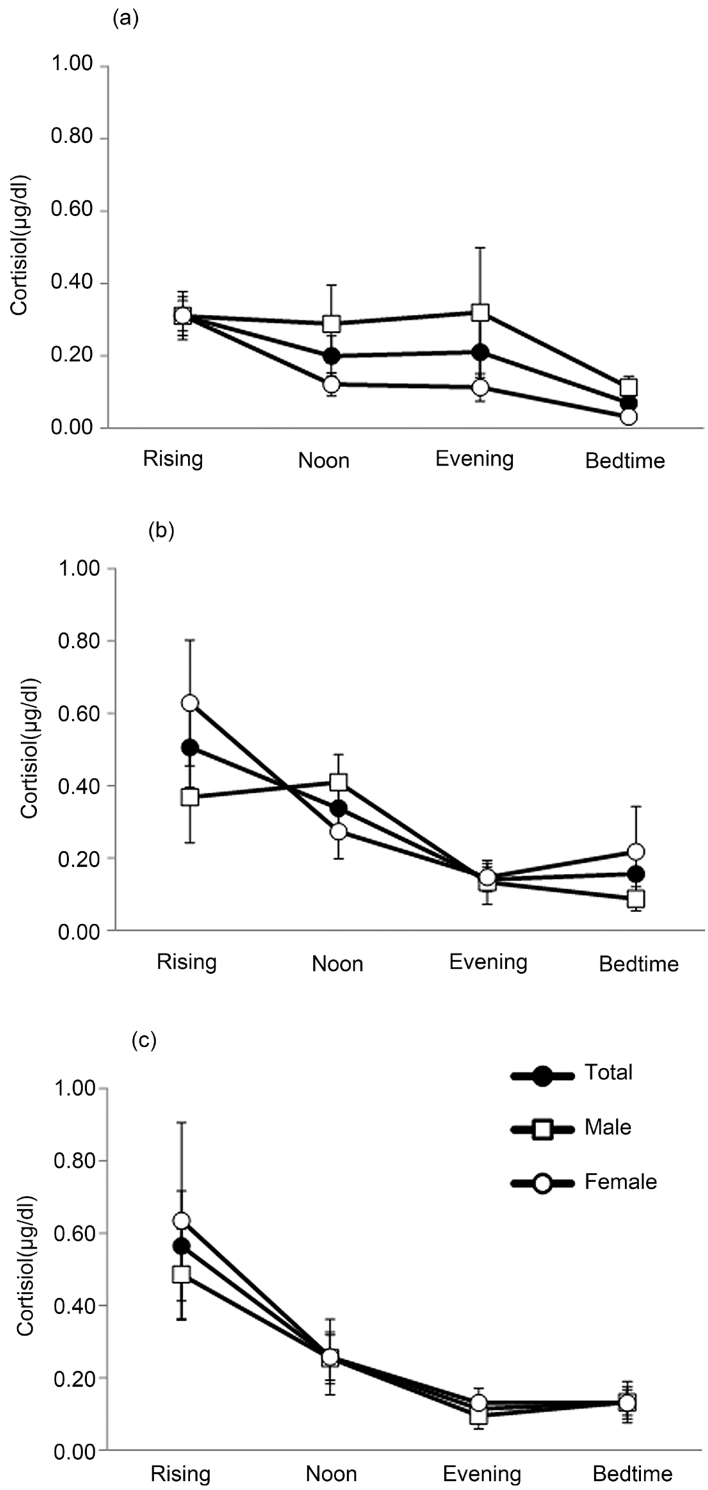

Figure 3. Effects of Fiberpro on circadian patterns of salivary cortisol; (a) 0, (b) Week 4, (c) Week 8 (Mean ± SE).

Week 8).

Melatonin levels in male athletes at baseline and Week 4 increased as the day progressed. At Week 8, the levels peaked upon waking and gradually dropped until bedtime.

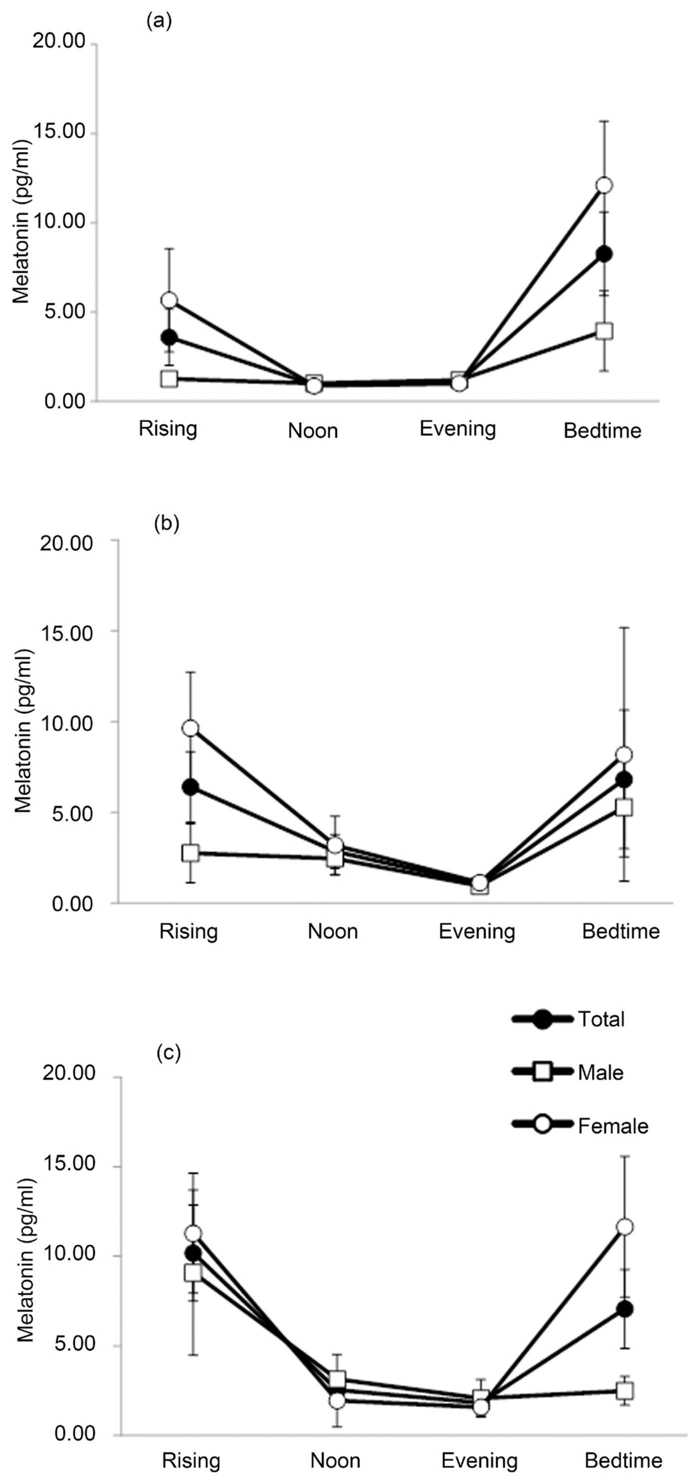

Figure 4. Effects of Fiberpro on circadian patterns of salivary melatonin; (a) 0, (b) Week 4, (c) Week 8 (Mean ± SE).

3.4.3. Salivary SIgA Levels

Figure 5 shows the effects of Fiberpro on circadian SIgA patterns. The SIgA levels demonstrated normal diurnal variations with peaks in the morning and troughs in the evening. The fluctuations in SIgA levels were not affected by Fiberpro supplementation. Differences in SIgA levels between men and women

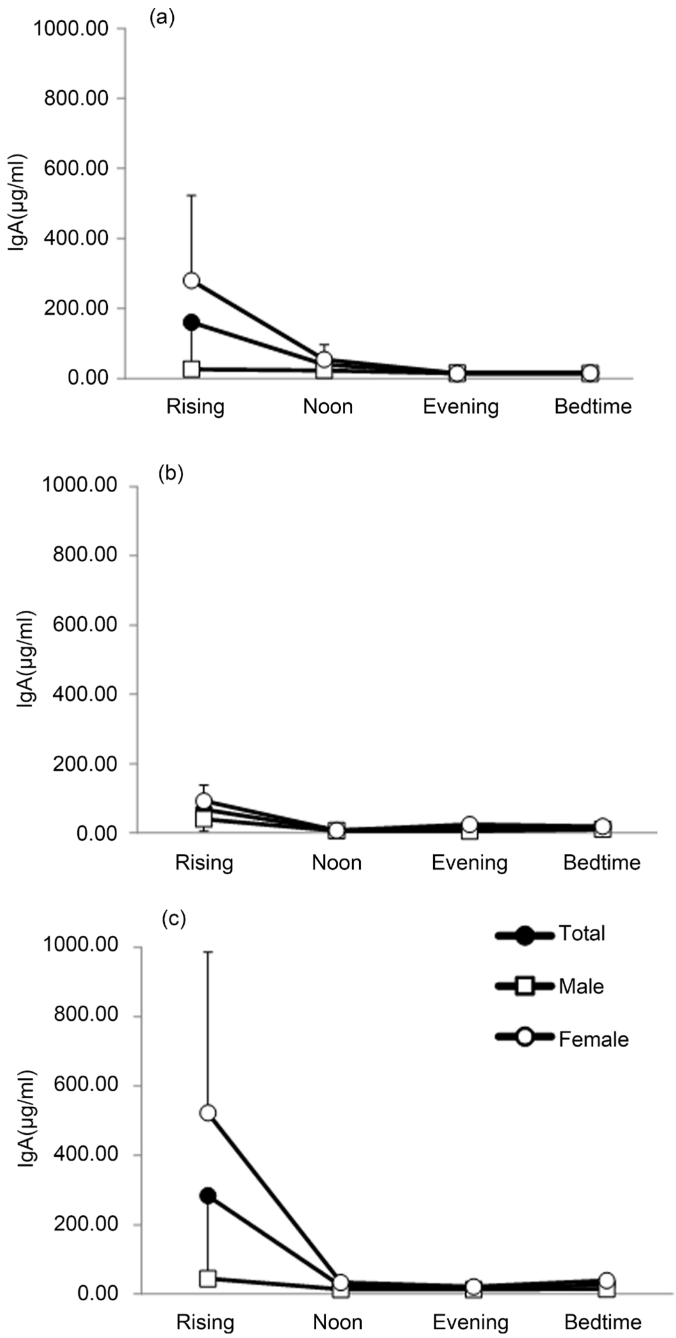

Figure 5. Effects of Fiberpro on circadian patterns of salivary SIgA; (a) 0, (b) Week 4, (c) Week 8 (Mean ± SD).

were not observed.

4. Discussion

Dietary fiber has been touted as "the sixth nutritional factor" and has received considerable attention for its beneficial effect in reducing the risks of various lifestyle diseases. Nevertheless, athletes reportedly consume less than half of the recommended daily allowance [5]. Further, the potential effects of fiber supplementation on athletic performance have not been thoroughly investigated.

Therefore, this study was conducted to determine the effects of dietary fiber on athletic performance in healthy college athletes.

We found that four weeks of Fiberpro intake (6 grams per day) enhanced athletic performance, particularly in male athletes. Further, the increase in salivary α-amylase activity was damped after four weeks of supplementation. Salivary α-amylase activity is a sensitive marker of physical stress and is known to elevate following a workout [6]. Thus, our findings imply that fiber may offset physical stress. Fiber is frequently referred to as "a nutritional substance that is neither digested nor absorbed in the small intestine, but bears a physiological role in maintaining optimal digestive health" [7]. In this study, we found that Fiberpro enhanced athletic performance. The significant improvement in performance among male athletes, however, may be due to their normally lower fiber intake than the reference daily intake as previously reported [2]. Further, we posit that the improvement in athletic performance may be due to the physiological effect of fiber in the GI tract, although the precise mechanism of this action warrants further investigation.

Psychological assessment of our participants showed that Fiberpro supplementation significantly elevated the Anger-Hostility score, but other negative mood scores remained unaffected. We found differences between men and women in POMS 2® results, with male athletes showing significant elevations in negative mood, *i.e.*, Anger-Hostility and Depression-Dejection scores. By contrast, female athletes had elevated positive mood as reflected in an increase in the Vitality-Activity score. Thus, our findings imply that there may be sex differences in response to continuous fiber supplementation. We conjecture that the increase positive mood in female athletes may be due to an improvement in gut microbial diversity that positively affects the brain-gut axis to alleviate stress [8]. The significance and relevance of gut microbiota on psychological health is a field ripe for further research.

Our salivary assays showed that Fiberpro did not affect salivary melatonin and SIgA levels. Meanwhile, the normal circadian patterns of cortisol were augmented by Fiberpro with peaks in the morning and troughs in the evening, and these patterns persisted even after the discontinuation of supplementation. Cortisol is a hormone that is released from the adrenal cortex in response to various stressors that activate the hypothalamic-pituitary-adrenal (HPA) axis [9] [10] [11]. As such, it is a well-known biomarker of stress. Cortisol is known to peak in the morning and gradually decrease over the course of the day. In this study, Fiberpro supplementation appeared to augment this normal daily fluctuation. Together, these findings imply that dietary fiber may confer an anti-stress effect, but more studies are necessary to characterize this effect in greater detail.

5. Conclusion

In summary, our findings suggest that dietary fiber enhances athletic performance, reduces physical stress, and augments the normal diurnal changes in cortisol levels. We propose that boosting fiber intake in young, healthy athletes may improve gut microbiota and confer resilience against stress. Future research may benefit from considering body weight, BMI and smoking habits, and clarifying the mechanisms of how fiber affects gut health and the stress response.

Acknowledgements

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