A significant decrease in the gene expression of interleukin-17 following the administration of synbiotic in patients with allergic rhinitis who underwent immunotherapy: A placebo-controlled clinical trial

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Background: Allergic Rhinitis (AR) is the most common allergic disease worldwide. The present study, evaluated effects of synbiotic on gene expression of interferon-gamma (IFN-γ), interleukin-4 (IL-4), interleukin-10 (IL-10), interleukin-17 (IL-17), transforming growth factor beta (TGF-β), and forkhead box P3 (FoxP3) in AR patients who received concomitant immunotherapy in a placebo-controlled clinical trial. Materials and Methods: Twenty AR patients were randomized in synbiotic and placebo groups and received cluster immunotherapy for 2 months. RNA was extracted from peripheral PBMCs, then the cDNA synthesized. Subsequently, SYBR Green real-time Reverse transcription polymerase chain reaction technique was employed for studying the expression of mentioned genes. In addition, SNOT-22 and mini-Rhinoconjunctivitis Quality of Life Questionnaire questionnaires were completed by patients. Data were analyzed before and also 2 and 6 months after intervention. Results: Clinical symptoms and quality of life were improved with immunotherapy, but there was no significant difference between the placebo and synbiotic groups. Gene expression of IFN-γ, TGF-β, and FoxP3 was increased whereas the gene expression of IL-4 and IL-10 decreased, but not significant. Interestingly, the gene expression of IL-17 in the synbiotic group was significantly decreased versus placebo after 2 months (P = 0.001) and also at the end of intervention (P = 0.0001) comparing with the time zero. Conclusion: Significant reduction in the IL-17 gene expression following administration of synbiotic versus placebo shows the importance of synbiotic in control of the immunopathogenesis of AR. Further studies with more samples are recommended. In addition, evaluating the effects of synbiotic in patients who do not undergo immunotherapy is suggested to get a better conclusion.

Key words: Allergic rhinitis, forkhead box P3 transcription factor, immunotherapy, interferon-gamma, interleukin-10, interleukin-17, interleukin-4, synbiotic, transforming growth factor beta

INTRODUCTION

Allergic diseases have become one of the most important health problems worldwide, and it is thought that 20%–30% of western populations suffer from at least one form of them.1[2] Allergic Rhinitis (AR) as the most common allergic diseases has an ascending prevalence worldwide[2,3] that annually billion dollars paid for the treatment of physical and mental problems and disabilities of such patients that imposes a heavy burden on health services.[4,5] General principles of treatment are education and awareness, the avoidance of allergen,
appropriate medicine use, and finally the immunotherapy application.\textsuperscript{[6–9]} Given that complete allergen avoidance is not possible and administrations of current medicines are restricted because of their side effects and also decreased effectiveness following continuous consumption. Therefore, trying to find ways to increase immunotherapy effects and choosing alternative treatments are still one of the issues of interest. Based on hygiene hypothesis and evidence, probiotics or nonpathogenic commensal microorganisms that coexist with the living being, especially human, are beneficial and can be considered as a complementary therapy for allergic diseases. Definition of the Food and Agriculture Organization of the United Nations and the World Health Organization for probiotics is “Live microorganisms that when administrated in sufficient quantities confer a health benefit on the host.” Prebiotics are nutrition elements that selectively induce growth and activity of limited numbers of the colon residing bacteria and is consist of indigestible carbohydrates such as inulin, fructooligosaccharides (FOS), galactooligosaccharides, and lactose. The mixture of probiotics and prebiotic called Synbiotic.\textsuperscript{[9]}

The aim of this study was to evaluate the effectiveness of synbiotic on gene expression of interferon-gamma (IFN-\(\gamma\)), interleukin-4 (IL-4), interleukin-10 (IL-10), interleukin-17 (IL-17), transforming growth factor beta (TGF-\(\beta\)), and forhead box P3 (FoxP3) when it administrated simultaneously with immunotherapy in a placebo-controlled, randomized, double-blind clinical trial in AR patients in the city of Mashhad, in North-Eastern Iran.

MATERIALS AND METHODS

Characterization of patients
Twenty AR patients enrolled at the Mashhad University of Medical Sciences, Allergy ward of Ghaem Hospital, Mashhad, North-Eastern Iran. Each participant signed a written informed consent. Patients were considered for the study based on clinical criteria, positive prick test for aeroallergens and established perennial AR. Exclusion criteria comprised pregnancy, history of autoimmune or immunodeficiency disorders, systemic corticosteroids or immunosuppressive medicine usage, suffering from allergic asthma, malnutrition, also infection and antibiotic intake during enrolment.

Study design
The study was designed as a placebo-controlled, randomized, double-blind clinical trial that the protocol was approved by the Ethics Committee of Mashhad University of Medical Sciences. Registration ID in Iranian Registry of Clinical Trail (IRCT) was IRCT2017061223235N11. The patient recruitment occurred from August 2015 to June 2016. The study was designed for 20 patients, ten in the synbiotic group who received synbiotic capsules from “ZistTakhmir” company (www.zisttakhmir.com) and each synbiotic capsule consisted of Lactobacillus casei, Lactobacillus acidophilus, Lactobacillus rhamnosus, Lactobacillus bulgaricus, Bifidobacterium breve, Bifidobacterium longum, Streptococcus thermophilus as probiotics and FOS as prebiotic. In addition, ten patients underwent immunotherapy and received placebo. Both groups took the synbiotic and placebo for 2 months. Cluster immunotherapy was performed based on a protocol in Middleton’s Allergy book\textsuperscript{[10]} for 2 months in both groups. Clinical symptoms and quality of life evaluated by SNOT-22\textsuperscript{[11]} and mini-Rhinoconjunctivitis Quality of Life Questionnaire (RQLQ)\textsuperscript{[12]} standard questionnaires in time points 0, 2, and 6 months. Meanwhile, 3cc of venous blood was taken in EDTA for RNA extraction from PBMCs and synthesis of cDNA.

Gene expression assessment for interferon-gamma, interleukin-4, interleukin-10, interleukin-17, transforming growth factor beta, and forhead box P3
RNA was extracted with GeneJET Whole Blood RNA Purification Mini kit (Made by Slovenian Thermo scientific company, Cat No, K0716#), then cDNA synthesis performed by RevertAid First Strand cDNA Synthesis Kit (Thermo scientific company).

The expression of mentioned genes was evaluated by SYBR Green real-time reverse transcription polymerase chain reaction (RT-PCR) technique. Primers designated by Beacon Designer software (7.9 version) and Primer NCBI online software and ordered by Pishgam company Tehran, Iran (www.pishgambc.com). Specificity of primers and product reaction confirmed by sequencing through Bioneer Company in South Korea. Sequences of primers are shown in Table 1.

Master mix provided by Takara Company (Japan [www. takara-bio.com]). The real-time RT-PCR amplifications were performed based on the following condition: for GAPDH, IFN-\(\gamma\), IL-4, IL-10, TGF-\(\beta\) genes, primary denaturation was started at 95°C for 10 min and followed by 40 cycles of denaturation at 95°C for 10 s, annealing at 60°C for 30 s and an extension at 72°C for 20 s. The reaction was conducted at the total volume of 10 \(\mu\)L which consisted of 0.4 \(\mu\)L forward primer (10 pmol/\(\mu\)L), 0.4 \(\mu\)L reverse primer (10 pmol/\(\mu\)L), 0.2 \(\mu\)L distilled water, 5 \(\mu\)L master mix, and 4 \(\mu\)L cDNA. For IL-17 and FoxP3 genes, primary denaturation was set up at 95°C for 2 min and followed by 50 cycles of denaturation at 95°C for 15 s, annealing at 60°C for 15 s and an extension at 72°C for 20 s. The reaction was prepared at the total volume of 10 \(\mu\)L which consisted of 0.25 \(\mu\)L forward primer (10 pmol/\(\mu\)L), 0.25 \(\mu\)L reverse primer (10 pmol/\(\mu\)L), 2.5 \(\mu\)L distilled water, 5 \(\mu\)L master mix, and 2 \(\mu\)L cDNA.
Statistics

Data of gene expression analyzed based on the 2^(-ΔΔCt) method,[13] and GAPDH chose as the house-keeping gene.[14] Statistical analysis such as descriptive statistics, Chi-square, unpaired t-test, and one way ANOVA was performed by SPSS software version 16 (SPSS Inc., Chicago, IL, USA) and the P < 0.05 was statistically significant.

RESULTS

Twenty AR patients randomized in Immunotherapy + Synbiotic (First group) and Immunotherapy + Placebo (Second group). Despite, lack of any side effects, three patients (two in the synbiotic and one in the placebo group) stopped treatment, and 17 patients (ten males and seven females) finished study procedure. The mean duration of the disease was 7.5 ± 2.3. The mean age of patients was 24 ± 12.82 with a range of 9–53 years. The age distribution was assessed by Kolmogorov–Smirnov test, and it was normal in both groups. Furthermore, the age difference was not significant between the two groups based on the t-test (P = 0.4). Demographic data were summarized in Table 2.

The analysis of SNOT-22 standard questionnaire showed a significant reduction in clinical symptoms in both groups with P = 0.0002 and P = 0.005 for the synbiotic the placebo group, respectively. However, in the comparison between groups, the reduction was higher in the synbiotic group, but not statistically significant (P = 0.9). Based on the mini-RQLQ standard questionnaire analysis, quality of life was significantly improved in synbiotic (P = 0.0001) and placebo (P = 0.014) groups. Although the quality of life showed better improvement in synbiotic group, the difference was not significant (P = 0.9). The data of standard questionnaires for SNOT-22 and mini-RQLQ were summarized in Table 3.

The analysis of gene expression showed no significant difference between the two groups for IFN-γ (P = 0.3), IL-4 (P = 0.2), IL-10 (P = 0.1), TGF-β (P = 0.01), and FoxP3 genes (P = 0.48) [Figure 2].

Similar analysis was performed in 2–6 months interval and showed no significant difference between the two groups with regard to IFN-γ (P = 0.7), IL-4 (P = 0.2), IL-10 (P = 0.21), TGF-β (P = 0.43) FoxP3 (P = 0.16), and IL-17 genes (P = 0.48) [Figure 2].

The analysis of gene expression in 0–6 months interval and comparison between the groups; showed no significant difference with regard to IFN-γ (P = 0.6), IL-4 (P = 0.3), IL-10 (P = 0.1), TGF-β (P = 0.24), and FoxP3 genes (P = 0.73), whereas the gene expression of IL-17 in synbiotic group was significantly decreased compared with placebo group (P = 0.0001) [Figure 3].

### Table 1: Sequence of primers for SYBR Green real time-polymerase chain reaction assay

| Characteristic | Forward primer | Reverse primer |
|---------------|----------------|----------------|
| GAPDH         | 5'-CAC TAG GGG ACT TCT CTC-3' | 5'-CCA ATA CGA CCA AAT CCG TTG AC-3' |
| IFN-γ         | 5'-GAG TGT GGA GAC CAT CAA GGA AG-3' | 5'-TGC TTT GCG TTG GAC ATT CAA GTC-3' |
| IL-4          | 5'-CCG TAA CAG ACA CTT CGT CC-3' | 5'-GAG TGT CCT CTT CAT GGT GGC T-3' |
| IL-10         | 5'-TCT CGG AGA TGG CTT CCA GAG A-3' | 5'-TCA GAC AAG CTT GGG CAC A-3' |
| IL-17         | 5'-GGG ACT GTG ATG CTT ACG TG-3' | 5'-GCC CTG AGA TGC CTT CCA GAT CAC A-3' |
| TGF-β         | 5'-TAC TG CAC CGG TGT TGC TCT C-3' | 5'-GTT GCT GAG GTA TCG CCA GGA A-3' |
| FoxP3         | 5'-GCC ACA ATG CCT TCT CCA GAG A-3' | 5'-TCA GCG AAT CCT TCC GGA CAC C-3' |

GAPDH = Glyceraldehyde-3-phosphate dehydrogenase; IFN-γ = Interferon-gamma; IL = Interleukin; TGF-β = Transforming growth factor beta; FoxP3 = Forkhead box P3; SYBR = SYBR Green

### Table 2: Demographic data of patients with allergic rhinitis

| Characteristics | Synbiotic group (n=8) | Placebo group (n=9) |
|-----------------|-----------------------|---------------------|
| Sex             | Male 6                | Female 2            |
|                 |                       | Age (year) 21.12±14.29 | 26.55±11.58 |

### Table 3: Data of standard questionnaires for Sinonasal Outcome Test-22 and mini-Rhinoconjunctivitis Quality of Life Questionnaire

| Characteristic | Before intervention | 2 months after intervention | 6 months after intervention |
|---------------|---------------------|-----------------------------|-----------------------------|
| SNOT-22       | Synbiotic 44.6±6.7   | 16.4±3.6                    | 11.4±3.5                    |
|               | Placebo 43±8.6       | 19.5±4.9                    | 13.7±3.7                    |
| Mini-RQLQ     | Synbiotic 51±6.3     | 16.9±3.7                    | 16±2.5                      |
|               | Placebo 40±6.9       | 21.3±5.9                    | 16.1±2.9                    |

Scores for severity of disease and quality of life obtained from SNOT-22 and mini-RQLQ standard questioners data, respectively. RQLQ = Rhinoconjunctivitis quality of life questionnaire; SEM = Standard error of mean; SNOT-22 = Sinonasal Outcome Test-22
Dehnavi, et al.: A significant decrease in the gene expression of IL-17 following intake of synbiotics

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DISCUSSION

Annoying symptoms in AR patients are due to the disturbance in protective physiologic functions of the immune system.[15] Based on the evidence, probiotics are one of the alternative treatments for allergic diseases especially AR.[9] The examination of gene expression profile is a powerful tool to diagnosis and differentiate diseases in human; also can clarify the progression or regression and to screening treatment responses. For the first time, in the present study, the expression of related genes to the T-cell subsets was evaluated in patients with AR who received placebo or synbiotic in combination with immunotherapy.

The evaluation of mini-RQLQ and SNOT-22 revealed that quality of life and clinical symptoms of all patients improved significantly regardless of taking synbiotic or placebo. Although the improvement was more in synbiotic group comparing to the placebo, the difference was not significant. Our results are similar to Lin et al. and Nembrini et al. studies that they also reported significant improvement in the quality of life and clinical symptoms. Lin et al. evaluated the effects of Lactobacillus paracasei (HF. A00232) in 6–13-year-old children with perennial AR in a 12-week treatment. They measured clinical symptoms and quality of life by nasal total symptom score, eye total symptom score, pediatric RQLQ standard questionnaires following the probiotic administration.[16] In addition, Nembrini et al. evaluated modulatory effects of L. paracasei NCC2461 on AR patients and measured clinical symptoms and quality of life by total nasal symptom score, total ocular symptom score, and mini-RQLQ standard questionnaires.[7] On the contrary, Nagata et al. who evaluated Lactobacillus plantarum No. 14 effects on seasonal AR in Japanese students[17] and Costa et al. that evaluated efficacy of L. paracasei LP-33 in the same disease[18] showed that clinical symptoms improved significantly in the intervention group versus placebo. Meanwhile, Singh et al. that evaluated the immunemodulatory effect of B. lactis NCC2818 in patients with seasonal AR revealed that nasal symptoms were improved significantly in the synbiotic group.[19]

Previous studies have shown that Th1/Th2 imbalance and subsequently IL-4 and IL-13 secretion by Th2 cells leads to class switching in B lymphocyte and produce allergen-specific IgE in AR patients.[20] Moreover, several modulatory effects considered for probiotics such as inhibition of Th2 differentiation through dendritic cells and also suppression of IL-4, IL-5, and IL-13 cytokines secretion.[21] In this study, gene expression of IL-4 considered as the Th2 main cytokine and our results showed a reduction during the intervention. Although it was more in the synbiotic group in the first 2 months, the differences were not significant. This part of our results was in concordance with Lin et al. and Ivory et al. studies that evaluated IL-4 cytokine level in serum, nasal mucosal secretions, and supernatants of PBMCs cultures.[16,22] However, significant reduction of IL-5 and IL-13 in studies of Singh et al. and IL-13 in Chen et al. as Th2 cytokines were seen in synbiotic group versus placebo.[19,23] In addition, Nagata et al. reported a significant increase in Th1 population and also in Th1/Th2
On the other hand, several studies showed an important role of Th1 and its cytokine, IFN-γ, in the cellular immune responses. Our results showed that the gene expression of IFN-γ increased in the first 2 months of treatment in the synbiotic group, whereas it was decreased in the placebo group. Although the gene expression of IFN-γ was lower in synbiotic receivers, it was not significant. Our results were similar to findings of Ivory et al., who reported that oral administration of *L. casei* significantly increased the level of IFN-γ cytokine production in cultured PBMCs. On the contrary, a significant decrease of IFN-γ as the main cytokine of Th1 subset was shown in Lin et al. who evaluated effects of *L. paracasei* (HF. A00232) on serum level of IFN-γ. Chen et al. who studied the influence of *L. gasseri* A5 on IFN-γ secretion by PBMCs. Singh et al. who assessed IFN-γ secretion of stimulated blood lymphocytes in the presence of *B. lactis* NCC2818 and also Lopez et al. who detected IFN-γ secretion by T-cells following treatment by *B. bifidum* CMG13195. All these results were not in accordance with our data, too. Notably, in Perrin and colleagues’ study, serum level of IFN-γ was shown to be not influenced by *L. paracasei* NCC2461. Controversial results in different studies may be related to differences in treatment protocols, the period of synbiotic intake and also various strains of probiotics and methods to evaluate serum cytokine level or supernatants of cell cultures and gene expression.

Contrary to common belief that AR is merely a result of the imbalance between Th1/Th2 subsets, recently proofs imply on Th17 subset role in AR pathogenesis and these cells were found in nasal mucus of AR patients. Furthermore, the severity of clinical symptoms increases along with serum level of IL-17. In our study, gene expression of IL-17 cytokine in 0–2 and 0–6-month intervals, was significantly decreased in the synbiotic group versus placebo. Similar findings showed in Zhang et al. that oral administration of *Enterococcus faecalis* FK-23 as in the murine model of allergy showed a significant reduction in the percentage of Th17 CD4+ cells. Moreover, Owaga et al. showed that administration of *Lactobacillus Gasseri* in the murine model of allergic asthma lead to significant reduction of IL-17 serum level in bronchoalveolar liquid and also suppressed significantly IL-17 secretion in splenocytes. These findings are in concordance with other studies that show probiotics lead to directly and indirectly downregulating and suppress Th17 subset and responses and cytokine secretion related to this cytokine.

On the other hand, modulatory effects of Treg in the immune system have shown in previous studies regarding allergic disease. It should be noted that suppressive phenotype of regulatory T cells is dependent on gene expression of the FoxP3 transcription factor that plays a critical role in the differentiation of Treg CD4+ CD25+. In our study, gene expression of FoxP3 increased in both groups. Although the gene expression of FoxP3 was more in synbiotic group, the difference was not significant. Our results are in agreement with Lopez et al. that used *B. bifidum* and Chen et al. which used *L. gasseri* as probiotics and reported that treatment with probiotics could trigger Treg CD4+ CD25+ FoxP3+ differentiation, but not significant.

Secretion of IL-10 and TGF-β as the major cytokines of Treg subset showed important modulatory effects. In our study, gene expression of IL-10 in 2 months and TGF-β in 6 months of intervention was not significantly increased in the synbiotic group in comparison with placebo receivers. Our results were in concordance with Lin et al. that used *L. paracasei* (HF. A00232) in 6–13-year-old children with perennial AR. Ivory et al. who assessed effects of *L. casei* in seasonal AR patients and Chen et al. who performed the same trial on children with AR by the administration of *L. gasseri* A5. We should note that all these three studies measured TGF-β and IL-10 in the serum of patients whereas our data was according to the gene expression. On the contrary, the serum level of IL-10 in Perrin et al. study which used *L. paracasei* NCC2461 and also nasal secretion level of this cytokine in Lopez et al. study which used *B. bifidum* was increased significantly due to synbiotic treatment and was in disagreement with our results.

**CONCLUSION**

Significant reduction in the gene expression of IL-17 as inflammatory cytokines in the synbiotic receivers compared with placebo in our study shows modulatory effects of synbiotic on immunopathogenesis of AR. To achieve a better conclusion regarding the effects of synbiotics, we suggest carry on more researches with a larger sample size and including of a group of patients who receive synbiotic without immunotherapy, extending the follow-up period and also taking advantages of more trial on various strains of synbiotics.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. Güvenç IA, Muluk NB, Mutlu PŞ, Eşki E, Altıntoprak N, Oktener T, et al. Do probiotics have a role in the treatment of allergic rhinitis? A comprehensive systematic review and meta-analysis. Am J Rhinol Allergy 2016;30:157-75.
2. Mandhane SN, Shah JH, Thennati R. Allergic rhinitis: An update on disease, present treatments and future prospects. Int Immunopharmacol 2011;11:1646-62.
3. Abtahi SM, Hashemi SM, Abtahi SH, Bastani B. Septal injection in comparison with inferior turbinate injection of botulinum toxin A in patients with allergic rhinitis. J Res Med Sci 2013;18:400-4.
4. Chatzi L, Apostolaki G, Bibakis I, Skypala I, Bibaki-Liakou V, Tzanakis N, et al. Protective effect of fruits, vegetables and the Mediterranean diet on asthma and allergies among children in Crete. Thorax 2007;62:677-83.
5. Hajiheydari MR, Yarmohammadi ME, Izadi P, Jafari F, Emadi F, Emaratkar E, et al. Effect of Nepeta brascatra bent. On allergic rhinitis symptoms: A randomized double-blind clinical trial. J Res Med Sci 2017;22:128.
6. Greiner AN, Hellings PW, Rotiroti G, Scadding GK. Allergic rhinitis. Lancet 2011;378:2112-22.
7. Nembrini C, Singh A, De Castro CA, Mercenier A, Nutten S. Oral administration of Lactobacillus paracasei NCC 2461 for the modulation of grass pollen allergic rhinitis: A randomized, placebo-controlled study during the pollen season. Clin Transl Allergy 2015;5:41.
8. Xie B. Benefits of Probiotics Consumption in Adults with Allergic Rhinitis: A Meta-Analysis; 2013.
9. Gibson GR. Prebiotics as gut microflora management tools. J Clin Gastroenterol 2008;42:Suppl 2:S75-9.
10. Adkinson NF Jr., Bochner BS, Burks AW, Busse WW, Holgate ST, Lemanske RF, et al. Middleton’s Allergy E-Book: Principles and Practice. Elsevier Health Sciences; 2013.
11. Jalessi M, Farhadi M, Kamrava SK, Amin Teheran E, Asghari A, Rezaei Hemami M, et al. The reliability and validity of the persian version of sinonosal outcome test 22 (snot 22) questionnaires. Iran Red Crescent Med J 2013;15:405-48.
12. van Oene CM, van Reij EJ, Sprangers MA, Fokkens WJ. Quality-assessment of disease-specific quality of life questionnaires for rhinitis and rhinosinusitis: A systematic review. Allergy 2007;62:1359-71.
13. Livak KJ, Schmittgen TD. Analysis of relative gene expression data using real-time quantitative PCR and the 2(-delta delta C(T)) method. Methods 2001;25:402-8.
14. Dheda K, Huggett JF, Bustin SA, Johnson MA, Rook G, Zumla A. Validation of housekeeping genes for normalizing RNA expression in real-time PCR. Biotechniques 2004;37:112-4, 116, 118-9.
15. Rosenwasser LJ. Current understanding of the pathophysiology of allergic rhinitis. Immunol Allergy Clin North Am 2011;31:433-9.
16. Lin WY, Fu LS, Lin HK, Shen CY, Chen YJ. Evaluation of the effect of Lactobacillus paracasei (HF-A0023) in children (6-13 years old) with perennial allergic rhinitis: A 12-week, double-blind, randomized, placebo-controlled study. Pediatr Neonatol 2014;55:181-8.
17. Nagata Y, Yoshida M, Kitazawa H, Araki E, Gomyo T. Improvements in seasonal allergic disease with Lactobacillus plantarum no. 14. Biosci Biotechnol Biochem 2010;74:1869-77.
18. Costa DJ, Marteau P, Amouyal M, Poulsen LK, Hamelmann E, Cazaubiel M, et al. Efficacy and safety of the probiotic Lactobacillus paracasei LP-33 in allergic rhinitis: A double-blind, randomized, placebo-controlled trial (GA2LEN study). Eur J Clin Nutr 2014;68:602-7.
19. Singh A, Hacini-Rachinel F, Gosoniu ML, Bourdeau T, Holvoet S, Doucet-Ladeveze R, et al. Immune-modulatory effect of probiotic Bifidobacterium lactis NCC2818 in individuals suffering from seasonal allergic rhinitis to grass pollen: An exploratory, randomized, placebo-controlled trial. Eur J Clin Immunol 2013;67:161-7.
20. Palomares O, Yaman G, Azkur AK, Akkok T, Akdis M, Akdis CA. Role of treg in immune regulation of allergic diseases. Eur J Immunol 2010;40:1232-40.
21. Jang SO, Kim HJ, Kim YJ, Kang MJ, Kwon JW, Seo JH, et al. Asthma prevention by Lactobacillus rhamnosus in a mouse model is associated with CD4(+)/CD25(+)Foxp3(+) T cells. Allergy Asthma Immunol Res 2012;4:150-6.
22. Ivory K, Wilson AM, Sankaran P, Westwood M, McCarville J, Brockwell C, et al. Oral delivery of a probiotic induced changes at the nasal mucosa of seasonal allergic rhinitis subjects after local allergen challenge: A randomised clinical trial. PLoS One 2013;8:e78650.
23. Chen YS, Jan RL, Lin YL, Chen HH, Wang JY. Randomized placebo-controlled trial of Lactobacillus on asthmatic children with allergic rhinitis. Pediatr Pulmonol 2010;45:1111-20.
24. Perrin Y, Nutten S, Audran R, Berger B, Bibiloni R, Wassenberg J, et al. Comparison of two oral probiotic preparations in a randomized crossover trial highlights a potentially beneficial effect of Lactobacillus paracasei NCC2461 in patients with allergic rhinitis. Clin Transl Allergy 2014;4:1.
25. Lee SM, Gao B, Dahl M, Calhoun K, Fang D. Decreased foxP3 gene expression in the nasal secretions from patients with allergic rhinitis. Otolaryngol Head Neck Surg 2009;140:197-201.
26. Pawanakan R, Hayashi M, Yamanishi S, Igaraishi T. The paradigm of cytokine networks in allergic airway inflammation. Curr Opin Allergy Clin Immunol 2015;15:41-8.
27. Zhang B, An J, Shimada T, Liu S, Maeyama K. Oral administration of enterococcus faecalis FK-23 suppresses Th17 cell development and attenuates allergic airway responses in mice. Int J Mol Med 2012;30:248-54.
28. Owaga E, Hsieh RH, Mengudi B, Masuku S, Shih CK, Chang JS, et al. Comparison of two oral probiotic preparations in a randomized crossover trial highlights a potentially beneficial effect of Lactobacillus paracasei NCC2461 in patients with allergic rhinitis. J Allergy Clin Immunol 2014;68:602-7.
29. Yan F, Polk DB. Probiotics and immune health. Curr Opin Immunol 2013;25:547-52.
30. Tanabe S. The effect of probiotics and gut microbiota on Th17 cells. Int Rev Immunol 2013;32:511-25.
31. Wu HY, Staines NA. A deficiency of CD4+CD25+ T cells permits the development of spontaneous lupus-like disease in mice, and can be reversed by induction of mucosal tolerance to histone peptide autoantigen. Lupus 2004;13:192-200.
32. López P, González-Rodríguez I, Sánchez B, Gueimonde M, Margolles A, Suárez A. Treg-inducing membrane vesicles from Bifidobacterium bifidum LMG13195 as potential adjuvants in immunotherapy. Vaccine 2012;30:825-9.