5.2 Application of the gastrointestinal non-motor symptom scale in screening high-risk populations

Non-motor gastrointestinal symptoms such as constipation often appear many years earlier than motor symptoms and are important clues for the early screening of PD. Gastrointestinal symptom scales and questionnaires can assist in identifying high-risk populations, especially when combined with prodromal symptoms such as rapid eye movement sleep behavior disorder (Heinzel et al., 2021). The accuracy rate of multiple non-motor symptom combinations in predicting the prodromal stage of PD exceeds 80%.

Combining the gastrointestinal symptom scale with the intestinal microbiota map can enhance the accuracy of prediction. There are certain types of microbiota that are directly associated with the risk of Parkinson's disease (Heinzel et al., 2021). Combining the two is expected to enhance the identification effect of high-risk groups and facilitate early intervention, but more long-term follow-up studies are still needed to verify and improve this method.

5.3 Risk prediction and disease classification models based on microbiome and multi-omics integration

The integration of multiple omics such as microbiome with metabolomics and neuroimaging has promoted the establishment of PD risk prediction models and subtype classification frameworks (Zhou et al., 2025). The machine learning model based on multi-omics has high prediction accuracy, and the AUC value in some external cohorts is greater than 0.9 (Makarious et al., 2021; Yu et al., 2025).

The combination of multi-omics techniques can also help us distinguish different types of Parkinson's disease, understand the disease development process, and lay the foundation for personalized treatment (Luo et al., 2025). For instance, combining the results of neuroimaging examinations with the characteristics of the intestinal flora can make the staging of cognitive dysfunction in patients with Parkinson's disease more accurate. As related technologies become increasingly mature, they will play a key role in the early diagnosis and personalized treatment of Parkinson's disease.

6 Intervention and Treatment Strategies Based on the Gut-brain Axis

6.1 Probiotics, synthetic bacteria and dietary adjustments

Regulating the intestinal flora through probiotics, synthetic bacteria and dietary adjustments has become a promising approach to influencing the progression of Parkinson's disease (PD). Probiotics are active beneficial bacteria that can restore the balance of intestinal flora to a certain extent, reduce intestinal inflammation, and also promote the production of metabolites such as short-chain fatty acids (SCFAs) that have protective effects on the nervous system. Clinical and laboratory studies have shown that supplementing probiotics can help improve gastrointestinal function in patients with Parkinson's disease (PD), reduce neuroinflammation, and have a slight improvement in motor and non-motor symptoms. However, the effect in improving core motor symptoms is still relatively limited (Singh et al., 2022). Synthetic probiotics (that is, the combination of probiotics and prebiotics) can promote the growth of beneficial bacteria, enhance their metabolic activity, thereby better maintaining intestinal health, and may also enhance the protective effect on nerves (Kumar et al., 2025).

Dietary adjustments, especially the Mediterranean diet or high-fiber diet, can help reshape the intestinal microbiota, which is associated with an increase in the abundance of ScFas-producing bacteria and a reduction in pro-inflammatory flora, thereby helping to maintain the integrity of the intestinal barrier and alleviate systemic inflammation (Salim et al., 2022; Zhu et al., 2022). Nutritional interventions, including nutritional supplements and foods rich in polyphenols, have also been proven to affect the composition and function of gut microbiota, creating an internal environment with more neuroprotective characteristics, which may delay the progression of PD (Yao et al., 2024; Sobral et al., 2025). Although the above-mentioned methods are generally safe and easy to implement, more large-sample, long-term follow-up clinical trials are still needed to determine the best intervention plan and the lasting efficacy.

6.2 Fecal microbiota transplantation and intestinal targeted anti-inflammatory and barrier recovery strategies

Fecal microbiota transplantation (FMT) restores microbial diversity and function by transplanting the intestinal