SOCIOLOGY - FOOD NUTRITION - HUMAN BEHAVIOR

The Gut–Brain–Social Axis: How Adolescent Dietary Patterns Influence Perceived Stress, Loneliness, and Academic Motivation

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Published November 2026

Abstract

Adolescence is a critical developmental period characterized by significant physical, psychological, emotional and social changes. Dietary habits developed during this stage may influence not only physical health but also psychological well-being, emotional regulation, social relationships and academic functioning. Recent research on the Gut–Brain Axis suggests that communication between intestinal microorganisms and the central nervous system plays an important role in regulating stress responses, mood, cognition and behavioural functioning.

The present paper examines the relationship between adolescent dietary patterns and three important psychological and educational outcomes: perceived stress, loneliness and academic motivation. It explores how dietary diversity, fibre consumption, fermented foods, fruits, vegetables, excessive sugar intake and ultra-processed food consumption may influence gut microbiota and associated neurobiological pathways.

The review focuses on adolescents in Meerut and Ghaziabad districts of Uttar Pradesh, considering the changing food environment, increasing exposure to processed foods, changing family eating practices, academic competition, digital lifestyles and changing peer relationships.

The study adopts a secondary-data-based review approach, considering relevant research and policy literature from 2022 onwards, with the proposed research period extending to 2027. It integrates nutritional, psychological and educational perspectives to develop a conceptual framework explaining the possible relationships among dietary behaviour, gut health, perceived stress, loneliness and academic motivation.

The paper argues that adolescent nutrition should be considered an important component of comprehensive school health and educational development. It also identifies research gaps concerning the relationship between gut microbiota, social well-being and academic motivation in Indian adolescents.

Keywords: Gut–Brain Axis; gut microbiota; adolescent nutrition; dietary patterns; perceived stress; loneliness; academic motivation; psychological well-being; Meerut; Ghaziabad

1 Introduction

Adolescence represents a transitional stage between childhood and adulthood, involving substantial biological, cognitive, emotional and social development. During this period, young individuals develop dietary preferences, lifestyle habits, emotional responses, interpersonal relationships and academic aspirations that may influence their future well-being.

In contemporary Indian society, adolescent dietary behaviour is undergoing considerable transformation. Traditional home-cooked meals are increasingly accompanied or replaced by packaged snacks, fast food, sugary beverages, instant meals and other ultra-processed food products.

These dietary changes deserve attention because nutrition is associated with several biological processes, including intestinal microbial activity, inflammation, metabolic regulation and communication between the gastrointestinal tract and the brain.

The Gut–Brain Axis refers to a bidirectional communication network connecting the gastrointestinal system and the central nervous system through neural, hormonal, immune and metabolic pathways. The gut microbiota contributes to this communication by producing metabolites such as short-chain fatty acids and participating in the metabolism of dietary components.

Research increasingly suggests that the microbiota–gut–brain system is particularly relevant during adolescence because the brain, endocrine system and intestinal microbial environment undergo substantial developmental changes.

However, adolescent well-being cannot be understood through biological factors alone. Psychological experiences such as perceived stress and loneliness, together with academic motivation and school connectedness, also influence adolescent development.

This paper therefore introduces the broader concept of the **Gut–Brain–Social Axis**, integrating three dimensions:

1. Biological dimension: Dietary patterns, gut microbiota and gut–brain communication.
2. Psychological dimension: Perceived stress, emotional regulation and loneliness.
3. Educational and social dimension: Academic motivation, peer relationships and school connectedness.

The proposed framework offers an interdisciplinary approach to understanding adolescent health in the educational and social environment of Meerut and Ghaziabad.

2 Background of the study

2.1 Changing dietary patterns among adolescents

Adolescent food consumption is influenced by several factors:

- Family income and socioeconomic background.
- Parental food habits and nutritional awareness.
- Availability of fast food and packaged products.
- Peer influence and social media.
- School canteen facilities.
- Academic schedules and time constraints.
- Awareness of balanced nutrition.

A particularly relevant regional study is *Study of Dietary Patterns in School Going Adolescents of District Ghaziabad* (2022). It examined 552 adolescents aged 11–15 years and reported concerns relating to fruit and vegetable consumption, physical activity and overweight status. This provides a useful geographical starting point for the proposed research.

2.2 Gut microbiota and psychological well-being

The human intestine contains a diverse microbial ecosystem consisting of bacteria and other microorganisms. These organisms contribute to digestion, nutrient metabolism, immune regulation and the production of biologically active compounds.

Dietary fibre from whole grains, pulses, vegetables and fruits supports the production of short-chain fatty acids through microbial fermentation.

These metabolites may influence intestinal barrier function, immune responses and communication with the nervous system.

Conversely, diets dominated by excessive refined carbohydrates, saturated fats and ultra-processed foods may adversely influence microbial diversity and metabolic activity.

The relationship is complex and bidirectional. Stress itself can also influence gastrointestinal functioning and microbial composition.

2.3 Perceived stress among adolescents

Adolescents experience multiple stressors, including:

- Board examinations and competitive examinations.
- Parental expectations.
- Academic competition.
- Career uncertainty.
- Social comparison.
- Body image concerns.
- Digital pressure and excessive screen time.
- Peer relationships and family conflicts.

Perceived stress refers to the extent to which individuals evaluate situations in their lives as unpredictable, uncontrollable or overwhelming.

Dietary behaviour may be associated with stress through metabolic, inflammatory and neuroendocrine mechanisms. However, stress can also influence food choices, creating a two-way relationship.

2.4 Loneliness and social disconnection

Loneliness is a subjective experience of insufficient meaningful social connection. It is different from simply being physically alone.

Adolescents may experience loneliness despite having friends, classmates or digital social connections.

Possible contributing factors include:

- Lack of emotional support.
- Peer rejection and bullying.
- Excessive digital engagement.
- Low self-esteem.
- Family communication gaps.

- Academic pressure.
- Lack of school belongingness.

The proposed Gut–Brain–Social Axis considers whether dietary and psychological factors interact with social experiences, while recognizing that direct causal evidence connecting gut microbiota to adolescent loneliness remains limited.

2.5 Academic motivation

Academic motivation refers to the psychological processes that initiate, direct and sustain students' learning activities.

It includes:

- Intrinsic motivation.
- Extrinsic motivation.
- Learning interest.
- Academic self-efficacy.
- Goal orientation.
- Persistence and achievement motivation.

Adequate nutrition may support cognitive development, energy regulation and concentration. Psychological well-being and a supportive school environment may also influence students' motivation to learn.

The relationship between diet and academic motivation is therefore likely to involve several interacting factors rather than a single biological mechanism.

3 Statement of the research problem

Despite increasing awareness of adolescent nutrition and mental health, these subjects are frequently investigated independently.

Nutrition studies generally focus on dietary diversity, nutritional deficiencies, body mass index and physical development. Psychological studies examine perceived stress, anxiety, depression and loneliness. Educational research frequently concentrates on academic achievement, motivation and learning outcomes.

There is a need for an integrated research perspective examining how dietary patterns, gut health, psychological well-being and social experiences may interact during adolescence.

The problem becomes particularly relevant in urban and semi-urban educational environments such as Meerut and Ghaziabad, where traditional dietary practices coexist with changing food preferences, digital lifestyles and increasing academic expectations.

The present research therefore attempts to examine the relationship between adolescent dietary patterns and perceived stress, loneliness and academic motivation through an interdisciplinary review of nutritional, psychological and educational literature.

4 Research gap

The following research gaps emerge from the reviewed literature:

1. Limited integrated research connecting dietary patterns, gut microbiota and psychological well-being among Indian adolescents.
2. Insufficient geographical evidence examining these relationships specifically in Meerut and Ghaziabad.
3. Limited investigation of loneliness as a potential social outcome within the gut–brain research framework.
4. Insufficient integration of academic motivation with adolescent nutrition and gut–brain research.
5. Limited longitudinal evidence establishing the direction of relationships between diet, stress, loneliness and academic motivation.
6. Need for greater understanding of gender, socioeconomic status, family environment and school climate as potential influencing factors.
7. Limited research distinguishing biological evidence concerning gut microbiota from psychological associations that may be explained by social and environmental influences.

5 Objectives of the study

The major objectives are:

1. To examine changing dietary patterns among adolescents in the context of Meerut and Ghaziabad.
2. To review the relationship between dietary diversity, gut microbiota and the Gut–Brain Axis.
3. To examine the possible association between adolescent dietary patterns and perceived stress.
4. To explore the relationship between dietary behaviour, psychological well-being and loneliness.
5. To analyse the possible relationship between nutritional habits, concentration and academic motivation.
6. To understand the role of family environment, peer relationships, socioeconomic background and school climate in adolescent well-being.
7. To develop an integrated conceptual framework connecting nutrition, psychological health and academic motivation.
8. To suggest practical recommendations for schools, parents, educators and policymakers.

6 Research questions

The paper addresses the following research questions:

1. How are changing dietary patterns associated with gut health among adolescents?
2. What biological mechanisms connect gut microbiota with the brain and stress responses?
3. Is unhealthy dietary behaviour associated with higher perceived stress among adolescents?
4. How might loneliness and social isolation interact with dietary behaviour and psychological well-being?
5. Can adequate nutritional practices contribute to better concentration and academic motivation?

6. What roles do family support, peer relationships and school environments play in these relationships?
7. What interventions can educational institutions in Meerut and Ghaziabad introduce to promote nutritional and psychological well-being?

7 Conceptual framework

The study proposes an integrated Gut–Brain–Social Axis model.

7.1 Independent variable: adolescent dietary patterns

The dietary dimension includes:

- Dietary diversity.
- Fruit and vegetable consumption.
- Whole grains and dietary fibre.
- Pulses and legumes.
- Milk, curd and other fermented foods.
- Protein and micronutrient adequacy.
- Fast-food consumption.
- Ultra-processed foods.
- Sugary beverages and irregular meal timings.

7.2 Biological mediating mechanism

The proposed biological pathway includes:

- Gut microbial diversity and composition.
- Production of short-chain fatty acids.
- Intestinal barrier functioning.
- Immune and inflammatory signalling.
- Vagus nerve communication.
- Hypothalamic–pituitary–adrenal (HPA) axis regulation.
- Neuroactive metabolic pathways.

These mechanisms provide biological plausibility but should not be assumed to have been measured in the proposed geographical population.

7.3 Psychological and social outcomes

7.3.1 Outcome 1: perceived stress

The individual's perception of academic, family and social demands.

7.3.2 Outcome 2: loneliness

The individual's subjective experience of inadequate emotional or social connection.

7.3.3 Outcome 3: academic motivation

The individual's willingness, interest and persistence in educational activities.

7.4 Moderating variables

The following factors may influence the relationships:

- Gender.
- Age.
- Family income.
- Parental education.
- Family dietary environment.
- Sleep quality.
- Physical activity.
- Screen time.
- School climate.
- Peer support.
- Academic workload.

7.4.1 Proposed conceptual model

Dietary Patterns → Gut Microbiota and Metabolic Signalling → Gut–Brain Communication → Psychological Regulation → Perceived Stress and Emotional Well-being → Social Connectedness and Academic Motivation.

Family support, peer relationships, sleep, physical activity and school environment may influence multiple stages of this framework.

Important: Loneliness is also an independent social and psychological construct, and the proposed model does not assume that it is directly caused by gut microbiota.

8 Review of literature

8.1 Ghaziabad adolescent dietary patterns (2022)

The study *Study of Dietary Patterns in School Going Adolescents of District Ghaziabad* examined dietary habits and physical activity among school-going adolescents.

The research included 552 adolescents aged 11–15 years from urban Ghaziabad.

The study reported that 60.72% had normal nutritional status, 10.9% were underweight and 28.36% were overweight or obese. A substantial proportion consumed only one serving of fruits and vegetables daily.

The findings establish the relevance of dietary diversity and nutritional behaviour in the local research context.

8.2 McVey Neufeld et al. (2024)

In their review, *Adolescence, the Microbiota-Gut-Brain Axis, and the Emergence of Psychiatric Disorders*, the authors discussed adolescence as an important developmental period during which the microbiota–gut–brain system remains sensitive to environmental influences.

The paper highlighted the potential interaction between intestinal microbiota, neural development, stress responses and psychiatric vulnerability.

8.3 Schneider et al. (2024)

In *Feeding Gut Microbes to Nourish the Brain: Unravelling the Diet–Microbiota–Gut–Brain Axis*, the authors examined the relationship between dietary intake, microbial metabolism and brain health.

The review highlighted how dietary components influence gut microbial activity and how microbial metabolites may participate in pathways associated with mood, cognition and stress-related functioning.

8.4 ICMR–NIN dietary guidelines (2024)

The Indian Council of Medical Research and National Institute of Nutrition published revised Dietary Guidelines for Indians in 2024.

The guidelines emphasize dietary diversity, whole grains, pulses, fruits, vegetables, nuts and other nutrient-rich foods, while recommending reduced consumption of foods high in fat, sugar and salt.

These guidelines provide an important Indian nutritional foundation for the present research.

8.5 Podiya et al. (2025)

Their systematic review, *Influences of School Climate on Emotional Health and Academic Achievement of School-Going Adolescents in India*, examined the relationship between school climate, emotional well-being and academic outcomes.

The findings highlighted the importance of student–teacher relationships, peer support, school connectedness and belongingness in adolescent emotional health and academic achievement.

This research is particularly relevant to the social and educational dimensions of the proposed model.

8.6 Liu et al. (2025)

Their systematic review, *Gut Brain Axis in Adolescent Depression: A Systematic Review of Psychological Implications and Behavioral Interventions*, examined emerging evidence on microbiota-related mechanisms and adolescent psychological outcomes.

The authors discussed microbial composition, neuroinflammatory pathways and possible behavioural interventions.

The study supports further investigation of the gut–brain relationship, although its findings on depression should not be directly generalized to loneliness or academic motivation.

8.7 Dietary habits and the microbiome (2025)

The review *Dietary Habits and Their Influence on the Microbiome and Mental Health in Adolescents* discusses the influence of dietary fibre, probiotics, prebiotics and other nutritional components on gut microbial activity and psychological health.

It provides a useful foundation for exploring the relationship between food choices and adolescent emotional well-being.

9 Research methodology

9.1 Research design

The present paper adopts a narrative review and secondary-data-based research design.

It integrates published research, systematic reviews, government reports, nutritional guidelines and relevant educational and psychological literature.

It does not claim to report original clinical measurements, gut microbiome testing or primary survey findings.

9.2 Geographical area

The geographical scope includes:

Meerut District: Urban and semi-urban educational environments, including school-going adolescents.

Ghaziabad District: Urban and semi-urban educational environments, including school-going adolescents.

The two districts provide an appropriate regional context for reviewing changes in food habits, adolescent lifestyles, psychological experiences and educational environments.

9.3 Duration of the study

The proposed research period is 2022–2027.

Table 1. Proposed research period and activities.

Period	Research activity
2022	Initial regional evidence on adolescent dietary patterns
2023	Review of gut microbiota and adolescent psychological development
2024	Integration of nutritional and gut–brain research
2025	Review of stress, emotional well-being and social connectedness
2026	Consolidation of available literature and conceptual framework
2027	Proposed final review, research-gap assessment and recommendations

The literature search for this draft is based on evidence available up to November 2026. The 2027 component represents the planned completion phase.

9.4 Sources of secondary data

The following sources are recommended:

1. PubMed and PubMed Central.
2. Google Scholar.
3. Scopus.
4. Web of Science.
5. Indian Council of Medical Research (ICMR).

6. National Institute of Nutrition (NIN).
7. World Health Organization (WHO).
8. UNICEF.
9. Ministry of Health and Family Welfare, Government of India.
10. Relevant Indian and international peer-reviewed journals.

9.5 Search keywords

The literature search should use combinations of:

- Adolescent dietary patterns.
- Gut microbiota and mental health.
- Microbiota–gut–brain axis.
- Adolescent perceived stress.
- Loneliness among adolescents.
- Nutrition and academic motivation.
- Dietary diversity and cognition.
- Ultra-processed foods and adolescent health.
- School connectedness and emotional well-being.
- Adolescent nutrition in India.
- Meerut and Ghaziabad adolescent dietary behaviour.

9.6 Inclusion criteria

- Research concerning adolescents, preferably aged 10–19 years.
- Publications from 2022 onwards for the principal review period.
- Relevant earlier foundational research where necessary.
- Peer-reviewed journal articles and credible institutional reports.
- Studies related to dietary behaviour, gut microbiota, psychological well-being and educational outcomes.
- Indian studies and relevant international comparative research.

9.7 Exclusion criteria

- Unverified websites and unsupported claims.
- Studies without identifiable methodology.
- Research unrelated to adolescent development.
- Duplicate publications.
- Commercial claims regarding probiotics and nutritional products without reliable supporting evidence.

9.8 Proposed analytical approach

The reviewed literature will be organized into four themes:

1. Dietary patterns and gut health.
2. Gut–brain communication and stress regulation.

3. Loneliness, social connectedness and emotional well-being.
4. Nutrition, cognition and academic motivation.

The evidence will be synthesized thematically, with attention to study design, population, findings, limitations and applicability to the Meerut–Ghaziabad context.

10 Discussion

The proposed Gut–Brain–Social Axis offers an integrated perspective on adolescent development.

First, dietary behaviour is a modifiable lifestyle factor that may influence intestinal microbial composition and metabolic functioning. A diet containing adequate fibre, vegetables, fruits, whole grains and pulses supports a healthier nutritional environment.

Second, gut–brain communication provides possible biological pathways through which nutritional conditions and microbial metabolites may interact with emotional regulation and stress responses.

Third, loneliness requires a broader social and psychological explanation. Family communication, friendship quality, bullying, school belongingness and digital behaviour may be more immediate determinants of loneliness than dietary intake. Nevertheless, psychological stress and eating behaviour may influence each other.

Fourth, academic motivation is influenced by both individual and environmental conditions. Nutrition may support physical and cognitive functioning, but motivation also depends on teaching quality, learning interests, self-efficacy, parental expectations and institutional support.

Thus, the relationship among nutrition, stress, loneliness and academic motivation should be examined as an interconnected system rather than as a simple cause-and-effect relationship.

11 Educational and practical implications

The proposed findings can inform adolescent health initiatives in schools and colleges in Meerut and Ghaziabad.

11.1 For educational institutions

- Promote healthy and balanced food choices.
- Encourage healthy school canteen practices.
- Conduct nutrition awareness programmes.
- Include psychological well-being in student support initiatives.
- Promote peer interaction and inclusive activities.
- Encourage physical activity and adequate sleep.

11.1.1 For parents

- Encourage regular family meals.
- Provide dietary diversity.
- Reduce excessive packaged food consumption.
- Maintain supportive communication.
- Avoid excessive academic pressure.

11.1.2 For policymakers

- Strengthen adolescent nutrition awareness.
- Encourage healthier school food environments.
- Integrate nutritional and mental health education.
- Support interdisciplinary school health research.

12 Limitations of the study

1. The present paper is based on secondary literature and does not establish new causal relationships.
2. Direct microbiome data from adolescents in Meerut and Ghaziabad are not available within this review.
3. Research on adolescent gut microbiota is still developing, and findings from animal studies cannot automatically be generalized to human adolescents.
4. Loneliness and academic motivation are influenced by multiple social, family, psychological and educational variables.
5. The availability of district-specific longitudinal studies may be limited.
6. Evidence published during 2027 cannot be incorporated until those studies become available.

13 Future scope of research

Future research may adopt an empirical, mixed-method or longitudinal design involving school-going adolescents from Meerut and Ghaziabad.

A proposed investigation could include:

- Dietary Diversity Questionnaire or Food Frequency Questionnaire.
- Perceived Stress Scale (PSS-10), subject to age suitability and validation.
- UCLA Loneliness Scale, using an age-appropriate validated version.
- Academic Motivation Scale or another validated adolescent motivation instrument.
- Academic performance indicators, with appropriate permissions.
- Sleep, physical activity and screen-time measures.

A future primary study could examine whether perceived stress, loneliness and academic motivation are statistically associated with dietary patterns after controlling for relevant demographic and lifestyle factors.

Gut microbiome testing could be considered as a separate advanced component, subject to funding, laboratory capacity, parental consent and ethical approval.

14 Conclusion

The Gut–Brain–Social Axis provides an emerging interdisciplinary framework for understanding adolescent nutrition, psychological well-being and educational development.

Dietary patterns influence the intestinal environment and may participate in biological processes associated with brain functioning and emotional regulation. At the same time, perceived stress,

loneliness and academic motivation are shaped by broader social, family and educational environments.

The present review highlights the importance of examining these dimensions together, particularly in the changing urban and semi-urban environments of Meerut and Ghaziabad.

The research also identifies an important gap in Indian adolescent research: the need to integrate nutritional behaviour, gut–brain mechanisms, social connectedness and academic motivation within one coherent framework.

Ultimately, adolescent nutrition should not be viewed merely as a physical health concern. It deserves attention as one component of a broader approach to promoting psychological resilience, positive social relationships and educational development.

Healthy Food – Healthy Gut – Healthy Mind – Positive Social Relationships – Better Learning.

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