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Genome-Environment Interactions in Tourism Employees and Genetic Susceptibility to Psychosocial Stress

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ABSTRACT

Tourism employees experience high levels of occupational stress stemming from customer interactions, irregular schedules, and task overload, yet responses to these stressors vary widely. This study investigates how genetic susceptibility interacts with environmental stressors to influence psychosocial stress among tourism workers. Candidate genes implicated in stress regulation—including BDNF, HSD11B1, NR3C1, and 5-HTTLPR—mediate neuroendocrine, neurotransmitter, and inflammatory pathways underlying stress response. Using gene–environment (G×E) interaction models such as diathesis–stress, differential susceptibility, and lifespan–bioecological frameworks, we explore how genetic variation moderates stress effects in diverse occupational contexts within tourism. Findings suggest that employees with vulnerable allelic profiles exhibit heightened cortisol responses, altered inflammatory markers, and increased psychosocial stress under high-demand work environments. These insights advance understanding of individualized vulnerability to occupational stress and inform targeted interventions to enhance resilience in tourism workforces.

Keywords: *tourism employees, occupational stress, psychosocial stress, gene–environment interaction, genetic susceptibility, BDNF, HSD11B1, NR3C1, 5-HTTLPR, cortisol, neuroendocrine pathways, inflammatory response*

INTRODUCTION

Tourism is one of the main providers of jobs at a global scale and the pandemic has brought some of the highest levels of stress faced by tourism employees. Yet, studies have shown these tourism employees to have lower than expected levels of psychosocial stress. This study seeks to assess the impact of stressors as

well as genetic susceptibility to stress in tourism employees. Questions will address how specific stressors and genetic susceptibility are associated with the psychosocial stress of tourism employees. Psychosocial stress is defined here as a state of anxiety that may influence physical and physiological wellbeing, gene-environment (Arnau-Soler et al., 2019) specify the concept of an environmental stimulus acting on the system, or a genome both contributing to the system and mediating the influence of the environment. Psychosocial stress consists of a stimulus.

Psychosocial stress comprises a stimulus, an organism, and an intellectual disruption. An environmental stimulus producing a perturbation in cognitive orchestration that threatens chronic consideration of physical or mental health is defined here as psychosocial stress. The stressors of tourism work demands, customer interaction, and irregular schedule were selected. GxE specifies genetic susceptibility, the existence of an environment by which stressors impact organism response is expected. Psychosocial stress comprises of health, environment, duration. Health consists of physical state, cognitive-sanity, social state, and contentment. Environment consists of work demands and tasks, customer interaction and intensity, irregularity of time and of supply.

The gene-environment interaction model considers both variation in genetic susceptibility and the existence of an environmental stimulus. In tourism work, irregular schedules and customer interaction have been linked to psychosocial stress, and interaction with a candidate genomic background may regulate the impact of that stressful exposure. GxE specifies the existence of an environment acting on the organism whereby the organism contains a genetic background that mediates the influence of the environment on an observable outcome. Those variations in genetic background consist of polymorphisms in epigenetic substrates and hormonal, neuroanatomical, and inflammatory pathways. Organizational demand, difficult customers, and irregular schedules comprise key environmental GxE elements in tourism work. Psychosocial stress constitutes the outcome. Such time and customer variations have received prior consideration in the field. Work Demands Task Wellbeing; Customer Stress Interaction

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Table 1: Key G×E Models Applied to Tourism Work Stress

Model	Description	Application in Tourism Context
Diathesis–Stress	Individuals with genetic vulnerability exhibit stress-related disorders under adverse environmental exposure	Employees carrying NR3C1 GG, BDNF Met, or 5-HTTLPR short alleles show heightened psychosocial stress when exposed to high work demands or aggressive customers
Differential Susceptibility	Genetic variants confer sensitivity to both positive and negative environments	Employees with stress-sensitive alleles may benefit more from supportive work environments (flexible schedules, good management)
Bioecological / Lifespan	Stress effects depend on dynamic interaction of genes, environment, and developmental stage	Chronic exposure to tourism work stress across career can compound or mitigate G×E effects, shaping long-term mental health

Theoretical Framework

Psychosocial stress defines a person's emotional and behavioral responses arising from perceived discrepancies between the social and personal demands of a given environment relative to their capacity to

manage those demands, psycho-social stress mediated by ongoing demands related to workplace and customer interaction is a known health risk in tourism. Tourism employees constitute an ideal sector for gene-environment ($G \times E$) interaction studies because they experience a range of stress pressure and exposure over their careers ranging from low to high. Stress directly influences peripheral salivary cortisol levels, a well-established biomarker for psychosocial stress, candidate gene research into genetic risk factors for three candidate $G \times E$ pairs on stress-related allelic profiles the short-variable 5-HTTLPR allelic long arm of the BDNF gene (Val66Met) and the GG genotype of NR3C1 predispose individuals in variable work-environment scenarios towards feelings of additional stress (Belsky et al., 2009). Psychosocial stress, the alteration of the HPA axis, neurotransmitters centred on dopamine, serotonin and norepinephrine are among the core pathways involved in the stressful process.

Three $G \times E$ interaction models diathesis-stress, differential susceptibility and a bio ecological model of development recurring salient events are framed using latent-exposure interaction equations appropriate to the cross-sectional and long-panel-lagged dataset collected using the same population for both response- and influencing-variable measures cross-sectional modelling applies to the first section of the data-trace while the secondary panel incorporates a two-wave lags-measure during a lengthy time span organisation continue to fulfil the primary purpose of $G \times E$ candidate-genes relevance in the provoking-dimension work-activity comprises the over-inevitably-base contact-environment and the positive-downplay direct-benefit provision-gain with extended easily available-of-service [table 2].

Table 2: Core Biological Mechanisms Linking $G \times E$ to Psychosocial Stress

Mechanism	Occupational Trigger	Molecular / Physiological Mediator	Outcome
HPA-axis dysregulation	Work overload, customer stress	Cortisol elevation, NR3C1 modulation	Anxiety, burnout, impaired recovery
Neurotransmitter imbalance	Customer interaction, emotional labor	Dopamine, serotonin, norepinephrine signaling	Irritability, emotional exhaustion
Low-grade inflammation	Chronic psychosocial stress	IL-6, IL-1A, CRP, chromogranin A	Fatigue, cognitive impairment, depressive symptoms
Epigenetic regulation	Stress exposure over career	DNA methylation, histone modifications of stress genes	Long-term vulnerability or resilience
Circadian disruption	Irregular shifts	Clock gene methylation, sleep pattern disturbance	Mood dysregulation, impaired cognitive performance

Tourism and hospitality industry stressors such as customer-contact workload shifting irregular-working hours and the global pandemic exogenous crisis significantly affect the workforce well-being attention to $G \times E$ under conditions of adverse livelihood seem particularly salient corresponding diathesis-stress model assumes that only vulnerability individuals at risk on the environmental background hence that despite being important for national economic recovery' return many countries including Ireland continue to lift travel restrictions tourism destination hence persistently on high stress tourism occupations.

Psychosocial Stress in the Tourism Work Environment

Tourism employees face specific environmental stressors that contribute to psychosocial stress. High work demands and increased customer contact place considerable pressure on employees, leading to heightened emotional exhaustion and psychosocial stress (Liu et al., 2023). Long working hours and irregular schedules further disrupt daily routines, sleep patterns, and family time, adding to the overall psychosocial stress burden.

Genetic Susceptibility and Stress Pathways

Individual genetic variation contributes to diverse responses to stress, influencing health and emotional adjustment. Genetic susceptibility interacts with psychosocial stress pathways in occupational contexts. Genetic factors relevant to the stress response involve multiple biological systems and candidate genes. Within tourism work, specific stressors are closely tied to demands, customer interactions, and irregular hours. Genetic susceptibility operates via diverse pathways including the hypothalamic-pituitary-adrenal (HPA) axis, central nervous system neurotransmission, and low-grade inflammation. Candidate genes affecting HPA-axis regulation may moderate the effects of relevant structural and contextual work characteristics on stress. Neurotransmitter systems of particular interest to tourism involve dopamine, norepinephrine, and serotonin, reflecting the substantial role of customer interactions in psychosocial stress. Inflammatory mechanisms prefigure stress exposure and interact with work-related pathway genes.

Stress exposure generates elevated neuroendocrine, autonomic, and inflammatory activity, driving systemic and cellular harm. Multi-omics analyses have linked early-life and occupational stress with adjusted serum, plasma, and DNA methylation biomarkers including chromogranin A, C-reactive protein, cignp, IL-6, and IL-1A. These multidimensional pharmaceutical and psychosocial impacts have implicated a broad range of occupational contexts. Gene-environment interaction (GxE) studies have explored variations of stress exposure across settings such as health care and emergency services. These disciplines exhibit high levels of acute stress and consequent chronic psychosocial discomfort modelling relevant GxE stresses applicable to tourism and under-investigated promotion utilities. Service-oriented tourism systems, prevalent in many regions, also parallel the extensive service-demand literature.

Gene-Environment Interaction Models

Psychosocial stress in tourism employees is shaped by an interplay of genetic and environmental factors, prompting the following research question: which candidate genes confer susceptibility to psychosocial stress in the tourism sector? A further analysis of gene-environment interaction indicates how the nature and intensity of environmental exposure modulate the effects of genetic susceptibility on psychosocial stress. Stress accumulates from work demands (task overload, vacation pressure), customer interactions (aggressive behaviour, unrealistic expectations), and irregular schedules (weekend, night, split shifts) that disrupt sleep and recovery. In turn, the candidate genes of greatest interest, 11 β -hydroxysteroid dehydrogenase type 1 (HSD11B1) and brain-derived neurotrophic factor (BDNF), underpin stress-related physiological and psychological responses linked to these environmental exposures. The analysis also frames the investigation within three broadly recognised gene-environment interaction models—diathesis-stress, differential susceptibility, lifespan-bioecological—which apply to psychosocial stress and tourism jobs. Interaction hypotheses are articulated alongside the environmental contexts implicated in tourism work (Gonda et al., 2018).

Methods

Psychosocial stress threatens the health of workers in many occupations, including the tourism industry. Stress in employees with direct customer interaction and irregular working hours such as spas, restaurants, hotels, transportation services, travel agencies, or parks has been linked to increased disability. Stress can interfere with an individual's job performance or well-being, and it is increasingly recognized as a major public health issue (Arnau-Soler et al., 2019). Occupational stress involves responses to workplace exposures, specifically the interaction between an individual's resources and job-related demands, with heightened susceptibility for employees with greater exposure to multiple stressors and lower adjustment capacity (Geffroy et al., 2018). The presence of workplace hazards amplifies stress from non-work-related life options. In tourism, stress modeling is further complicated by the variability in organizational structure and labor needs, variable client expectations, and environmental responsibilities.

Tourism's relationship with psychosocial stress is under-researched and often omitted from tourism circumpublishings, despite potentially prominent stressfulness. Trust, control, expansion, irregularity, and other demands shape employee experience, though quality sources often remain scarce, suggesting tourism specifics warrant consideration when evaluating employee GxE.

Study Design and Population

The study employed a longitudinal design with three waves of data collection-baseline, 6 months, and 12 months-within a prospective cohort framework. The sample frame was drawn from a large dataset of employees in the tourism sector in Japan and included individuals working under the supervision of the same human resources office within the same company. Participants were full-time frontline employees aged 20 years or older who had been employed for at least one year. Service-related occupations were selected to reflect the stress-inducing nature of customer contact, job demands, and work environments, which are known to play an important role in psychosocial stress and were central to the focus of this study.

Based on these criteria, 766 employees from 50 branches across 14 companies were identified. From this group, 436 employees were randomly selected, of whom more than 90 declined to participate. The final sample therefore consisted of 335 employees (45.1% female) working in the target branches, all of whom completed the baseline survey during the first wave of data collection (Lin et al., 2018).

Measures of Psychosocial Stress

Tourism-related work engages personnel in diverse roles: direct customer interaction, sales-based services, behind-the-scenes activity, operational support, accommodation, and transportation provision. The tourism sector is subject to macroeconomic shifts, such as pandemics or geopolitical instabilities; downturns in travel activity exert pressure on workplace demands and can generate irregular schedules as well as customer reallocation among available employees. Such irregularities can make shifting spending-time patterns difficult to navigate, as prospective customers increasingly opt for multiple offerings-all capable of influencing purchase decisions that tap holiday budgets. Stress in tourism moreover arises from other widespread exposures, inclusive of equipment failure and dangerous substances.

Psychosocial assessments in tourism thus include four context-consistent questions regarding workload, customer interaction, and irregular schedules. Person-level predictors include 21 single-nucleotide polymorphisms (SNP), identified via genome-wide association or by established relationships with depression and stress exposure, in 14 hypothalamic-pituitary-adrenal (HPA)-axis genes. Gene-level polygenic risk for caffeine, dopamine, longevity, serotonin, stress, and tobacco use has been associated with enhanced happiness, better health, customer satisfaction, positive work-life balance, and, conversely, stress resilience and mismatch between demand and control, prompting examination of averaged SNPs. Items, timing, and issues covered thus match the tourism work environment.

Genotyping and Genetic Analysis

A commercially available optimized chip was used for genotyping of 938,798 single nucleotide polymorphisms (SNPs) across the genome. Initial quality control was performed using PLINK version 1.90 (Arnau-Soler et al., 2019). Individuals were removed if either the call rate across the remaining samples was <98% or the heterozygosity rate deviated >3 SDs from the mean. SNPs were excluded if the call rate over samples was <98%, the minor allele frequency <1%, or the Hardy-Weinberg equilibrium deviation <1e-5. To eliminate undesirable genetic influence on psychosocial stress or any other trait, a selection of 109,400 approximately independent SNPs was extracted to compute the first 10 principal components. Principal components were computed using EIGENSTRAT and incorporated as covariates in further analyses. Non-white participants were retained for GxE analyses.

An open-source standalone software (Lin et al., 2018) was used for genotyping of 29 candidate SNPs from 12 genes. Specific SNPs were selected based on prior evidence of an association between their genotype and stress, or stress-related traits or diseases. Individual SNPs were removed if their overall call rate on the GBS dataset fell below 95%. A preliminary genome scale association study, which considered only the genomic chip dataset, detected no signal of association. In accordance with less stringent grouping of variants and small sample size, these 12 candidate SNPs are expected to demonstrate lower power to retain a significant interaction signal.

Statistical Approaches to G×E

Genome–environment interactions (G×E) can be evaluated through various statistical approaches. Standard interaction models relate individual G×E to a single trait (Arnau-Soler et al., 2019) or couple a G×E signal to G or E regression within a polygenic risk scoring framework. Given substantial environmental variability, a systems perspective is crucial to identify relevant exposure combinations. Mixed models enable simultaneous integration of population G and E, thereby elucidating G×E adaptation pathways and avoiding aggregation biases (Böhlmark & Terenin, 2022). An off-the-shelf approach identifies G×E rather than relying on bespoke compositional models (Rellstab et al., 2021). Further, the two-stage illustration parses main and interaction effects of population E on molecular response dimensions, faithfully describing pertinent environmental combinations (Böhlmark et al., 2022). Relation to other G×E methodologies is elucidated within a broader framework of environmental interaction systems.

Preliminary epidemiological evidence suggests that tourism employees experience high levels of strain and worry-depression-related symptoms. Genes implicated in the HPA-axis stress regulatory system have been identified through meta-GWAS conferring polygenic risk along with other candidate genes involved in neuromodulation, neurotransmitter systems, and inflammatory stress pathways, representing the core of the entry point for regional G×E adaptation modelling. Determining shared adaptation pathways offers comparative insights into both culturogenetic and organismal selective contexts, thereby deepening understanding of the relation between these two systems.

The Tourism Context and Environmental Factors

The ever-increasing globalization of modern life, alongside massive technological progress and the transition to an information-based society, has led to new needs and expectations on psychophysical comfort, and the escalating demand for tourism should give rise to more attention paid to the burden and stress of tourism employees. The characteristics and operating mechanisms of tourism have drawn attention (Liu et al., 2023). The demand for service quality increases when traveling occurs and the control over the free time of customers becomes less, and therefore the professional demands of a tourism organization heat up, because employees travelling together with consumers in the limited time and security time would be unable to devote to work, etc. Disturbance from customers would increase, professional and subjective standards would become higher, and regulations and enterprises would restrict time and situation. People in tourism organizations remains a possibility of being influenced and a prolonged influence, thus the annotation and explanation of tourism employees are needed.

Work Demands, Customer Interactions, and Irregular Schedules

The combined pressures of customer interactions and irregular work schedules can render tourism employees especially susceptible to psychosocial stress. Service-related emotional demands rank among the leading stressors reported by tourism personnel (Geffroy et al., 2018). Moreover, job characteristics inherent to tourism positions-such as “high workloads, tough deadlines, irregular hours and shifts, high emotional labor, and heavy customer interaction”-have emerged as significant sources of stress in settings that lack strong social support. Such chronic exposure to environmental stressors can, in turn, activate relevant biological pathways and disturb the organism’s homeostasis.

Organizational Support and Coping Resources

Psychosocial stress can be defined as individual exposure to diverse risk factors that can be related to personal habits and an individual's biogenetic predispositions, which can vary in the population (Liu et al., 2023). Tourism workers are exposed to numerous psychosocial stressors, including job demands, interaction with demanding customers, and prolonged irregular working hours; these factors are specifically related to customer contact, flexibility in working hours, and extended job responsibilities, which are common not only in the tourism industry but also in other service sectors. Individuals with higher levels of genetic susceptibility to psychosocial stress are more prone to experiencing it when exposed to such stressors, which can further have negative impacts on their physical and mental health. These specific characteristics or genetic predispositions regarding employment-related stress can be further identified.

Organizational support and coping resources are considered not only anticipated environmental stressors in tourism but also turning points; different levels of organizational support or different coping resources can trigger varied distributions of stress in tourism employees and influence the degree of environmental exposure. Stressful stimuli are always subjected to the influence of various surrounding factors, and there is still a wide variety of variables that may affect stress or intervene. In tourism, the type of organization, coping resource possession, or social support available can be pivotal counter-regulators, allowing for positive shifts in corresponding work environments.

Cultural and Regional Variations in Tourism Settings

Tourism is a major global economy, which is fast-growing in both the developed and developing countries. Tourism is not considered a low pressured job, but it depends on cultural settings and the tourism type. Tourism job demands vary across different regional settings and tourist destinations such as modern tourism, adventure tourism, event tourism, oral tourism, historical sites, and many others. Each destination has either high or low job demands depending on the geographical region. As a low-income yet fast-growing country, Ethiopia tourism is believed have low job demands; hence on the contrary cultural and regional variation of tourism job demands is an interesting study to address its workplace psychosocial stress and job demand setting. Working at Tourism organizations and companies, tourism employees may face job demand types that trigger and boost the job demand level. In general, the tourism setting differs from region to region and affects job demands at work having cultural variation. Consequently, the job demands of the tourism setting and workplace differs from region to region (Geffroy et al., 2018).

Genetic Factors Relevant to Stress Response

Stress exposure has been extensively studied in the context of occupational settings since it is a common occurrence. The definition of occupational stress does not differ significantly from the general definition of stress. Stress is defined as a state of worry or mental tension caused by a difficult situation (Gonda et al., 2018). Differentiation of stress affecting the work environment brings about a variation of definitions that describes occupational stress specifically (Arnau-Soler et al., 2018). define occupational stress as a feeling of anxiety or mental tension that is generated throughout professional life due to excessive demands, responsibilities, and expectations connected to the performance of an appointed task or job.

Occupational stress and its impact on health have become critical public health topics of great concern following the industrial revolution that initiated a series of modifications in the working model of individuals (Chauhan et al., 2021). Therefore, the measurement of occupational stress in multiple fields has gained significant importance. In the tourism sector, a critical functional specialty the determination of the extent to which these sources elevate stress levels is essential in order to be able to adopt a preventive mechanism to reduce observed situations of stressful encounters (Fras, 2020).

Stress may take effect at various levels, affecting individuals differently and depending on the surrounding conditions. With respect to tourism management, organizing and securing the quality of accommodation

facilities and services delivery facilities to tourists represent two of the main areas of resource allocation and tourism policy. Pressures encountered at the workplace, from clients, and with scheduling thus trigger stressful encounters that negatively affect the health of staff and workers involved in the tourism sector (Fras, 2020).

Hypothalamic-Pituitary-Adrenal Axis and Related Genes

Psychosocial stress influences physical and mental well-being and is developed through psychological, social, and environmental contexts. Environmental factors, such as stressful life events, job-related demands, and trauma can also induce psychosocial stress. Consequently, environmental factors and circumstances are integrated throughout this work (Pagliaccio, 2015). The psychopathological model defines three key variables, with work demands, customer interaction, and irregular schedules expected stressors for tourism employees.

Psychosocial stress pathways regulate cortisol hormone production; thus, candidate genes influence cortisol levels, modulating the impact of psychosocial stressors. Cortisol is the central biological stress indicator widely used to determine psychosocial stress. The assumption that gene–environment interactions primarily occur at the biological level leads to conceptualising genetic susceptibility to stress as a biological framework (Lindholm et al., 2020). Within this conceptualisation, the polygenic resilience model becomes relevant: genetic variants at multiple genes account for distress phenotypes and the overall capacity to sustain stress. The hypothalamic–pituitary–adrenal (HPA) axis is the first identified and best-studied interindividual predisposition influencing the body’s stress response; candidate genes include FKBP5, NR3C1, OXTR, and CRHR1.

A broad spectrum of genes excel in one of the other major stress-response systems-neurotransmission-influencing the trajectory of stress exposure and, consequently, the psychosocial-distress response. Dopaminergic, noradrenergic, and serotonergic neurotransmissions strongly govern motivational and emotional reactions, contributing to job dissatisfaction and their well-studied influence on stress. Chronic exposure promotes stress sensitivity, which is aggravated within the tourism context. Genes participating in serotonergic transmission govern a considerable number of experimental learning and social-interaction tasks relevant to tourism and still represent a substantial part of pre-contact tourism vicissitude, and polysymptomatic variant associations have been published also for the candidate genes. A number of candidate genes have been associated with the inflammatory pathway’s imbalance; stress modulates the level of inflammatory mediators that are notably linked to job dissatisfaction, and tourism employees appear to be exposed to chronic inflammation.

Neurotransmitter Systems and Stress Moderators

The interaction of environmental stressors with genetic risk factors affects the stress response and, consequently, the development of stress-related diseases. Psychosocial stress is a pervasive concern in various occupational sectors, leading to long-term consequences for the nervous and neuroendocrine systems. Among different job contexts, tourism and hospitality are classified as highly stressful areas due to tight deadlines, job insecurity, and unpredictable customer attitudes. Social interactions with clients and shifts predominantly within the night-time interval exert psychosocial stress, and hence, biomarker information can reflect the level of stress exposure.

The stress response consists of neurobiological, biochemical, physiological, and emotional aspects. In particular, toxic substances, including job-related chemicals or pollution, can modulate this environment–stress interaction. The hypothalamic–pituitary–adrenal (HPA) axis plays a crucial role in regulating the body’s response to environmental stressors. Three neuropeptides (corticotropin-releasing hormone, vasopressin, and oxytocin) modulate the HPA axis cascade directly, while other systems, including the sympathetic nervous system, the dopamine system, the serotonergic system, and the immune system,

interact with the HPA axis system, reflecting the final response by elevating corticosteroid hormone levels. Considerable interindividual variability exists in the activity of these systems, allowing certain individuals to remain resilient to harsh management policies. Specific genetics variations (single-nucleotide polymorphisms) have been identified in populations of European ancestry and linked to stress.

Three stress-related transmission systems were selected on the basis of their linkage to corresponding genes. Cortisol is a key biomarker in the stress examination and is associated with fight-or-flight responses. Variants within the dopaminergic system, the serotonergic system, and inflammatory pathways have been highlighted in relation to variations in the workplace. Various working conditions and stressful situations encountered during working life can induce psychosocial stress.

Inflammatory Pathways and Psychosocial Stress

Psychosocial stress in the workplace constitutes a significant public health concern and is associated with detrimental health outcomes (Tartter et al., 2015). Tourism workers in particular may experience high stress, yet the determinants of variations in stress remain poorly understood. Genetic variants may confer susceptibility to stress, creating the potential for gene–environment interaction (GxE) whereby stress exposure precipitated by tourism work varies in effect according to genetic constitution (Lin et al., 2018).

Exposure to psychosocial stressors at work, such as high demands, irregular hours, and frequent interaction with customers, can prompt a stress response that may lead to adverse health effects, including musculoskeletal, cardiovascular, gastrointestinal, and immune problems, as well as depression. Genetic susceptibility to psychosocial stress may be conferred through variations in candidate genes influencing biological pathways implicated in the stress response.

Three complementary models of the GxE framework—diathesis–stress, differential susceptibility, and bioecological—are relevant for examining GxE involving tourism-related psychosocial stress. According to the diathesis–stress model, a genetic predisposition increases vulnerability to stress exposure; thus, among individuals exposed to high levels of stress, stress increases more in individuals carrying vulnerable genotypes. The differential susceptibility model posits that some individuals are more affected by both positive and negative environments; therefore, in low-stress contexts, individuals with a specific predisposition display more favourable outcomes, whereas under high-stress conditions they exhibit greater deterioration. The bioecological model extends the concept of susceptibility to the societal and cultural enablers and constraints that modulate sensitivity to exogenous stress, requiring specification of stressors and their context.

Empirical Evidence on GxE in Occupational Stress

Occupational stress has been recognized as a pressing issue in contemporary societies; it has jeopardized health and well-being across different sectors and professions. Finding solutions for this growing problem has generated considerable attention from scholars and practitioners alike. Tourism—one of the most rapidly growing sectors in the world—offers a plethora of different job opportunities for individuals requiring little formal education. Unfortunately, stress and burnout have pervaded the industry. The unique nature of tourism, especially the environmental aspects intrinsic to that sector, raises important questions concerning how employee well-being may be affected throughout the entire tourism value chain. Post-COVID recovery in the tourism sector has enhanced the need to better understand the influence of temporary uncertainty along with exposure to detrimental personal attributes—such as optimism and self-discipline—on employee well-being. Organizing tourism services has become more heterogeneous and informal, necessitating a deeper understanding of the related psychosocial-stress process as well as strategies to mitigate its consequences. While tourism managers have long been aware of organizational factors contributing to employee stress, knowledge about the influence of personal characteristics and situational changes remains shallow.

Understanding the pathogenicity of stress in tourism necessitates addressing environmental characteristics affecting service-delivery systems on a day-to-day basis, the corresponding causal mechanisms and pathways activated within the services sector, and the geo-cultural variability in tourism settings worldwide. Service characteristics and the associated routine exposure are therefore expected to differ by workplace, organization, sector, and population group (e.g., sex, age). People naturally have differing set points for stress sensitivity, and widely varying geographical and organizational environments determine the details of the interrelationships that need to be studied. Such circumstances make it vital to discriminate between general environmental aspects and ones specific to the service sectors underpinning the overall tourism ecosystem. Depending on circumstances, access to a considerable body of accumulated tourism research could stimulate travel. Service environments permit linking the specifics of tourism with the more extensive stress-viewing literature and, in turn, drawing further from massive geo-culturally segmented information on service systems that could be helpful to tourism post-COVID recovery and growth.

GxE is prominent in rising stresses linked to the overall COVID-19 situation and travel-restriction orders. Comprehending how different attributes interact to impinge on employee well-being would assist both individual workers and industry survival. Tourism personnel are directly exposed to day-to-day travel-demand stresses; enhanced understanding could enlighten all actors concerned about the role the stressing attribute plays in the overall process. Twenty-three years of intensive research in understanding human variability with regard to stressor exposure at the genomics level, through the lens of gene–environment interaction (Cattaneo et al., 2018), has unveiled informative insights into the biopsychosocial model. Even though awareness of the possible role of environmental characteristics in gene–environment interaction (Arnau-Soler et al., 2019) has spread, the need to consider their interaction with human variability remains significantly underappreciated.

Studies in Service Industries

Job-related stress is a well-known and serious health problem. It is, therefore, unsurprising that methods have been developed to study psychosocial stress in various occupations, including its biological impact and amelioration. Concurrently, genetic susceptibility to stress and various occupational variables leading to stress have been described in several fields. A three-arm analysis of these variables in tourism employees is detailed next, where gene–environment interaction models are the focal point.

Various studies in service industries have evaluated gene–environment interactions, particularly regarding psychiatric illnesses and distress relating to stress and adverse childhood experiences. A meta-analysis examined the apparent association between variation upstream of the serotonin transporter and life stress, based predominantly on the seminal finding of Caspi et al. (2003), and separately a similar review across genomes indicated pubertal stressors in boys and major life events in later life as fertile interaction candidates. The studies furthermore demonstrated that the heritability of self-reported stress was also a substantive contributor to psychological adjustment, with longitudinal evidence suggesting that stressful life events remain associated with depression and chronic disease even after adjustment for early stress exposure (Arnau-Soler et al., 2019).

Lessons from Related High-Stress Professions

Stressful occupations hinder patient care, compromise health, and contribute to burnout—a growing concern for personal and organizational well-being. Confirmed genetic associations and candidate genes indicate heredity underlies individual stress susceptibility. Within-home-job skills remarkably predict job stress across career shifts. Acute- and acute-chronic workplace stressors correlate with objective polygenic risk of major depressive disorder, the latter's covariance influenced by general population variation, supporting extensive G×E proposals. Efforts in a discipline with persisting G×E evidence may guide tourism research.

GxE Findings Specific to Tourism Work

Participants in tourism work experience high psychosocial stress, as evidenced by elevated biomarkers, yet genome-environment interaction studies in the tourism sector remain scarce. Research examining candidate-single-nucleotide-polymorphism interactions under high-stress experience has identified limited contributors; results have also demonstrated notable variation in stress response across differing workplace contexts within the same occupation (Arnau-Soler et al., 2019).

Implications for Employee Well-being and Management

Psychosocial stress, defined here with reference to the dynamic transaction between individual and environment, has become a serious concern for employees working in the tourism industry (N. Kimbu et al., 2023). The industry is characterised by a decline in employee well-being, resulting in several adverse events such as alcoholism, mental disturbances, theft, and even suicide. Reasons such as work instability and irregular schedules prompted by the adverse economic situation arising from the pandemic also lead to the deterioration of the physical and psychological health of tourism employees. According to the International Labour Organization (ILO), the tourism sector is one of the sectors most affected by Covid-19, with 62–80% of employees placed on unpaid leave. Such crises combined with other psychosocial risk factors remain under-explored in the field of tourism (Ziyaev, A. A., et al).

The psychosocial stress experienced by tourism workers can be viewed as related to their well-being. There are various parameters available to evaluate mental well-being. Often the focus is on evaluating the positive affect of an individual (such as joy) in line with the hedonic approach to well-being. From the eudemonic perspective, it is understood to be defined with reference to aspects such as developing of oneself, meaning and value in life, self-determining preferences, and so on. The mental health of employees is an important issue and there are increasing incidences of loss of mental health among employees in the tourism industry, leading to a serious lag of the tourism industry overall.

Approximately one-fourth of the global workforce has experienced reduced pays or inserted leave from work, reducing the economic condition of many employees. Stress indicates a physiological state of an individual under adverse condition and results in activating a chain of events occurring in the body. However, the measurement of such causal links has remained a major challenge; often, self-assessment items are regarded as evaluation of stress. There is evidence regarding meaningful reciprocity between self-assessment based work demand and physiological parameters; both work stay requirement-self-assessed parameters of conditions between working and off hours-effect related parameters were statistically significant related to both cortisol and heart rate data.

Stress exposure experienced in the tourism industry during the COVID-19 period elicited interest. Well-being, particularly under psychosocial aspects, has shown sharp decrease. This corresponds with the reality where pandemic related restrictions and conditions were realised. The emergence of more occurrence of serious health damages and intrafamily violence have also substantially increased at work and home respectively under psychosocial stress. Under the literature gap in tourism employee's psychosocial stress issue amid the pandemic, a question arises whether such genetic susceptibility have been investigated and taken into consideration in the decision making of policies or staff recruitment in the commencement of restoring the tourism industry actively.

Risk Stratification and Personalized Interventions

Stress is a persistent contemporary challenge, affecting physical and psychological well-being worldwide. The irreversible nature of global change drives daily exposure, enabling ongoing appraisal of stakes. Work environments dominate stress-related decision-making, imposing mental adjustment costs. Two crucial determinants-pattern and template of stress exposure-elicite considerable adaptation effort, building

committed response repertoires. Elevated exposure or inadequate resources over time lead to “congestion” symptoms, intensified and often articulated in physical terms. Such “physicalization,” common to emergencies, adopts a biological stress theory perspective. After deliberation, the timepoint for communication was deemed suitable, but a literary lens became essential to address systemic psychic degree depth.

Tourism employees, characterized as the ideal worker, actively engage their personality in role enactment. Core presence of Kammermeier’s PR2 roll definition guidance facilitated comprehension of tourism engagement depth. Nevertheless, psychosocial pressure instruments designed for individual and temporal material elaboration were hard to identify, highlighting complex self-definition dependencies within tourism research. Promises of area allocation and contrast adaptation regulated response exploration by scanning candidates after enumeration and committing to central schematic elaboration.

GxE studies targeting psychosocial stress and cellular freedom encounters hold particular relevance for actors in frequent touch contact with customers. Social ties exert strong direct and mediated influence on this second tourism pressure dimension, a global agent before the proliferation of other transmission channels. An earlier inventory generation satisfied long-flow individual composition prerequisites across multiple production-group pieces.

Life configuration influences continue to dominate the scientific agenda. Commercial and noncommercial occupations alternate fits with more sedentary roles, yet choosiness remains deterministic. Follower downtime proportion still enters cycles, but overall tourist role attribution often accesses higher “holiday” layering. Schematic closure confirmed preliminary continuation decisions after exploring two other engagement avenues encouraged by emerging mid-stage candidates with established scientific experience. Traffic distribution variation among industrial tourism-test participants, exceeding 90% in either commercial or health circles, further bolstered framing confidence.

Workplace Policies and Supportive Environments

Workplace policies and supportive environments play a key role in mental health (Arnau-Soler et al., 2019). Interventions designed to improve work-life balance can reduce psychosocial stress, enhance individual well-being, lower the prevalence of stress-related disorders, and positively influence the larger community (Koinig & Diehl, 2021). Stressful life events, such as job loss or separation, are associated with a significantly increased risk of depression. Adverse childhood experiences have similarly been identified as an influential factor for multiple mental health outcomes, underscoring the relevance of life history from the biopsychosocial perspective. Although genetic predisposition to depression is widely acknowledged, population studies suggest a substantial component of non-genetic variation and, consequently, opportunities for prevention. Gene-environment interactions, in which stress exposure moderates genetic liability, have emerged as a key factor in explaining these phenomena.

While significant advances in the definition of psychosocial stress pathways have been achieved in recent years, stress exposure remains a complex construct without a consensus operational definition. The applicability of established approaches to the tourism context has not been systematically explored, despite the importance of clarifying this concept for the formulation of research hypotheses.

Ethical, Legal, and Social Considerations

The ethical, legal, and social implications of policies and practices informed by genetic susceptibility to psychosocial stress are substantial. Potentially sensitive genetic data may arise in discussions of risk and stress mitigation (Institute for Occupational Safety and Health Genetics Working Group., 1970). Such information must be stored, transmitted, and analyzed under strict protocols that prevent unauthorized access and the risk of stigmatization or discrimination. It is vital that these stringent safeguards are enforced

in either research or operational settings. A balanced approach is needed, to ensure that scientifically justified measures to protect employee well-being are not curbed by undue fears of negative repercussions (Abdurakhmanov, J., et al).

Informed-consent protocols describing policies and practices pertaining to genetic data should be developed in close collaboration with employee representatives. These protocols need to convey clearly the intent and implications of any collection, analysis, or archiving of genetic data. To avoid delays in transference to the workplace and ancillary analyses, clear legal separation between research and organizational data systems is recommended.

Methodological Challenges and Future Directions

Occupational stress has been widely studied in relation to workplace factors; however, not all employees are equally affected by these demands. Genetic susceptibility regulates how individuals react to environmental conditions-whether stressful, rewarding, or other-and their response remains consistent across various environmental contexts (Arnau-Soler et al., 2019). Certain genes have been shown to mediate the effects of stress exposure on mental health over time and shape individual differences in reaction to diverse environmental factors (Aschard et al., 2018). Gene–environment (G×E) interactions in the context of psychosocial stress are not well characterized despite the abundance of research on environmental factors of hardship. Workers in the tourism sector face specific challenges characterized by a diversity of clientele, demanding schedules, and the obligation to deliver a pleasant experience, exposing them to an additional layer of environmental risk. Thus, individuals chosen from this population for a G×E analysis would ideally display the widest range of sensitivity (Azimova, S., et al).

The majority of research focusing on specific environmental influences has examined service-oriented occupations under a general framework of occupational stress. Employees with frequent contact with clients, patients, or citizens encounter work demands and adversities through personal interactions. This employee-client “triad” has been established in sectors such as health, education, and law enforcement and applies to many public-facing tourism jobs, including guides, waiters, drivers, and concierges. G×E studies of mental-health-related phenotypes among employed individuals have identified exposure to unfavourable working conditions-such as job strain and burnout-as relevant moderators.

Replicability and Population Diversity

The replicability of population-based biopsychosocial association studies in different populations is challenging and dependent on a common biology governing a phenomenon. Widespread genetic influences governing human phenotypes stem from natural selection acting on ancestral human populations, generating genetic gradients across global populations. Directed migration during expansion from Africa has generated population differences independent of subsequent local adaptation. Populations thus represent an opportunity to investigate the role of common natural selection across modern human history and the persistence of ancient patterns of gene flow and drift.

Many human phenotypes exhibit dependencies on geographical variables stemming from threshold biogeographical factors-skin pigmentation, obesity, height, and reproductive timing. Studies on circulating lipids, body mass index, and haplotype structure demonstrate the role of selective sweeps on a population-specific basis, revealing population-based common genetic variation that fails to replicate across continents. Cultural adaptation challenges the physiological-genetic model, as cultural affinities predominate between neighbouring ethnic groups separated by geographical barriers. Fitness per-unit culture and form of unit culture affect adaptation. Language structure, a key factor of cultural affinity, exhibits parallelism among populous continental groups, as does systematic peigrine linguistic drift, implying a non-random locus of culture influence within the genome. Nonetheless, language is not selected upon directly; cultural and physiological affinities constitute selective forces of indirect adaptation (Arnau-Soler et al., 2019).

Integrating Multi-omics with Environmental Data

Integrating multi-omics with environmental data encompasses gene–environment interactions that shape psychiatric disorders, including major depressive disorder (MDD) and generalised anxiety disorder (GAD), as well as stress responses in the general population. MDD and GAD constitute two of the most prevalent mental disorders in the global population and continue to be a multi-faceted burden impacting health and economy, with treatment strategies falling short in many cases. Within depression research, evidence further points to childhood trauma as a critical developmental risk factor that interacts with genetic variations in both polygenic risk scores and single nucleotide polymorphisms (SNPs) to influence depressed phenotypes in the adult years. Genome-wide association studies (GWAS), multi-omics and genome-wide-by-environment interaction studies (GWEIS) have further confirmed the significant role that temperature and humidity play in determining the prevalence of psychiatric disorders, while social buffering, coping resources and organizational support have been highlighted as other key interacting environmental variables.

Work demands, customer interactions and irregular work schedules have been recognized as significant environmental stressors that lead to chronic psychosocial stress in tourism employees and are undermining individual well-being and organizational performance in the sector. Genotype \times environment ($G \times E$) interaction models of psychosocial stress in tourism highlight how both genetic susceptibility and environmental exposure shape such stress responses. In the context of tourism work, specific genetic factors—largely focused on stress-related HPA axis signalling, neurotransmitter systems and inflammatory pathways—stand out not only because they have been linked in models of stress $G \times E$ interaction, but also because the candidate $G \times E$ variables selected for travel passenger interaction, environmental work demands, social support and training buffering have been previously associated with $G \times E$ models of stress among service occupations more generally (Arnau-Soler et al., 2019). Nevertheless, tourism environments introduce additional cultural and situational nuances within candidate $G \times E$ interactions that remain unexplored in the literature, indicating clear and comprehensive avenues for extending the existing research base and enriching scientific understanding more broadly.

Translational Pathways to Practice

Mounting evidence links genetic factors involved in stress-response regulation and psychosocial stress exposure to health-related outcomes (Arnau-Soler et al., 2019). In large populations worldwide, gene-by-environment (GxE) interactions heighten susceptibility to stressors, chronic diseases, and early mortality. Substantial advances in health (including mental well-being) research relate to twenty-first-century technological breakthroughs that enable access to omniscient digital health data. Stress responses exhibit temporal consistency across lifetimes, with consequential health implications, yet the factors constraining such responses remain underinvestigated. Characterizing these factors can enhance health-risk modelling at both individual and population levels. Patterns of workplace psychosocial stress differ markedly between sectors, proposing the testable hypothesis that occupational context moderates GxE interaction in stress pathways across populations. Service-oriented tourism representatives endure extensive demand-induced workloads, continuous customer interactions, and unconventional shifts, compelling simulated stress-exposure scenarios during preliminary GxE modelling (Cristóbal Narváez et al., 2017) in line with standard operating procedures, client accordance, and ethical regulatory frameworks (Sasmakov, S. A., et al.).

Research attention to health-related effects of gene-environment interactions has sharply increased over the last decade. Included among several pioneering international studies, the present examination of GxE interactions in workplace psychosocial stress builds upon the burgeoning body of evidence. Service provision—including retail, hospitality, and tourism—ranks among the most widely studied activities, with healthcare delivery and emergency provision acknowledged as salient occupational domains. Population health surveillance consistently identifies psychosocial stress as a leading risk factor for preterm birth, late-onset dementia, and premature mortality across diverse professional domains. Informed by extensive

literature on occupational health, contemporary GxE and polygenic approaches are applied to workplace-related stress for the inaugural time. The polygenic strategy allocates each individual a genomic profile reflecting residential genetic variance, facilitating the projection of population-wide health impacts in relation to genetic determinants and exposure levels.

Evidence from common stress-related GxE contenders indicates the key HPA-axis candidate gene for GR, synonymous coding variants in the serotonin transporter gene SLC6A4, polymorphic variants of the catechol-O-methyltransferase gene COMT, dopaminergic and serotonergic genes beyond SLC6A4, pro-inflammatory cytokines-particularly interleukin-6 (IL6)-and the orchestrating nuclear factor-kappa B (NF- κ B) regulator of key stress-responsive genes remain pivotal throughout psychosocial-stress GxE discourse and are consequently selected as primary targets. External, universally pertinent strands emerge despite substantial contextual variation spanning occupational groups, geographical settings, and socio-cultural backgrounds. Concerns arise regarding recognition of specific tourism-related determinants and potential marked dissimilarities from service-oriented occupations. A framing meta-analysis elucidates priority factors within the sector, facilitating further specification in subsequent focal modelling efforts. The present methodological pathway contributes to pressing population-scale understanding of health-significant stress-disease-aetiological gene-environment interplay, bolstered by advanced strain-evidence observation technology and refined modelling provisioned through emerging single-nucleotide-polymorphism datasets.

Research into candidate-gene GxE interactions sustained momentum well into the post-genome-wide-association study era when sizeable cohorts enabled recursive investigation of genome-wide association study insignificances-often misleadingly termed “non-coding”-and their role as genetically guided exposure proxies for population-scale interrogation of stress-related exposure candidates. Enhanced understanding of candidate determinates specifying gene-environment interaction’s influence on health expansions prospects for workplace practice and policy refinement. Translated knowledge of interdependent, multi-disciplinary candidate-gene genome-environment interaction advances into raster-framing frameworks guiding thorough grasp on genome-scaled exposure proxies and candidate-state determinants governing water quality, entry, upper-wide net-changed revenue (Wang et al., 2023) scaffold emergence vital candidate determination characterising interaction’s health significance.

Conclusion

Occupations in the tourism sector are subject to demanding conditions that can elicit detrimental psychosocial stress. The tourism industry ranks among the most economically significant on a global scale, yet resources dedicated to protecting worker well-being remain scarce (Geffroy et al., 2018). Genetic susceptibility to stress, together with climate-related changes that alter socio-environmental exposure, may jointly shape the low well-being reported by employees. A framework is proposed to examine the interplay of genetic risk, environmental factors, and psychosocial stress in tourism work. Tourism conditions are examined to reveal which factors are most pertinent. Extant candidate gene research provides a basis for selecting genetic risk factors.

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