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Move Past Adversity or Bite Through It? Diet Quality, Physical Activity, and Sedentary Behavior in Relation to Resilience

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Adverse life experiences are associated with an increased risk of mental disorders. The successful adaptation to adversity and maintenance or quick restoration of mental health despite adversity is referred to as resilience. Identifying factors that promote resilience can contribute to the prevention of mental disorders. Lifestyle behaviors, increasingly recognized for their impact on mental health, are discussed as potential resilience factors. Several studies found that healthy eating and physical activity (PA) are positively associated with resilience. However, most of these studies assessed resilience through questionnaires, which is unsatisfactory given that resilience research is moving toward conceptualizing resilience as the outcome of a dynamic process, which can only be assessed prospectively and longitudinally. The present study is the first to assess the relationship between diet quality, PA, sedentary behavior (SB), and resilience, captured prospectively and longitudinally in a sample of 145 individuals (75.17% female; $M_{age} = 28.88$, $SD_{age} = 7.80$; $M_{BMI} = 24.11$, $SD_{BMI} = 3.97$). Resilience was assessed as the relationship between stressor exposure and mental health (i.e., the stressor reactivity score: higher scores indicate lower resilience and vice versa). Diet quality (i.e., the Healthy Eating Index) was assessed on the basis of app-based food records and 24-hr dietary recalls. PA and SB were objectively recorded through accelerometers. Regression analysis showed that neither diet quality nor PA and SB predicted resilience ($ps > .30$). Profound differences in the conceptualization and operationalization of resilience might explain the contrary findings. Prospective longitudinal studies are needed to replicate the findings of the present study.

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The data and R code that support the findings of this study are available in the supplemental material of this article. This study was not preregistered. A brief overview of the results was submitted to the European Commission as part of a deliverable report published at https://cordis.europa.eu/project/id/728018/results.

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continued

Public Significance Statement
Adversity increases the risk of mental disorders. Favorable lifestyle behaviors, such as eating healthy and engaging in physical activity, may facilitate the successful adaptation to adversity and thereby promote resilience, whereas unfavorable lifestyle behaviors, such as sedentary behavior (SB), may hamper adaptation and reduce resilience. The present study found, however, that diet quality, physical activity, and SB were not associated with resilience when assessed as a dynamically changing outcome as opposed to as a stable trait captured through resilience questionnaires in previous studies. These findings suggest that diet, physical activity, and SB may not facilitate or hamper the adaptation process to adversity.

Keywords: resilience, stressor reactivity, diet quality, physical activity, sedentary behavior

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While the importance of lifestyle behaviors, such as diet and physical activity (PA), has long been recognized in the context of physical health, rapidly growing evidence suggests that lifestyle factors also play a substantial role in mental health (Adan et al., 2019; Firth et al., 2020). Mental disorders are one of the ten leading causes of the global burden of disease (GBD 2019 Mental Disorders Collaborators, 2022), highlighting the need for effective prevention and treatment approaches. An important construct in the prevention of mental disorders and the maintenance of mental health is resilience, which is defined as "the process and outcome of successfully adapting to difficult or challenging life experiences" (American Psychological Association, n.d.; https://dictionary.APA.org/resilience). Resilience research is interested in the mechanisms that prevent illness (Kalisch et al., 2015) and in factors that facilitate the successful adaptation to stressors and adverse events (i.e., which predict resilience) that are often referred to as resilience factors (Kalisch et al., 2017) or resilience-promoting factors (Bonanno et al., 2015).

The growing body of evidence supporting a close link between lifestyle behaviors and mental health raises the question of whether favorable lifestyle behaviors (i.e., healthy diet, adequate levels of PA) may buffer against stress, promote resilience, and thereby function as resilience factors. Biological and psychological mechanisms, discussed as potential pathways by which diet and/or PA may promote resilience, include (a) the gut–brain axis (Berding et al., 2023; Foster et al., 2017; Guan et al., 2023), (b) epigenetics (Smeeth et al., 2021), and (c) self-efficacy (Neumann et al., 2022). While the importance of the gut–brain axis in the regulation of stress-related responses is well documented, more recent evidence identified the gut microbiome as a key player in controlling this axis, particularly when individuals are exposed to stress (Foster et al., 2017). Diet is one of the most important factors influencing the microbiota–gut–brain axis (Ross et al., 2024). An increasing number of studies indicate that microbiota-targeted diets, for example, high in prebiotic, probiotic, and/or fermented foods, might reduce perceived stress and stress-related disorders by positively influencing the gut–brain communication (Berding et al., 2023; Nishida et al., 2017; Tillisch et al., 2013). Beyond that, a study found that higher levels of PA were associated with distinct gut microbiome signatures and a production of metabolites that are protective toward mental health (Guan et al., 2023). A second mechanism through which diet and PA may promote resilience includes their effects on the

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epigenome, such as DNA methylation, histone acetylation, and microRNA expression (Alegría-Torres et al., 2011). While there is consensus that the epigenome is susceptible to adversity, less is known about protective factors, such as healthy diets and exercise. However, studies indicate that healthy diets, rich in polyunsaturated fatty acids, polyphenols, and fiber, as well as PA may influence epigenetic mechanisms (Alegría-Torres et al., 2011). In the context of resilience, a first study in mice indicates that specific dietary components, such as dietary phytochemicals found in grape juice and grape seed extract, may promote resilience to stress through epigenetic mechanisms that target systemic inflammation and neuronal plasticity (J. Wang et al., 2018). Moreover, evidence in humans indicates that a healthy lifestyle may positively affect epigenetic patterns and methylation age (Klemp et al., 2022) as well as epigenetic aging (Quach et al., 2017), thereby potentially fostering resilience (Smeeth et al., 2021). A psychological mechanism through which the effects of diet and PA on resilience may manifest is self-efficacy, which promotes resilience in the face of adversity by influencing people's feelings, cognitions, and behaviors (for an overview, see Schwarzer & Warner, 2013). For instance, individuals high in self-efficacy are confident in their abilities to cope when exposed to adversity, perceive problems as challenges (not threats), experience less negative emotions, engage in self-enhancing thinking, motivate themselves, and persist in their efforts (Schwarzer & Warner, 2013). Research has shown that engaging in PA is associated with higher levels of self-efficacy (e.g., Han et al., 2022), which may represent a pathway through which PA is linked to resilience.

Several studies assessed the association between resilience and diet as well as resilience and PA. For instance, studies found that higher resilience was associated with (a) better overall diet quality in a French population-based study (Robert et al., 2022) and in a sample of Army and Air Force recruits (Lutz et al., 2017), (b) higher adherence to Mediterranean dietary patterns as well as vegetable-based dietary patterns in an Italian general adult population sample (Bonaccio et al., 2018), (c) higher fruit and vegetable intake as well as less frequent soft drink and takeaway food consumption in a sample of Australian university students (Whatnall et al., 2019), (d) a higher likelihood to consume five or more servings of fruit and vegetables a day in a German population-based cohort study (Perna et al., 2012), (e) less frequent consumption of fried foods in Japanese company workers (Yoshikawa et al., 2016), and (f) dietary diversity in a community-based sample of Chinese older adults (Yin et al., 2019). Findings also indicate that higher resilience is associated with (a) a higher likelihood to perform moderate and high PA in the German population-based cohort study mentioned above (Perna et al., 2012); (b) higher levels of PA in Chinese pupils (Ho et al., 2015), Chinese college students (Z. Zhang, Wang, et al., 2022), last-year student teachers in Turkey (Ozkara et al., 2016), and among U.S. undergraduates with high trait anxiety, but not with low and moderate trait anxiety (Hegberg & Tone, 2015); and (c) a higher likelihood to attain PA recommendations in Australian adults during the COVID-19 pandemic (To et al., 2022) and Chinese university students (Yu & Ye, 2023), but not the recommendation for sedentary behavior (SB) in the same Chinese university student sample (Yu & Ye, 2023).

All the studies described above used questionnaires to assess resilience: the Brief Resilience Scale (Ozkara et al., 2016; Robert et al., 2022; To et al., 2022; Whatnall et al., 2019), a version of the Connor–Davidson Psychological Resilience Scale (Bonaccio et al., 2018; Hegberg & Tone, 2015; Ho et al., 2015; Lutz et al., 2017; Yu & Ye, 2023; Z. Zhang, Wang, et al., 2022), the Simplified Resilience Score (Yin et al., 2019), or a version of the Resilience Scale (Perna et al., 2012; Yoshikawa et al., 2016). Relying on self-reports, that is, asking individuals to what extent they believe they can adapt to stressors, is problematic, given that predicting their own response to unexpected circumstances is extremely difficult (Denckla et al., 2020). Beyond that, resilience research is moving away from conceptualizing resilience as an individual trait and toward conceptualizing resilience as the outcome of a dynamic process of successful adaptation to adversity (Chmitorz et al., 2018; Denckla et al., 2020; Kalisch et al., 2017; Masten et al., 2021; Rutter, 2006; Stainton et al., 2019). Taking into account the process nature of resilience, resilience cannot be understood as a trait or stable personality characteristic and cannot be represented adequately by a score on a resilience questionnaire (Kalisch et al., 2017). Instead, resilience should be operationalized as good mental health following stressor exposure and adversity and should be assessed in prospective longitudinal studies (Kalisch et al., 2017).

Despite the growing consensus to conceptualize resilience as the outcome of a dynamic process of successful adaptation to adversity, the number of studies assessing the relationship between resilience conceptualized as such and lifestyle behaviors is very limited. To the best of our knowledge, so far, no study has captured resilience prospectively and longitudinally to study the association between resilience and diet. To assess the relationship between resilience and PA, two studies refrained from relying on questionnaires to quantify resilience and employed a longitudinal, prospective assessment to adequately account for the process nature of resilience. The first study by Szuhany et al. (2023) categorized individuals (age ≥50) who experienced a major life stressor (e.g., divorce) into four groups based on depression symptoms in the assessments immediately before stressor exposure, immediately after stressor exposure, and 2 years after: (a) *resilient group* (constant low depression symptoms), (b) *improving group*[1] (clinically relevant symptom levels before the stressor, which

[1] According to the definition of resilience by Kalisch et al. (2017), which defines resilience as the maintenance or quick recovery of mental health during and after adversity, the improving group (also referred to as "recovery" by Bonanno, 2004) would also conform with the definition of resilience.

decreased continuously after the stressor), (c) *emerging group* (low-to-moderate symptom levels before the stressor, which intensified to clinically relevant levels after the stressor), and (d) *chronic group* (constant clinically elevated symptom levels. Membership in the resilient group was predicted by PA at baseline. Higher levels of PA were found in the resilient group compared with the other groups for all time points. The emerging and chronic groups showed a decrease in PA after the stressor, while PA levels stayed relatively stable in the improving group. These findings may indicate that prestressor PA may buffer against depressive symptoms (i.e., promote resilience) and poststressor PA may be associated with lower depression levels following adversity. The second study by Neumann et al. (2022) assessed the relationship between resilience and PA in the LOngitudinal Resilience Assessment (LORA) study. Resilience was assessed on the basis of data collected following the Frequent Stressor and Mental Health Monitoring (FRESHMO) paradigm (Kalisch et al., 2021) and operationalized according to the residualization approach, that is, a stressor reactivity (SR) score was calculated based on an individual's deviation from the normative relationship between stressor exposure and mental health problems for a specific time window. Positive deviations (high SR scores, i.e., more mental health problems than expected given the stressor exposure) indicate that an individual's mental health is vulnerable to the effects of stressors in the studied time window, implying low resilience (Kalisch et al., 2021). Negative deviations (low SR scores, i.e., less mental health problems than expected given the stressor exposure) reflect low vulnerability to stressors and high resilience (Kalisch et al., 2021). It is important to highlight that resilience is not understood as a trait in this approach, wherefore the SR score varies across time and represents resilience only for a specific time window. Interestingly, no relationship between PA and the SR score (covering a period of 9 months) was found (Neumann et al., 2022). Even though these two studies make a valuable contribution to the field, the authors note that the results are somewhat limited due to relying on self-reports for the assessment of PA (e.g., the International Physical Activity Questionnaire). Self-reports of PA are prone to bias (e.g., social desirability and recall bias) and differ substantially from objective measures, such as accelerometers (Adamo et al., 2009; Prince et al., 2008). Beyond that, SB was not assessed in the two studies. However, SB has been discussed as a risk factor for mental health (e.g., Huang et al., 2020; X. Wang et al., 2019; J. Zhang, Yang, et al., 2022), wherefore research is needed to study whether SB may be associated with lower resilience.

Given the lack of studies assessing resilience prospectively and longitudinally and its relationship to diet and objectively measured PA and SB, the aim of the present study was to collect detailed nutritional data as well as PA and SB through accelerometers in a subsample of the LORA study cohort. Hence, instead of relying on questionnaire-based assessments of resilience, resilience was operationalized as the SR score (see above). Detailed nutritional data were used to quantify diet quality. Moderate to vigorous PA (MVPA) and SB were specified via accelerometry. It was studied whether diet quality, MVPA, and low SB predict resilience (i.e., the SR score). Because the importance of taking the potential interaction between diet and PA into account has been highlighted (Hershey et al., 2022; Koehler & Drenowatz, 2022), the present study is the first to assess whether diet and PA not only influence resilience independently but whether they reinforce each other, that is, whether the combined effect is different from the mere sum of their individual effects.

Method

Procedure

Participants of the LORA study, which follows up individuals not affected by a mental disorder at baseline over several years to quantify resilience prospectively and longitudinally (Chmitorz et al., 2021), were invited to take part in the APPetite study after participating in the LORA study for at least 1.5 years. Inclusion and exclusion criteria as well as a brief description of the recruitment strategies of the LORA study can be found in Supplemental Material 1. Individuals who agreed to participate in the APPetite study were invited to two in-person sessions and an ecological momentary assessment (EMA) period in between the in-person sessions. In the first in-person session, sociodemographic information was collected, body weight and height were measured, and participants completed a web-based 24-hr dietary recall under supervision. Participants were familiarized with the APPetite mobile app (Ruf et al., 2021) and the accelerometer, which were used for the EMA period to capture food intake for 3 days and PA as well as SB for 7 days. Three months after the first in-person session, participants were contacted via email and asked to complete another 24-hr dietary recall from home. A subsample ($n = 50$) was invited to take part in the validation study, which comprised three additional 24-hr dietary recalls from home the week before or after the EMA period (for a complete description of the study procedure of the APPetite study, see Ruf et al., 2021).

The local ethics committee approved the study. All participants declared that they understood the study procedure and signed a written informed consent. The study design was not preregistered.

Sample

A total of 186 LORA participants agreed to take part in the APPetite study. However, 19 participants had to be excluded from the analysis because no SR score matching the criteria described in the Measures section was available. Due to incomplete dietary data, 12 participants had to be excluded.

One participant had to be excluded as the food records were biased due to physical sickness. Four participants did not wear the accelerometer long enough (see criteria in the Measures section) and were therefore excluded. Four participants dropped out, and one participant did not respond truthfully (i.e., the same response selected for all questionnaire items), which led to exclusion. The final sample thus consists of 145 participants. Sociodemographics of the final sample are shown in Table 1.

Measures

Resilience

Resilience was quantified by the SR score, which was calculated on the basis of data collected in the LORA study. The LORA study collects data on stressor exposure and mental health problems every 3 months over several years according to the FRESHMO paradigm (Kalisch et al., 2021; for a detailed description of the LORA study, see Chmitorz et al., 2021). The residualization approach was used to calculate the SR scores (see Kalisch et al., 2021, for a comprehensive overview of this approach). This approach takes into account that resilience has to be measured in relation to adversity, wherefore both mental health problems and stressor exposure (i.e., life events and daily hassles) were assessed repeatedly every 3 months. Life events were captured using an adapted German version of the Life Events Questionnaire by Canli et al. (2006), which assessed the occurrence of 27 life events (e.g., death of spouse) in the past 3 months. The Mainz Inventory of Microstressors by Chmitorz et al. (2020) was used to capture the number of days participants experienced each of 58 daily hassles (e.g., nightmares, traffic) in the past 7 days. The number of life events and the total count of days daily hassles occurred were averaged across the two or three measurements within the chosen 9-month period (see below), before calculating a combined stressor exposure score as the mean of the z scores of the average life event count and average daily hassle count. Mental health problems were assessed based on the General Health Questionnaire (Goldberg & Hillier, 1979; Klaiberg et al., 2004) and averaged over the two or three measurements within the chosen 9-month period. A linear regression model was used to obtain the sample's normative relationship between stressor exposure and mental health problem (= regression line) in the total LORA sample ($N > 1{,}000$) in the first 9 months of the LORA study. To make SR scores comparable across time, this regression line was used as the reference for establishing residual variations for all following time windows (for more details, see Kalisch et al., 2021).

Table 1
Sociodemographic Characteristics of the Final Sample

Variable	*n*/*M*	%/*SD*
Gender		
Female	109	75.17%
Male	36	24.83%
Age (years)	28.88	7.80
Marital status		
Single	42	28.97%
In a relationship	86	59.31%
Married	17	11.72%
Highest level of education		
Certificate of Secondary Education	1	0.69%
School-leaving examination	58	40.00%
Completed vocational training	9	6.21%
University degree	77	53.10%
Monthly gross income		
0–1,000 €	71	48.97%
1,001–2,000 €	20	13.79%
2,001–3,000 €	18	12.41%
3,001–4,000 €	13	8.97%
4,001–5,000 €	11	7.59%
Over 5,000 €	12	8.28%
Nationality		
German only	121	83.45%
German and other	19	13.10%
Other only	5	3.45%
BMI	24.11	3.97

Note. $N = 145$. BMI = body mass index.

SR scores reflect an individual's deviation from the sample's normative mental health reaction given their stressor exposure, that is, individuals who report more mental health problems than would be expected given their stressor exposure are more vulnerable to stressors and have higher SR scores and lower resilience. Individuals who report less mental health problems than would be expected given their stressor exposure are less vulnerable to stressors and have lower SR scores and higher resilience. First evidence supporting construct and predictive validity of the SR score has been provided by Ahrens et al. (in press), that is, the established resilience factor *sense of coherence* predicted low SR trajectories (i.e., resilient trajectories), which were also associated with lower probability to develop mental disorders.

SR scores used in the present study were calculated for periods of 9 months in which at least two of the three measurement time points were complete (two time points included: $n = 26$; three time points included: $n = 119$). The 9-month period within the LORA study was chosen based on the temporal proximity to the participation in the APPetite study (see figure for illustration in Supplemental Material 2): For 136 participants (93.8%), the APPetite data collection fell within the chosen 9-month period, and for nine participants (6.2%), it was not within the 9-month period but less than 1 year apart from it. Participants whose closest 9-month period was more than 1 year apart from the APPetite data collection were excluded from the analysis.

Healthy Eating

Participants reported food intake for up to 8 days. Food intake of up to 5 days was captured through the web-based 24-hr dietary recall myfood24-Germany (Koch et al., 2020).

For up to 3 days, food intake was captured through the food record of the APPetite mobile app, which was developed to record foods and drinks as soon as possible after consuming them, to minimize recall bias. The feasibility, usability, and validity of the app were evaluated. Results indicate that the APPetite mobile app is overall a feasible and valid dietary assessment tool (Ruf et al., 2021). Dietary data collected through the app were transferred to myfood24 by trained staff. Myfood24-Germany comprises food items from two German food composition databases: (a) the German Food Code and Nutrient Database (Bundeslebensmittelschlüssel Version 3.02), which includes generic food items (Hartmann et al., 2008), and (b) the database of the Dortmund Nutritional and Anthropometric Longitudinally Designed study (Buyken et al., 2012), LEBTAB, which includes branded products.

The Healthy Eating Index (HEI) of the German National Nutrition Survey II (Nationale Verzehrsstudie II [NVS]) was used to assess overall diet quality (Wittig & Hoffmann, 2010). The HEI-NVS is calculated based on a scoring system (maximum score = 110) used to define an "optimal diet" on the basis of the national food-based dietary guidelines of the German Nutrition Society. Higher scores indicate better overall diet quality. To calculate the HEI-NVS, the intake of ten food categories is compared with optimal intake (see Table 2). The intake of each food category was determined by (a) summing up all consumed amounts of each category for each included day and (b) averaging these daily intakes across included days for each participant for categories comprising daily recommendations and additionally multiplying it by 7 for categories with weekly recommendations. To allow a more accurate assignment to the ten food categories, Bundeslebensmittelschlüssel and LEBTAB food items were disaggregated into their ingredients where applicable (e.g., instead of assigning the item "coffee with milk" to one category as a whole, it was proportionally assigned to the "drinks" and "milk" categories).

The HEI-NVS was calculated exclusively based on days on which complete dietary data were available. Participants who reported food intake completely for less than 3 days were excluded from the analysis. On average, 5.57 days of complete dietary data (SD = 1.46) per participant were available and used to calculate the HEI-NVS.

PA and SB

PA and SB were captured using Move 3 sensors from movisens (movisens GmbH, Karlsruhe, Germany). Participants were asked to wear the sensor on the nondominant wrist for

Table 2
Scoring System of the Healthy Eating Index of the German National Nutrition Survey II

Category	Food	Recommendation	Scoring
Fruits	Raw and cooked fruits, fruit products (e.g., fruit sauces), nuts, and seeds	250 g per day (= two portions): 200 ml of fruit juice and 25 g of seeds and/or nuts[a] can substitute one portion each, but not more.	x × 10/250 (max. 15 points)
Vegetables	Raw and cooked vegetables, lettuce, pulses, and vegetable-based dishes	400 g per day (= three portions): 200 ml of vegetable juice can substitute one portion, but not more.	x × 10/400 (max. 15 points)
Grains	Grain products such as bread, baked goods, cereals, pasta, potatoes, and grain-based dishes	350–560 g per day	If x = 350–560 g: 10 points If x ≤ 350 g: x × 10/350 If x > 560 g: 560 × 10/x
Milk	Milk, milk products such as cheese, yogurt, curd, and milk-based dishes	Two portions per day: 1 portion = 200–250 g milk/yogurt or 50–60 g cheese/curd[b]	If x = 400–500 g: 10 points If x ≤ 400 g: x × 10/400 If x > 500 g: 500 × 10/x
Fish	Fish, fish products, and fish-based dishes	150–220 g per week	If x = 150–220 g: 10 points If x ≤ 150 g: x × 10/150 If x > 220 g: 220 × 10/x
Meat	Meat, meat products, sausages, and meat-based dishes	<300–600 g per week	If x ≤ 600 g: 10 points If x > 600 g: 600 × 10/x
Egg	Eggs and egg-based dishes	≤3 eggs per week (= 180 g)	If x ≤ 180 g: 10 points If x > 180 g: 180 × 10/x
Alcohol	Pure alcohol (i.e., ethanol)	Women: ≤10 g ethanol per day Men: ≤20 g ethanol per day	If x ≤ 10/20 g: 10 points If x > 10/20 g: 30 × 10/x
Spreadable fats	Butter and margarine	≤15–30 g per day	If x ≤ 30 g: 10 points If x > 30 g: 30 × 10/x
Drinks	Alcohol-free drinks such as water, coffee, tea, fruit juice and nectar, vegetable juice, and lemonade	≥1.5 L per day	If x ≥ 1.5 L: 10 points If x < 1.5 L: x × 10/1.5

Note. x = actual intake; max = maximum.
[a] According to the 10 guidelines of the German Nutrition Society, 25 g of seeds and/or nuts can substitute one portion of fruits and were therefore included in the fruit category. [b] To streamline the parallelization of the two subcategories, the amount of the subcategory cheese/curd was transferred to the subcategory milk/yogurt by multiplying it by 4. As a result, 400–500 g could be used as the recommendation of two portions while keeping the portion discrepancy between the two subcategories minimal.

7 days and nights. Only days on which the sensor was worn at least 10 hr while being awake were included. Participants who did not meet this criterion for at least 3 days were excluded from the analysis. In the final sample, the sensor was worn on average 92.93% (SD = 8.41%) of the 7-day period. The software DataAnalyzer (movisens GmbH, Karlsruhe, Germany; Version 1.13.7) was used to calculate metabolic equivalents per minute. Metabolic equivalent values were adjusted to the sensor placement on the wrist based on a conversion factor obtained by a sensor validation study (Giurgiu et al., 2020). Nonwear and sleep times were excluded. Metabolic equivalents of 3 and above were categorized as MVPA and 1.5 or below as SB (Sedentary Behaviour Research Network, 2012) for each day. Minutes of MVPA and minutes of SB were averaged across included days (M = 6.79 days, SD = 0.64) for each participant.

Data Preprocessing and Statistical Analysis

Data preprocessing and analyses were performed using R (Version 4.2.2; R Core Team, 2022) and RStudio (Version 2022.07.2 + 576; RStudio Team, 2022). Two multiple linear regression models with the SR score as the dependent variable were run, first for the complete sample and subsequently for two thirds of the participants with the highest overall stressor exposure as recommended by Kalisch et al. (2021). Both models included the predictors HEI, MVPA, and SB. In line with Neumann et al. (2022), gender (0 = male, 1 = female), age, and body mass index (BMI) were included as covariates. Beyond that, smoking (0 = nonsmoker, 1 = smoker), another lifestyle factor linked to mental health (Firth et al., 2020; Taylor & Munafò, 2019) and resilience (Y. Wang et al., 2016), was included as a covariate. The second model also included an interaction between HEI and MVPA. The covariates age and BMI were centered around 30 and 25, respectively (i.e., 30 or 25 were subtracted from participants' age and BMI, respectively, to make the model intercept more interpretable as recommended by Viechtbauer, 2022). The predictors HEI, MVPA, and SB were centered on the group mean.

The assumptions of multiple linear regressions were tested. Variance inflation factors were calculated to evaluate multicollinearity, which were below 2 for all predictors, indicating that multicollinearity was not present. Homoscedasticity was verified by the Breusch–Pagan test (BP = 5.25, df = 7, p = .63). The Durbin–Watson test confirmed independence across observations and found no autocorrelation (DW = 2.028, p = .57). The Shapiro–Wilk test showed that the residuals of the model were not normally distributed (W = 0.97, p = .008). However, given the sample size of the present study, the results of the multiple linear regression model are expected to be valid despite violating the normality assumption (Schmidt & Finan, 2018).

Transparency and Openness

This study was not preregistered, and the sample size was not predetermined. We report all data exclusions and all measures in the study. The data and R code that support the findings of this study are available in the Supplemental Material of this article.

Results

Means, standard deviations, and ranges of the dependent variable and the independent variables are shown in Table 3.

Model 1, a multiple linear regression model adjusted for the covariates gender, age, BMI, and smoking, showed that neither diet quality (HEI) nor MVPA and SB were significant predictors of resilience (SR score). Beyond that, the interaction term between diet quality and MVPA was not significant in Model 2. Results of the two models for the complete sample are displayed in Table 4 and for two thirds of the sample with the highest overall stressor exposure in Table 5.

Discussion

The importance of lifestyle behaviors, such as diet and PA, is increasingly recognized in mental health research. In light of the high disease burden associated with mental disorders, effective prevention approaches are urgently needed. Healthy diet and sufficient PA are discussed as potential resilience factors that may facilitate the dynamic process of successful

Table 3
Descriptive Statistics of the Dependent and Independent Variables

Variable	M	SD	Range
Stressor reactivity (SR) score	0.099	0.92	−1.90–2.72
Daily hassles[a]	57.02	24.77	7.67–141
Life events[a]	1.88	1.33	0–6.33
Mental health problems (GHQ)[a]	19.98	8.06	5–46.33
Healthy Eating Index	80.11	8.70	56.61–100.18
Moderate to vigorous physical activity (min/day)	47.64	45.45	1.00–203.71
Sedentary behavior (min/day)	618.97	91.97	330.14–870.00

Note. Means, standard deviations, and ranges of the dependent variable stressor reactivity score and the variables it is derived from (daily hassles, life events, and mental health problems) as well as the independent variables. GHQ = General Health Questionnaire.
[a] Mean across the two/three measurement time points within the chosen 9-month-resilience window.

Table 4
Model Summaries for the Complete Sample

Effect	Estimate	*SE*	95% CI *LL*	95% CI *UL*	*p*
Model 1					
Intercept	−0.222	0.157	−0.533	0.089	.160
HEI	0.008	0.009	−0.01	0.026	.369
MVPA	−0.0014	0.002	−0.006	0.003	.544
SB	0.0001	0.001	−0.002	0.002	.935
Gender	0.402	0.189	0.027	0.776	.036*
Age	−0.016	0.011	−0.038	0.006	.155
BMI	−0.006	0.027	−0.059	0.047	.833
Smoking	−0.081	0.367	−0.806	0.644	.825
Model 2					
Intercept	−0.227	0.157	−0.538	0.084	.152
HEI	0.009	0.009	−0.009	0.027	.335
MVPA	−0.002	0.002	−0.007	0.003	.418
SB	0.00004	0.001	−0.002	0.002	.966
Gender	0.385	0.191	0.008	0.762	.046*
Age	−0.017	0.011	−0.039	0.006	.140
BMI	−0.009	0.027	−0.062	0.045	.747
Smoking	−0.087	0.367	−0.813	0.639	.813
HEI × MVPA	0.0002	0.0002	−0.0002	0.0005	.385

Note. Model estimates of the multiple linear regression models for the complete sample (dependent variable: stressor reactivity (SR) score; positive estimates indicate that the predictor is associated with lower resilience; $N = 145$). *SE* = standard error; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; HEI = Healthy Eating Index; MVPA = moderate to vigorous physical activity; SB = sedentary behavior; BMI = body mass index; gender (0 = male, 1 = female); smoking (0 = nonsmoker, 1 = smoker).
* $p < .05$.

adaptation to adversity (i.e., promote resilience and prevent mental disorders). On the contrary, SB may hamper the adaptation process (i.e., reduce resilience and promote mental disorders). The present study is the first to assess the association between resilience assessed prospectively and longitudinally and (a) diet quality, (b) objectively recorded PA and (c) SB, as well as (d) the interaction between diet quality and PA.

The results of the present study suggest that diet quality, PA, SB, and the interaction between diet quality and PA are not associated with resilience. Hence, this study could not replicate the findings of earlier studies that found a positive association between diet and resilience as well as PA and resilience. There are several possible explanations for the discrepant findings that are discussed in the following.

1. *Differences in the measurement of the outcome:* The vast majority of previous studies assessed resilience through questionnaires. However, consensus in resilience research is growing that resilience cannot be conceptualized as a stable trait but rather as the outcome of a dynamic process (see introduction). For this reason, resilience was assessed prospectively and longitudinally as the dynamically changing relationship between stressor exposure and mental health in the present study. Resilience questionnaires ask participants to evaluate their own adaptability to stressors, which is not only extremely difficult but may also be confounded by self-beliefs, wherefore resilience questionnaires may capture aspects of an individual's self-concept rather than resilience per se. This might explain why these studies found an association between healthy diet, PA, and resilience, as research suggests that health behaviors might be associated with the self-concept. For instance, a study found that adherence to the Mediterranean diet was associated with more positive academic and physical self-concepts (Zurita-Ortega et al., 2018). Beyond that, even though the study by Szuhany et al. (2023) also assessed resilience prospectively, the operationalization of resilience differs considerably from the one used in the present study (see details below). Hence, the measurement approaches of the present and previous studies (apart from Neumann et al., 2022, who also used the FRESHMO paradigm) might have captured distinct or only marginally overlapping concepts of resilience.

2. *Differences in the measurement of the predictors:* With the exception of Robert et al. (2022), previous

Table 5
Model Summaries for the High-Stress Subsample

Effect	Estimate	*SE*	95% CI *LL*	95% CI *UL*	*p*
Model 1					
Intercept	−0.326	0.200	−0.723	0.071	.106
HEI	0.004	0.012	−0.020	0.027	.741
MVPA	−0.0006	0.003	−0.007	0.006	.853
SB	0.0003	0.001	−0.002	0.003	.845
Gender	0.559	0.247	0.069	1.050	.026*
Age	−0.019	0.015	−0.048	0.010	.197
BMI	0.002	0.035	−0.067	0.071	.952
Smoking	0.036	0.558	−1.072	1.145	.948
Model 2					
Intercept	−0.326	0.201	−0.726	0.075	.110
HEI	0.004	0.012	−0.020	0.028	.739
MVPA	−0.001	0.003	−0.007	0.006	.849
SB	0.0003	0.001	−0.002	0.003	.844
Gender	0.557	0.252	0.057	1.058	.030*
Age	−0.019	0.015	−0.048	0.010	.199
BMI	0.002	0.035	−0.068	0.072	.958
Smoking	0.033	0.565	−1.091	1.156	.954
HEI × MVPA	0.00001	0.0003	−0.001	0.001	.958

Note. Model estimates of the multiple linear regression models for two thirds of the sample with the highest overall stressor exposure (dependent variable: stressor reactivity (SR) score; positive estimates indicate that the predictor is associated with lower resilience; $n = 97$). *SE* = standard error; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; HEI = Healthy Eating Index; MVPA = moderate to vigorous physical activity; SB = sedentary behavior; BMI = body mass index; gender (0 = male, 1 = female); smoking (0 = nonsmoker, 1 = smoker).
* $p < .05$.

studies relied on Food Frequency Questionnaires (e.g., Bonaccio et al., 2018; Lutz et al., 2017) or other self-reports of usual or normal consumption of certain food groups (e.g., Perna et al., 2012; Whatnall et al., 2019) to assess the relationship between resilience and diet. Even though all self-report dietary assessment methods show some degree of underreporting, 24-hr dietary recalls, as used in the present study, were found to have the lowest level of underreporting (Burrows et al., 2019). However, even though at least three 24-hr dietary recalls are often used to operationalize habitual dietary intake (e.g., Robert et al., 2022), it is not clear whether this approach allows capturing habitual intake accurately due to large day-to-day variability in dietary intake. PA was assessed through self-reports in all previous studies, including Neumann et al. (2022) and Szuhany et al. (2023). However, self-reports of PA (Adamo et al., 2009; Prince et al., 2008) and SB (Prince et al., 2020) differ substantially from objective measures (i.e., accelerometers). For this reason, the present study used accelerometers to measure PA and SB. Hence, the measurement of the predictors differed considerably.

3. *Differences in the study samples:* The sample of the present study was predominantly young, educated, female, and from a Western, educated, industrialized, rich, and democratic country. Previous studies included a variety of samples, including samples similar to the one of the present study. Thus, a positive association between resilience and diet as well as resilience and PA was found across different age groups, nations, and levels of education. Given that the positive association was also found in similar samples as the sample of the present study, there is no indication that the different findings may be explained by differences in the study samples.

In conclusion, even though all explanations might play a role and no explanation can be rejected completely, we believe that the discrepancy between the findings is most likely due to profound differences in the conceptualization and operationalization of resilience, which greatly impair comparability. Hence, the distinct concepts of resilience should be carefully considered when interpreting and comparing results.

The present study found that PA, *objectively recorded*, did not predict resilience (i.e., the SR score), which is in line with the findings of Neumann et al. (2022) who found that *self-reported* PA was not associated with resilience (i.e., the SR score). This highlights that differences in the measurement of the predictors might not necessarily produce different findings and that it is more relevant that resilience is operationalized the same way to allow direct comparison. Even though Szuhany et al. (2023) also assessed resilience longitudinally, their outcome differs substantially from the SR score used in the present study because they categorize individuals into four groups based on their mental health trajectories after an adverse event. The advantage of the SR score is that it allows to quantify resilience on a continuum and takes into account both macro- and microstressors (i.e., daily hassles and life events). However, it is important to note that SR scores of individuals with low levels of stressor exposure in the studied time window might be biased (Kalisch et al., 2021) because resilience can only be accurately quantified in the presence of adversity. For this reason, the analyses of the present study were repeated for two thirds of the sample with the highest overall stressor exposure, which confirmed the results found within the complete sample. Szuhany et al. (2023) did not account for other stressors occurring before or during the observation time window, which may affect an individual's mental health response above and beyond the original adverse event and which should therefore be accounted for (Ahrens et al., in press). Hence, again, the discrepancy between our finding (i.e., no relation between resilience and PA) and the finding of Szuhany et al. (2023; i.e., higher levels of PA predict membership in the resilient group) might be explained by the different conceptualizations of resilience.

Despite evidence suggesting that SB negatively influences mental health (e.g., Huang et al., 2020; X. Wang et al., 2019; J. Zhang, Yang, et al., 2022), the current findings do not suggest that SB is a risk factor in the context of resilience. So far, only one study assessed aspects of both diet and PA in the same study (Perna et al., 2012); however, it did not account for possible interactions between these lifestyle factors. Meanwhile, taking the potential interaction between diet and PA into account can help gain a better understanding of the unique and joint effects of lifestyle behaviors on mental health and resilience. Hence, future studies should not only study PA and diet as separate resilience factors but also study the interaction between diet and PA as well as SB as a potential risk factor. Furthermore, diet and PA might not promote resilience in all individuals. Future research should address individual differences in the association between lifestyle factors and resilience. Resilience is a complex construct that is influenced by a large number of factors of which many remain unidentified. Hence, unaccounted resilience factors might have made it difficult to detect an association between diet, PA, and resilience in the present study.

Even though this study has many strengths including its prospective longitudinal assessment of resilience, detailed dietary assessment, and use of accelerometers to record PA and SB, there are some limitations. The results of the present study only provide evidence on the basis of a relatively small and selective sample and on the cross-sectional level. However, because resilience is increasingly recognized as a dynamically changing construct, the association between resilience and lifestyle behaviors should be studied

longitudinally, which would also allow to capture fluctuations in diet quality and PA levels. Potential mechanisms through which diet and PA influence resilience might require extended periods of stable dietary and PA exposure to demonstrate their effects. While dietary modification can produce detectible shifts in some bacterial species in the gut microbiome within 24 hr, the gut's structure of bacterial communities is relatively stable and is formed by long-term diets over the course of several years (Wu et al., 2011). Not only the duration of dietary and PA exposure but also past exposure may play a role, as epigenetic mechanisms induced by lifestyle factors in early life have been shown to produce long-lasting effects, supporting the hypothesis of epigenetic memory (Y. Zhang & Kutateladze, 2018). For instance, a study showed that lactation in mice causes epigenetic changes that influence the likelihood of the development of obesity later in life (Yuan et al., 2018). Longitudinal assessments of diet and PA would not only allow to capture fluctuations but also allow to draw conclusions about how long individuals must eat or move in a certain way before effects on resilience manifest. Beyond that, repeated assessments of diet and PA would allow to disentangle whether lifestyle behaviors may be preexisting and/or concurrent factors that facilitate successful adaptation in the face of adversity. For this reason, the present study may have been unable to capture the full spectrum of potential effects of diet and PA on resilience in terms of exposure duration and past exposure. Furthermore, it is important to note that the residualization approach used in the present study quantifies resilience in relation to others in the sample. Hence, SR scores cannot be compared across different samples. Given that the number of studies assessing resilience prospectively and longitudinally is extremely limited, more studies of high methodological rigor are needed. This includes (a) the prospective longitudinal assessment of resilience, (b) the repeated objective measure of PA and SB, and (c) the collection of detailed, long-term dietary data. Future studies are needed to answer questions of temporality and directionality in the context of the interplay between diet quality, PA, and resilience, such as the following: (a) "Does eating healthy and engaging in PA lead to improved resilience, do higher levels of resilience improve lifestyle behaviors, or is there a bidirectional relationship between lifestyle behaviors and resilience?" (b) "Do lifestyle behaviors function as preexisting factors present before any adversity which then promote positive mental health in the face of adversity, as potential mechanisms following adversity which either promote or hamper mental health, or both?"

Constraints on Generality

Our findings provide the first evidence that resilience, operationalized on the basis of the FRESHMO paradigm and the residualization approach, is not linked to diet quality, PA, and SB. Given that previous studies that captured resilience through questionnaires or as the membership in the resilient group (Szuhany et al., 2023) suggest that there is a link between resilience, diet quality, and PA, our findings may be specific to the conceptualization of resilience. Hence, a direct replication would use the same approach to capture resilience. The HEI-NVS used to quantify diet quality in the present study is based on German national food-based dietary recommendations, wherefore its application is only reasonable in German samples. While we believe that the results may generalize to HEIs based on national dietary guidelines of other countries, research on the generality across country-specific indices is needed.

Some sample characteristics may limit the generalizability of the findings: (a) high proportion of young, educated, and female individuals; (b) Western, educated, industrialized, rich, and democratic population; (c) age inclusion criteria (18–50 years at inclusion in the LORA study); and (d) potentially greater interest in healthy eating and PA compared with the general population due to selection bias. Given that this is the first study to assess the relationship between resilience (operationalized on the basis of the FRESHMO paradigm and the residualization approach), diet quality, PA, and SB, research on the generality of the findings is needed. We have no reason to believe that the results depend on other characteristics of the participants, materials, or context.

Conclusion

Previous studies indicate that resilience—assessed through questionnaires or operationalized as the membership in the resilient group—is associated with diet and/or PA. Given that resilience research is moving away from the concept of resilience as a stable trait and toward conceptualizing it as the outcome of a dynamic process of successful adaptation to stressors, the present study is the first to assess the relationship between diet quality, objectively recorded PA and SB, the interaction between diet quality and PA, and resilience, captured prospectively and longitudinally. Contrary to the findings of most previous studies, diet quality and PA were not associated with resilience in the present study, neither in the complete sample nor in the more stressed subsample. Beyond that, no associations between resilience and SB as well as resilience and interaction between diet quality and PA were found. However, profound differences in the conceptualization and operationalization of resilience greatly limit comparability. More prospective longitudinal studies are needed to assess the relationship between resilience and lifestyle factors to replicate and expand the findings of the present study.

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