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The association between precarious employment and stress among working aged individuals in the United States

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ABSTRACT

Objective: Precarious employment is a plausible stressor, which may adversely affect health. We investigated the association between multidimensional precarious employment and perceived and biological stress in the U.S.
Methods: We used data from waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health. Eight indicators were mapped to five dimensions of precarious employment to create a continuous score (PES, range: 0–5): material rewards, working-time arrangements, stability, workers' rights, and interpersonal relationships. Perceived stress was constructed from the four-item Cohen's perceived stress score (PSS; range: 0–16; wave 4). We measured biological stress in waves 4 and 5 via C-reactive protein (CRP). Given variability in CRP collection between waves, we treated wave 4 and 5 as cross-sectional. We employed adjusted linear regression models to estimate whether the PES was associated with the PSS in wave 4 (n = 11,510) and CRP in waves 4 (n = 10,343) and 5 (n = 3452).
Result: Individuals were aged 28 and 37 years on average in wave 4 and 5, respectively. Half were female and most identified as non-Hispanic (NH)-White (~73 %), followed by NH-Black (~14 %), Hispanic (~9 %) and NH-other (~4 %). Average PES was inversely related to education. The PSS averaged 8.1 (Interquartile Range [IQR] = 7.0,9.0). Average CRP was 4.4 mg/L (IQR = 0.8,5.0) in wave 4 and 3.6 mg/L (IQR = 0.8,4.2) in wave 5. The PES was associated with perceived stress (β=0.06; 95 % CI = 0.01,0.10) and CRP in wave 5 (β=0.34; 95 % CI = 0.07,0.62).
Conclusions: Given the deleterious effects of stress on health, policies to reduce precarious employment warrant consideration.

1. Introduction

Economic recessions, technological advancement, and an erosion of labor and social protections in the United States (U.S.) have resulted in an increase in precarious employment (Oddo et al., 2021), which can be characterized by job instability, low wages, few fringe benefits and limited rights and protections. Precarious employment is a plausible psychosocial stressor, which may adversely affect health, and because of intersecting systems of oppression that result in racialized people, women, and immigrants being overrepresented in precarious employment, precarious employment may contribute to health disparities in the U.S. (Hajat et al., 2024).

Stress is a multidimensional construct that includes exposure to objective negative stimuli or events, subjective appraisals, and coping abilities (Smyth et al., 2013). Psychosocial stressors can increase perceived stress and stress-evoked physiological dysregulation (i.e., biological stress) (Belvis et al., 2022; Caroz-Armayones et al., 2023; Julià et al., 2022; Cohen and Janicki-Deverts, 2012; Knight et al., 2021; Ranjit et al., 2007; Tsutsumi et al., 1999; Dunkel Schetter et al., 2013), which adversely impacts health. For example, a prior meta-analysis showed an association between perceived stress and body mass index, waist circumference, serum triglyceride and HDL levels, and diastolic

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blood pressure (Tenk et al., 2018). Both acute (Wirtz et al., 2007; Hamer et al., 2006; Nijm et al., 2007) and chronic (Ranjit et al., 2007) stressors can activate inflammatory cytokines, including C-reactive protein (CRP). Elevated CRP is involved in the pathogenesis of obesity, insulin resistance, and cardiovascular disease (Choi et al., 2013; Park et al., 2005; Wang et al., 2013; Montgomery and Brown, 2013) and inflammatory markers are associated with the development of depressive and anxiety symptoms (Ye et al., 2021; Wium-Andersen et al., 2013).

Although stress is a highly plausible mechanism of the observed associations between precarious employment and health (Hajat et al., 2024; Oddo et al., 2023; Andrea et al., 2021; Eisenberg-Guyot et al., 2020), U.S.-based studies have yet to explore precarious employment as a *multi*dimensional concept, in relation to perceived or biological stress. Nevertheless, we can draw on evidence from other national contexts to support our hypothesis. For example, evidence from Europe finds that higher levels of employment precariousness were associated with higher levels of perceived stress (Belvis et al., 2022; Caroz-Armayones et al., 2023; Julià et al., 2022). Qualitative studies from Canada reported that those in precarious employment indicated that the stress associated with their employment had an impact on their health (Clarke et al., 2007; Premji, 2018). However, research conducted in Europe and Canada may have limited generalizability to the U.S. given specific features of the U.S. socio-political and labor context (e.g., lack of universal health insurance, less stringent labor laws, and widespread at-will employment). A few studies using a *uni*dimensional indicator of employment quality suggest that precarious employment is associated with higher CRP (Kwak et al., 2019; Lee et al., 2021); while these studies have contributed to our understanding of how individual employment indicators affect health, this approach does not use a conceptually informed indicator of precarious employment nor capture the fact that many unfavorable features of employment (e.g., low wages, unpredictable hours) co-occur. Moreover, multidimensional indicators of precarious employment enable a broader assessment of potential health effects and differences between subgroups (Vives et al., 2020).

This study aimed to fill those gaps in the literature by testing whether precarious employment was associated with perceived and biological stress, using a multidimensional indicator, and data from a nationally representative sample of working aged adults in the U.S. A better understanding of the potential mechanisms by which precarious employment may contribute to poor health is needed to develop effective interventions that can mitigate the growing burdens of chronic disease and mental illness among Americans.

2. Methods

2.1. Data source

We used data from waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally representative cohort of U.S. adolescents in 1994–1995, that have now been followed for >20 years. The study design and procedures are described elsewhere (National Longitudinal Study of Adolescent to Adult Health, 2024).

2.2. Key variables of interest

Independent Variable. We derived our precarious employment score (PES) based on research conceptualizing precarious employment as a multidimensional construct of accumulated adverse employment conditions, which is often measured by 7 dimensions of the employment relationship (Julià et al., 2017). A total of 8 survey indicators, collected in both survey waves, were available to operationalize our PES, in alignment with 5 of the 7 dimensions (Table 1): material rewards (total income, paid vacation or sick time); working time arrangements (total hours worked per week); employment stability (tenure in the job, number of jobs); workers' rights and social protections (employer-sponsored retirement benefits, health insurance); and interpersonal relations (proxied by decision-making freedom). Indicators to represent

Table 1
Precarious Employment Dimensions and Indicators used in the Precarious Employment Score, Waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health.

Dimensions	Item	Scoring Rubric[1,2]	Question(s) in Add Health[3]	Wave 4 % (N)[4,5]	Wave 5 % (N)[4]
(1) Material rewards	(1.1) relative wages	0.5 pt.: Total income earned in the past year below the U.S. median; 0 otherwise	In the last calendar year, how much income did you receive from personal earnings before taxes? Include wages or salaries, tips, bonuses, overtime pay, and income from self-employment.	76.6 (8749)	49.6 (1696)
	(1.2) paid time off	0.5 pt.: No paid time off, 0 otherwise	Does your employer make available to you paid vacation or sick leave?	23.5 (2525)	17.5 (593)
(2) Work time arrangements	(2.1) total hours	1 pt.: Total hours/week worked <20 or > 40, 0 otherwise	How many hours a week do you usually work at this job?	47.6 (5272)	47.2 (1573)
(3) Stability	(3.1) weeks employed	0.5 pt.: Number of weeks worked/ employed in past calendar year is <48 weeks, 48 weeks	In what month and year did you begin your current primary job?	29.5 (3386)	18.5 (652)
	(3.2) number of jobs	0.5 pt.: Number of jobs held >1, 0 otherwise	Wave 4: On how many jobs are you currently working for pay at least 10 h a week? Wave 5: How many jobs are you currently working for pay?	14.4 (1665)	13.4 (466)
(4) Workers' rights	(4.1) health insurance	0.5 pt.: Health insurance not offered by employer, 0 otherwise	Does your employer make available to you health insurance?	24.0 (2588)	20.5 (687)
	(4.2) retirement plan	0.5 pt.: No retirement plan (other than social security) offered by the employer, 0 otherwise	Does your employer make available to you retirement benefits (such as 401(k), 403b, or a company pension plan)?	31.4 (3428)	23.9 (803)
(5) Interpersonal relations	(5.1) freedom to make decisions	1 pt.: Minimal freedom to make decisions without supervision, 0 otherwise	Overall, how often do you have the freedom to make important decisions about what you do at work and how you do it?	11.8 (1361)	5.5 (185)

[1] The primary precarious employment score maps items to dimensions, so that each dimension represented =1. The total possible score is 5.
[2] As sensitivity analyses, alternative scores include: 1) taking the sum of all items versus dimensions (score range = 0 to 8); 2) excluding the number of jobs (item 3.2) (score range = 0 to 5); 3) excluding freedom to make decisions (item 5.1) (score range = 0 to 4); and 4) moving paid time off from the material rewards to the workers' rights domain (score range = 0 to 5).
[3] Questions are based on the current primary job, except for number of jobs (3.2).
[4] Represents the N (%) of individuals assigned a 0.5 or 1, indicating more precarious employment. Percents incorporated the Add Health survey weights and the IPCW.
[5] For wave 4, $n = 11{,}520$; there are 11,510 individuals in the PSS model and an additional 10 individuals in the CRP models that do not have the PSS.

the collective organization and training and employability dimensions were not available in Add Health. Each dimension represented in the PES consisted of one or two equally weighted binary variables, with 1 (versus 0) indicating more precarious employment. Dimensions were summed, with the score ranging from 0 (least) to 5 (most precarious).

Previous research has found that those in precarious employment are demographically similar to the unemployed (e.g., lower-income, women, racialized) and those in precarious employment tend to cycle into and out of unemployment (Benach and Muntaner, 2007). Moreover, prior studies have observed that associations between poorer employment quality and health were similar in magnitude to those observed between unemployment and health (Van Aerden et al., 2017). Consequently, if an individual was temporarily unemployed ("only temporarily laid off" or "unemployed and looking for work"), and thus, did not respond to questions on employment, they were assigned a 5, synonymous with assigning them the more precarious value for each item (e.g., income below median), as we have done in prior studies (Oddo et al., 2021; Oddo et al., 2023; Andrea et al., 2021).

Importantly, each indicator included in this multidimensional construct maps to a specific policy or workplace-level intervention (e.g., increasing minimum wage) that may not *independently* alter overall precarious employment. Consequently, we only present results for an overall PES versus each domain independently, as resulting estimates may lead to incorrect conclusions about how to intervene overall.

2.3. Dependent variables

Our dependent variable was stress, which was measured in two ways. First, perceived stress, a continuous variable, was constructed from the four-item Cohen's perceived stress score (PSS) (range: 0 to 16), which was only available in wave 4. Second, we measured biological stress in waves 4 and 5 via CRP. Documentation of the collection, assays, and quality control for CRP for waves 4 (Whitsel et al., 2012) and 5 (Whitsel et al., 2021), are detailed elsewhere. In wave 4, values were derived from capillary blood, whereas in wave 5, CRP values were derived from venous blood. The distribution of CRP values was right skewed; therefore, for these analyses, CRP was winsorized at the 99th percentile.

2.4. Confounders and effect modifiers

Using a directed acyclic graph, we identified confounders, defined as variables that are associated with both the independent and the dependent variables and *not* on the causal pathway (i.e., not potential mediators). Confounders in our primary model included: gender (male, female), race and ethnicity (non-Hispanic [NH]-White, NH-Black, Hispanic, NH of another race), age (continuous), educational attainment ($\leq$high school, some college or associate degree, $\geq$bachelor's degree), nativity (U.S. born, non-U.S. born), and marital status (married, not married). Additionally, we tested gender, race/ethnicity, and education as effect modifiers. These individual-level characteristics represent social identity groups (e.g., race, gender) or circumstances (e.g., marriage) and are included to proxy systemic drivers (e.g., racist and sexist policies and practices) that shape the disproportionate allocation of opportunities throughout the life course.

2.5. Statistical analyses

Given the variability in CRP collection and assays used between waves, we treated wave 4 and 5 as separate cross-sectional samples. All analyses incorporated the Add Health cross-sectional survey weights and sample design parameters to account for clustered sampling, attrition, and oversampling.

Of the 15,701 and 12,300 respondents in wave 4 and wave 5, respectively, our analyses were restricted to respondents who were in the civilian labor force and who had complete data for all study variables (wave 4 = 11,510 for the PSS model and 10,343 for the CRP model; wave 5 = 3452, see Appendix 1). Additionally, due to the large number of otherwise eligible participants that would be excluded from analyses (wave 4 = 4028 for PSS and 3672 for CRP, wave 5 = 1307) due to either medication use, pregnancy, and/or infection status, we estimated stabilized inverse probability of censoring weights (IPCWs) based on sociodemographic characteristics, BMI, self-reported health and included IPCWs in all analyses (i.e., these individuals were down-weighted and their like counterparts, based on demographics, BMI, and health were up-weighted, Appendix 1). IPCWs were combined with Add Health weights by taking the product of the two and truncating at the 1st and 99th percentiles to reduce bias.

We calculated descriptive statistics (means and interquartile ranges [IQR] or percents) stratified by wave. Additionally, we descriptively estimated the average PES, stratified by wave and by selected demographic characteristics. Our primary analyses employed separate adjusted linear regression models to estimate whether the PES was associated with PSS in wave 4; CRP in wave 4; and CRP in wave 5.

2.6. Sensitivity analyses

We assessed the robustness of our results when using several alternative specifications. First, we assessed the sensitivity of our CRP models when also controlling for waist circumference. Although having more adipose tissue, often correlated with a higher waist circumference, has been shown to increase CRP levels in this sample (McDade et al., 2021), waist circumference was not included in our primary model because it is a plausible mediator of the PES-CRP association. Second, we investigated the association between precarious employment and stress when taking the linear sum of all indicators, which weights employment variables (e.g., wages, hours) equally rather than weighting the employment dimensions (e.g., material rewards, workers' rights) equally (score range = 0–8). Third, we tested the robustness of our results when excluding the indicators for number of jobs and decision-making. Research has shown that employees without a permanent contract are more likely to have multiple jobs (Bouwhuis et al., 2017) and multiple-job holding has been classified as a type of precarious employment in prior research (Koranyi et al., 2018), in part, because those holding multiple jobs may receive inadequate income from each job alone. However, multiple-job holding is not necessarily equivalent to precarious employment, as multiple-job holders are a heterogenous group (Bouwhuis et al., 2019). Likewise, freedom to make decisions about what to do at work is considered by some as an intrinsic job characteristic (Karasek et al., 1998) and by others a proxy for imbalanced interpersonal power relations. Fourth, we tested the association when moving paid time off from the material rewards to the workers' rights domain, since paid time off could be conceptualized in either. Fifth, we excluded the temporarily unemployed individuals (wave 4 = 764 for PSS and 712 for CRP). Sixth, we excluded (versus down-weighted with IPCWs) individuals due to relevant medication use, pregnancy, and/or infection status (wave 4 = 4028 for PSS and 3672 for CRP, wave 5 = 1307). Finally, we tested gender, race/ethnicity, and education ($\leq$ highschool, $>$ highschool), as effect modifiers using interaction terms in our primary models.

All analyses were conducted in R version 4.1.3. This study was exempted by the University of Illinois Chicago institutional review board.

3. Results

Participant Characteristics. The average age was 28 years (range = 24–34) in wave 4 and 37 years (range = 33–44) in wave 5 (Table 2). Half of the sample were female (wave 4 = 46.9 %, wave 5 = 53.1 %) and a majority of individuals identified as NH-White (wave 4 = 71.8 %, wave 5 = 74.5 %), followed by NH-Black (wave 4 = 14.7 %, wave 5 = 14.1 %), Hispanic (wave 4 = 9.9 %, wave 5 = 8.0 %), and NH of another race (waves 4 and 5≅3 %). Educational attainment was lower in wave 4

Table 2
Selected Descriptive Statistics by Survey Wave, Waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health.

	% (N) or mean (IQR)[1]	
	Wave 4 $N = 11{,}520$[2]	Wave 5 N = 3452
Female	46.9 (5858)	53.1 (2011)
Mean age (years)	28.4 (27.0, 30.0)	37.2 (36.0, 39.0)
Race and ethnicity		
Non-Hispanic white	71.8 (6789)	74.5 (2250)
Non-Hispanic black	14.7 (2392)	14.1 (624)
Hispanic	9.9 (1607)	8.0 (368)
Non-Hispanic other	3.6 (732)	3.4 (210)
Educational attainment		
≤ high school	24.3 (2511)	13.9 (407)
Some college or associates degree	43.1 (5060)	39.2 (1308)
≥college degree	32.7 (3949)	46.9 (1737)
Married[3]	41.5 (4797)	60.0 (2140)
U.S. born	95.7 (10766)	95.4 (3262)
Mean precarious employment Score[4]	1.7 (0.5, 2.0)	1.2 (0.5, 2.0)
Mean perceived stress scale	8.1 (7.0, 9.0)	NA (NA)
Mean C-reactive protein (mg/L)	4.4 (0.8, 5.0)	3.6 (0.8, 4.2)

IQR = interquartile range; NA = not applicable.
[1] Mean (IQR) and percents incorporated the Add Health survey weights and sample design parameters to account for clustered sampling, attrition, and oversampling. Estimates also incorporate the IPCW.
[2] For wave 4, $n = 11{,}520$; there are 11,510 individuals in the PSS model and an additional 10 individuals in the CRP models that do not have the PSS.
[3] Includes those cohabitating, currently dating, single.
[4] The precarious employment score is composed of 8 indicators, mapped to 5 dimensions: material rewards; working time arrangements; employment stability; workers' rights and social protections; and interpersonal relations. Each of the 5 dimensions represented in the PES consisted of 1 or 2 equally weighted binary variables, with 1 (versus 0) indicating more precarious employment. Dimensions were summed, with the score ranging from 0 (least precarious) to 5 (most precarious).

Table 3
Average PES by Wave and Selected Characteristics, Waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health.

	Mean (IQR)[1,2]	
	Wave 4 N = 11,520[3]	Wave 5 $N = 3452$
Gender		
Female	1.6 (0.5, 2.0)	1.3 (0.5, 2.0)
Male	1.8 (1.0, 2.5)	1.2 (0.5, 1.5)
Race and ethnicity		
Non-Hispanic white	1.7 (1.0, 2.0)	1.2 (0.5, 1.5)
Non-Hispanic black	1.8 (0.5, 2.5)	1.3 (0.5, 2.0)
Hispanic	1.6 (0.5, 2.0)	1.2 (0.5, 1.5)
Non-Hispanic other	1.4 (0.5, 2.0)	1.2 (0.5, 1.5)
Educational attainment		
≤ high school	2.0 (1.0, 2.5)	1.6 (1.0, 2.0)
Some college or associate degree	1.7 (1.0, 2.0)	1.3 (0.5, 2.0)
≥college degree	1.4 (0.5, 2.0)	1.1 (0.5, 1.5)
Nativity		
U.S. born	1.7 (1.0, 2.0)	1.3 (0.5, 2.0)
Non-U.S. born	1.5 (0.5, 2.0)	1.2 (0.5,1.5)

IQR = interquartile range; PES = precarious employment score.
[1] Mean (IQR) and percents incorporated the Add Health survey weights and sample design parameters to account for clustered sampling, attrition, and oversampling. Estimates also incorporate the IPCW.
[2] The PES is composed of 8 indicators, mapped to 5 dimensions: material rewards; working time arrangements; employment stability; workers' rights and social protections; and interpersonal relations. Dimensions were summed, with the score ranging from 0 (least precarious) to 5 (most precarious).
[3] For wave 4, n = 11,520; there are 11,510 individuals in the PSS model and an additional 10 individuals in the CRP models that do not have the PSS.

(32.7 % with ≥ 4-year degree) versus wave 5 (46.9 %). The mean PES was higher in wave 4 (1.7; IQR = 0.5, 2.0) versus wave 5 (1.2; IQR = 0.5, 2.0) (Table 3). The PES was similar by gender and race/ethnicity but was highest among those with ≤ high school education and lowest among those with ≥ bachelor's degree.

Descriptive Stress Measures. The PSS averaged 8.1 (IQR = 7.0, 9.0). Average CRP was 4.4 mg/L (IQR = 0.8, 5.0) in wave 4 and 3.6 mg/L (IQR = 0.8, 4.2) in wave 5.

Association Between PES and Stress. Overall, the PES was positively associated with perceived stress in wave 4 (β=0.06; 95 % Confidence Interval [CI] = 0.01, 0.10) (Table 4). While the PES was not associated with CRP in wave 4 (β=0.05; 95 % CI:-0.08, 0.18), a higher PES was associated with a higher CRP in wave 5, both in our primary specification (β=0.34; 95 % CI = 0.07, 0.62) and when controlling for waist circumference (β=0.34; 95 % CI = 0.10, 0.59).

Sensitivity Results. The associations in wave 4 were unchanged in alternative specifications (Appendix Table 1). For wave 5, a higher PES remained significantly associated with higher CRP when summing the 8 employment indicators (β = 0.17; 95 % CI = 0.01, 0.32), when paid time off was in the workers' rights domain (β = 0.45; 95 % CI = 0.18, 0.72), when excluding number of jobs (β = 0.35; 95 % CI = 0.06, 0.63), and when excluding individuals due to relevant medication use, pregnancy, and/or infection status (β = 0.37; 95 % CI = 0.02, 0.72) (Appendix Table 1). Results were no longer significant when excluding decision-making (β = 0.21; 95 % CI = -0.05, 0.46). We did not observe heterogeneity in the associations by demographic characteristics (Appendix Table 2).

4. Discussion

We tested whether a multidimensional measure of precarious employment was associated with stress, using a nationally representative sample of working age adults in the U.S. In most specifications, a higher PES was associated with higher levels of perceived stress and biological stress, measured via CRP in venous blood, in wave 5.

Prior research analyzing the relationship between precarious employment and stress is very limited and to our knowledge, no prior studies have been conducted in the U.S. Furthermore, the use of more objective measures of stress in relation to precarious employment, such as biomarkers, is still in its infancy. However, our results are generally consistent with the few prior studies that have investigated a

Table 4
Association between PES and the Perceived Stress Scale and C-Reactive Protein, Waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health.

	β (95 % CI)[1,2]	
	Wave 4[3]	Wave 5[3]
Perceived stress scale	0.06 (0.01, 0.10)*	NA
C-reactive Protein[4]	0.05 (−0.08, 0.18)	0.34 (0.07, 0.62)*
+ controlling for waist circumference[4]	0.02 (−0.09, 0.14)	0.34 (0.10, 0.59)*

CI = confidence interval; NA = not applicable; PES = precarious employment score.
[1] Estimated using linear regression models, controlling for gender, race/ethnicity, age, educational attainment, nativity, and marital status. Regression estimates incorporate the IPCWs and the Add Health survey weights and sample design parameters, to account for clustered sampling, attrition, and oversampling.
[2] The PES is composed of 8 indicators, mapped to 5 dimensions: Material rewards; working time arrangements; employment stability; workers' rights and social protections; and interpersonal relations. Dimensions were summed, with the score ranging from 0 (least precarious) to 5 (most precarious).
[3] For wave 4, $n = 11{,}510$ for PSS model and $n = 10{,}343$ for CRP model. For wave 5, $n = 3452$.
[4] CRP values are winsorized at the 99th percentile.
* $P < 0.05$.

multidimensional indicator of employment quality in relation to perceived stress (Belvis et al., 2022; Caroz-Armayones et al., 2023; Julià et al., 2022). These studies, all from Spain, reported that higher precarity was associated with a higher PSS. Our results for CRP in wave 5 are also generally consistent with a UK-based study that assessed job quality based on job satisfaction, job anxiety, job autonomy, job insecurity, and low pay; in this study, adults who remained unemployed, formerly unemployed adults who transitioned into poor quality jobs (defined as at least two adverse job quality indicators) had higher CRP (Chandola and Zhang, 2017). Additionally, Lee and colleagues reported that long work hours (>52 h/week) were associated with high CRP (> 3.0 mg/L) in Korea (Lee et al., 2021).

Consistent with prior studies, we observed a positive association between precarious employment and stress, although our associations are weaker than prior studies, particularly for perceived stress. Employment-related stressors can limit workers' control over their professional and personal lives, which can create feelings of powerlessness (Lewchuk et al., 2008), social isolation (Mirowsky and Ross, 1986), and a lack of support (Siegrist and Theorell, 2006). Thus, precarious employment can increase perceived stress and in turn, *could* result in physiological dysregulation, activating the sympathetic nervous system and hypothalamic-pituitary-adrenal axis, resulting in the release of catecholamines and glucocorticoids. The secretion of these hormones may result in endothelial dysfunction and initiate an inflammatory response, involving the release of CRP. However, we acknowledge that the literature empirically testing an association between perceived stress and CRP is mixed (Barbosa-Leiker et al., 2014; Johnson et al., 2013).

We likewise observed a positive association between precarious employment and CRP that was only significant for one of the two waves evaluated. Discrepancies between waves may be the result of differences in the blood collection method. While CRP concentrations of dried capillary whole blood spots and paired plasma samples were strongly correlated and linearly associated in wave 4 (Whitsel et al., 2012), intraclass correlation coefficients suggest the venous blood collected in wave 5 was a more reliable measure (Whitsel et al., 2021). Differences between waves may also reflect age-related differences in CRP. For example, younger individuals (wave 4) may better cope with precarious employment under the expectation of better opportunities in the future. In wave 5, individuals are middle-aged and may be less optimistic about moving out of precarious employment, thus, the biopsychological toll is greater.

While our observed associations between precarious employment and both perceived stress and CRP are relatively small in magnitude and should be interpreted cautiously, small individual-level effects can still have considerable impacts at the population-level (Carey et al., 2023). This may be particularly true of outcomes like perceived stress, as simulations recently demonstrated that relatively small shifts in mean scores on mental health measures can indicate a large shift in the number of cases of anxiety and depression, when scaled to an entire population (Carey et al., 2023). Currently, ~167 million Americans participate in the labor force, and up to one-third are plausibly in precarious employment (Oddo et al., 2021; Hajat et al., 2024). Thus, study findings begin to suggest a need for comprehensive policy development to reduce precarious employment. Precarious employment is a multidimensional problem that requires a suite of policies such as universal health care, increasing the minimum wage, increasing unemployment insurance, secure scheduling, paid leave and/or policies that support unionization/collective bargaining, among others, as they have the potential to reduce precarious employment, and in turn stress, which could improve health.

Notably, we observed some compositional differences in who is exposed to more precarious employment in this sample compared to our prior work (Oddo et al., 2021; Oddo et al., 2023; Andrea et al., 2021; Eisenberg-Guyot et al., 2020). In the present study, we observed that respondents had a comparable PES regardless of their gender or race/ethnicity. This finding contrasts with our prior work using other nationally representative samples in which we have consistently observed higher PES for women and racialized workers (Hajat et al., 2024). There are several possible reasons for this observation. First, prior research has leveraged data from individuals born between 1957 through 1964, who consequently were experiencing the labor market in different contexts. Second, comparatively fewer employment indicators are available in Add Health, which may further reduce our ability to capture variation in precarious employment. Third, the weighted sociodemographic composition of our analytic sample contained disproportionately fewer foreign born and Hispanic individuals and more individuals with a college degree, when compared to prior samples and the U.S. population. We speculate these attributes contributed to differential selection into and out of the Add Health sample (e.g., consenting to initial home exam, loss to follow-up) and because those who are foreign born, Hispanic, and/or less educated tend to be employed in more precarious employment, this may contribute to an overall underestimation of precarious employment in this sample. Moreover, we did not observe heterogeneity by gender, race/ethnicity or education; however, inequities can be present even in absence of statistical evidence of effect modification (i.e., differential susceptibility) (Ward et al., 2019).

This study has limitations. The primary limitation is the creation of the PES as there is debate, even among this group of co-authors, about which indicators best capture the intention of precarious employment as a construct and which domain survey indictors best represent. In part, this is a result of being reliant on a construct conceptualized in Europe. For example, in Europe, healthcare is universal and more clearly conceptualized as a "right". In the U.S., there is debate about workers having any "rights", and health insurance, leave, and pensions are part of the fringe benefits package, which could also be seen as a material reward. Similarly, "number of jobs" could fall under material rewards, as multiple job holdings may be because individuals receive inadequate income from any one job, *or* could reflect the lack of a permanent contract (i.e., job instability). Moreover, for number of jobs and several other indicators (e.g., total hours/per week, weeks employed) we are unable to determine if the individual chose said employment arrangement (i.e., working part-time by choice). Additionally, "freedom to make decisions" does not best capture the power dynamics intrinsic to employment relations, such as fear of dismissal or retribution for exercising worker rights (Julià et al., 2017). If considered an intrinsic job characteristic, including it in the PES would be conceptually misaligned, as it would not measure either the contractual or relational aspects of the employee-employer relationship. However, no existing large-scale data collection effort has been designed to look at precarious employment in the U.S.; to study the relation between precarious employment and health, we are reliant on secondary data sources like Add Health, which often lack other indictors (e.g., union membership, contract type, ability to take leave) and result in less comprehensive measures of precarious employment than those explicitly developed to capture precarious employment in Europe (i.e., The Employment Precariousness Scale EPRES (Vives et al., 2010)). While we have assessed the sensitivity of our models with several alternative scores, we acknowledge the debate and limitations. Second, we cannot espouse causality to our associations because this is observational data and we cannot establish the temporality of the exposure-outcome relation (i.e., the PES and outcomes are collected concurrently and we treated waves as cross-sectional). Moreover, it is challenging to estimate the causal relationship between most social exposures and health; experimental (e.g., randomized controlled trials) or quasi-experimental (e.g., difference-in-differences) study designs would largely not be feasible nor appropriate. Thus, to get closer to causal estimates, it would likely require several longitudinal studies and using methods that better account for unobserved confounding (e.g., individual fixed-effects). Third, Add Health does not sample with replacement and differential loss-to-follow-up by demographic characteristics, precarious employment, or health is possible; we aimed to address this selection bias with IPCWs. Fourth, the sample includes

individuals in a relatively narrow age range (wave 4: 24–32, wave 5: 32–44); generalizability of these results beyond adults aged 24–44 years may be limited. Despite these limitations, this study enhances our understanding of the association between precarious employment and stress in the U.S., adding to the cumulation of insight needed to inform future policy making (Ogilvie et al., 2020).

5. Conclusions

This study begins to suggest that higher employment precarity is associated with higher levels of stress in the U.S. Given the deleterious effects of both perceived and biological stress on health, policies to improve employment quality warrant consideration. Additionally, there remains an urgent need for large-scale longitudinal studies that are explicitly designed to capture precarious employment and health in the U.S.

CRediT authorship contribution statement

Vanessa M. Oddo: Writing – original draft, Supervision, Funding acquisition, Conceptualization. **Sherif Mabrouk:** Writing – review & editing, Formal analysis. **Sarah B. Andrea:** Writing – review & editing, Methodology. **Emily Q. Ahonen:** Writing – review & editing, Methodology. **Megan R. Winkler:** Writing – review & editing, Methodology. **Emilia F. Vignola:** Writing – review & editing, Methodology. **Anjum Hajat:** Writing – review & editing, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix 1. Derivation of Analytic Sample and IPCW

Of 20,745 respondents in wave 1, 15,701 (80.3 %) and 12,300 (71.8 %) individuals completed interviews for wave 4 and wave 5 of the Add Health survey, respectively. All 15,701 individuals were eligible for the measurement of CRP in wave 4. In wave 5, however, CRP was ascertained among a subsample of 5381 individuals (68 % of the 12,300 first consented and then participants were sampled from the 8379 individuals that consented to the home exam).

Analyses were first restricted to 14,091 in wave 4 and 10,989 in wave 5 people in the civilian labor force (military: $n = 341$ in wave 4 and $n = 166$ in wave 5; incarcerated: $n = 73$ in wave 4 and $n = 0$ in wave 5; and those permanently disabled, keeping house, students: $n = 1610$ in wave 4 and $n = 1311$ in wave 5). The final primary analytic sample contained 11,510 respondents for the PSS model and 10,343 respondents for the CRP model in wave 4 and 3452 respondents for wave 5 with complete data for all necessary study variables (individuals excluded for missing weights, strata and PSU information in waves 4 [$n = 773$] and 5 [$n = 207$], for missing the exposure in waves 4 [$n = 961$] and 5 [$n = 993$], for missing the outcome measure in wave 4 [n = 0] and 5 [$n = 6027$] and for missing covariates in wave 4 [$n = 423$] and 5 [$n = 144$]). Note that for descriptive statistics the n in wave 4 = 11,520 because there are 11,510 individuals in the PSS model and an additional 10 individuals in the CRP models that do not have the PSS.

Additionally, due to the large number of otherwise eligible participants that would be excluded from analyses (wave 4 = 4028 for PSS and 3672 for CRP, wave 5 = 1307) due to either medication use (anti-inflammatories, anti-hyperlipids, Cox inhibitors, anti-diabetics, inhalers, and medications for rheumatoid arthritis or psoriasis), pregnancy, and/or infection status, we estimated stabilized inverse probability of censoring weights (IPCW) based on sociodemographic characteristics, self-reported health, BMI and included IPCWs in all analyses.

The IPCW is split into two parts, the numerator and denominator. For the individuals we do not wish to "censor", observations in the numerator are equal to the probability of being included (number of included observations / total number of observations). For the denominator, it varies from one observation to the other, and it is equal to the estimated probability of being included given demographic characteristics, BMI, and self-reported health status. Therefore, if the given demographic characteristics, BMI, and health status of the observation is similar in characteristics to those observations that we want to censor (based on relevant medication usage, pregnancy or infection), then their estimated probability of being included (denominator) is lower, and the overall weight will be higher (i.e., those individuals are upweighted). For the individuals we want to censor due to medication usage, pregnancy or infection, the numerator is equal to the probability of being censored (number of censored observations / total number of observations). The denominator for the censored observations is equal to the estimated probability of being censored due to medication usage, pregnancy, and/or infection status, given individuals' demographic characteristics, BMI, and health status. These observations are down-weighted. Additionally, we perform a sensitivity analyses whereby the individuals we want to censor are excluded all together (i.e., their IPCW = 0).

Appendix Table 1

Association between Alternative PES specifications and the Perceived Stress Scale and C-Reactive Protein, Waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health.

	β (95 % CI)[1]					
	Equally weighted PES[2]	Paid time off in Workers' rights Domain[3]	PES minus decision-making freedom[4]	PES minus number of jobs[5]	Excluding the temporary Unemployed[6]	Excluded individuals due to relevant medication use, pregnancy, and/or infection status[7]
Wave 4						
Perceived stress Score[8] (N = 11,510)	0.04 (0.01, 0.06)*	0.06 (0.02, 0.11)*	0.08 (0.02, 0.13)*	0.06 (0.02, 0.10)*	0.08 (0.03, 0.13)*	0.08 (0.02, 0.13)*
C-reactive Protein[8,9] (N = 10,343)	0.03 (−0.05, 0.10)	0.09 (−0.04, 0.23)	0.06 (−0.10, 0.22)	0.07 (−0.06, 0.19)	0.07 (−0.15, 0.28)	0.03 (−0.13, 0.19)
+ controlling for waist circumference	0.01 (−0.06, 0.08)	0.05 (−0.07, 0.17)	0.03 (−0.11, 0.17)	0.03 (−0.08, 0.14)	0.07 (−0.12, 0.25)	0.02 (−0.13, 0.16)
Wave 5						
C-reactive Protein[8,9] (N = 3452)	0.17 (0.01, 0.32)*	0.45 (0.18, 0.72)*	0.21 (−0.05, 0.46)	0.35 (0.06, 0.63)*	NA	0.37 (0.02, 0.72)*
+ controlling for waist circumference	0.19 (0.05, 0.33)*	0.37 (0.13, 0.60)*	0.26 (0.02, 0.49)*	0.35 (0.10, 0.60)*	NA	0.40 (0.08,0.73)*

CI = confidence interval; NA = not applicable; PES = precarious employment score.

[1] Estimated using linear regression models. Regression estimates employ the Add Health survey weights and sample design parameters to account for clustered sampling, attrition, and oversampling.

[2] PES equally weighting all employment variables (e.g. wages, hours worked, tenure) versus equally weighting the domains (e.g. material rewards, workers' rights) (total score range = 0 to 8).

[3] PES moving paid time off from material rewards to workers' rights domain (total score range = 0 to 8).

[4] PES excluding the indicator for freedom to make decisions (Table 1, 6.1) (total score range = 0 to 4).

[5] PES excluding the indicator for number of jobs (Table 1, Table 3.2) (total score range = 0 to 5).

[6] Wave 4 models include 10,746 observations for perceived stress and 9631 observations for CRP.

[7] Wave 4 models include 7482 observations for perceived stress and 6671 for CRP. Wave 5 models for CRP include 2145 observations.

[8] Controls for gender, race/ethnicity, age, educational attainment, nativity, and marital status.

[9] CRP values are winsorized at the 99th percentile.

* $P < 0.05$.

Appendix Table 2

Heterogeneity in the Association between PES and the Perceived Stress Scale and C-Reactive Protein, Waves 4 (2008–2009) and 5 (2016–2018) of the National Longitudinal Study of Adolescent to Adult Health.

	β for interaction (95 % CI)[1,2]				
	Gender	Education	NH-White[3]	NH-Black[3]	Hispanic[3]
Wave 4					
Perceived stress scale (N = 11,510)	−0.01 (−0.08, 0.06)	−0.02 (−0.15, 0.10)	0.09 (−0.08, 0.26)	0.07 (−0.14,0.27)	0.22 (−0.00, 0.44)
C-reactive Protein[4] (N = 10,343)	0.12 (−0.13, 0.36)	−0.01 (−0.30, 0.28)	−0.04 (−0.36, 0.29)	−0.02 (−0.45, 0.41)	0.24 (−0.39, 0.87)
Wave 5					
C-reactive Protein[4] (N = 3452)	0.24 (−0.31, 0.79)	−0.63 (−1.65, 0.39)	0.99 (0.11, 1.87)*	0.46 (−0.50, 1.43)	0.65 (−0.39, 1.67)

CI = confidence interval; NH = non-Hispanic; PES = precarious employment score.

[1] Estimated using linear regression models with an interaction term (e.g., PESxgender). Models additionally control for gender, race/ethnicity, age, educational attainment, nativity, and marital status, as appropriate. Regression estimates incorporate the IPCWs and the Add Health survey weights and sample design parameters, to account for clustered sampling, attrition, and oversampling.

[2] The PES is composed of 8 indicators, mapped to 5 dimensions: material rewards; working time arrangements; employment stability; workers' rights and social protections; and interpersonal relations. Dimensions were summed, with the score ranging from 0 (least precarious) to 5 (most precarious).

[3] Estimates by race/ethnicity are not statistically difference from each other. Smaller sample sizes prohibit the inclusion of NH-other.

[4] CRP values are winsorized at the 99th percentile.

* $P < 0.05$.

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