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Original Research

Does work–family conflict predict allostatic load? A 4-year longitudinal study

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Abstract

Objective: A growing number of studies have reported that occupational psychosocial factors increase the risk of cardiovascular disease. Allostatic load (AL) is a main biological mechanism that explains the pathway from stress to disease. This study examined whether work-to-family conflict (WFC) and family-to-work conflict (FWC) at baseline would be associated with changes in the AL index (ALI) across four years.

Methods: We used the Midlife in Japan survey, Wave I, and the biomarker projects, Waves I and II. This study included 152 participants with paid jobs and variables of interest at baseline and target biomarkers at baseline and follow-up. We examined the four-year longitudinal changes in the ALI using two methods: comparing ALI scores at baseline and follow-up, named "Two ALI approach," and creating one ALI score considering changes at baseline and follow-up, named "One ALI approach." Negative binomial regression analysis and generalized estimating equations were used for analyses. The results were reported by count ratios (CRs) and 95% confidence intervals (CIs).

Results: In the final model, our results demonstrated that WFC at baseline was significantly associated with increased ALI using the "Two ALI approach" (CR 1.15, 95% CIs: 1.03, 1.28) and "One ALI approach" (CR 1.15, 95% CIs: 1.01, 1.32), whereas FWC did not show statistical significance in both methods.

Conclusions: WFC was longitudinally associated with increased ALI. It is crucial to mitigate the effects of work-to-family conflict.

Key messages:

What is already known on this topic?

- Previous studies have documented that occupational psychosocial factors adversely affect workers' cardiovascular health. However, the underlying mechanisms, particularly whether perceptions of work–family conflict influence biomarkers prior to disease onset, are poorly understood.

What this study adds?

- This study found that work-to-family conflict at baseline was significantly associated with increased allostatic load index over 4 years.
- Family-to-work conflict at baseline was not associated with increased ALI in 4 years.

How this study might affect research, practice, or policy?

- Companies and occupational health providers can use work-to-family conflict and ALI as screening tools to enhance employees' cardiovascular health.
- Interventions targeting the reduction of work-to-family conflict might improve workers' cardiovascular health.

Keywords: work–family conflict; allostatic load index; biological stress responses; longitudinal study

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Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide, and the prevalence of CVD risk factors, such as hypertension, diabetes, obesity, and hyperlipidemia, is high among those of productive age [1]. Although the literature documents that workplace psychosocial factors are associated with the incidence of CVD [2], there are limited studies on stress arising from role conflicts between work and home.

Work–family conflict refers to the stress arising from interrole conflicts between work and home, which has two directions: work-to-family conflict (WFC), where a role at work interferes with a role at home, and family-to-work conflict (FWC), where a role at home interferes with a role at work [3]. Recently, a study from Germany suggested an increased 5-year incidence of CVD events in women associated with WFC, although it did not reach statistical significance [4]. An increased risk of CVD would be consistent though with prior evidence research on the links between WFC and several CVD risk factors, including blood pressure (BP) [5–8], total cholesterol (TC) [5, 7], triglycerides (TGs) [8, 9], high-density lipoprotein cholesterol (HDL-C) [7, 9], low-density lipoprotein cholesterol (LDL-C) [9], C-reactive protein (CRP) [9], interleukin-6 (IL-6) [9], glycosylated hemoglobin (HbA1c) [7], and body mass index (BMI) [5, 7, 8]. However, findings based on single biomarkers were inconsistent.

An alternative approach to estimating the effect of work–family conflict is to create a combined score using multiple risk factors. One relevant concept in this respect is allostatic load (AL), which captures physiological perturbations due to cumulative stress exposures and can be operationalized through various sets of biomarkers, including those predictive of CVD [10]. This study examined the long-term effects of work–family conflict on the AL index (ALI). Since the concept of ALI was introduced in 1997 [11], several studies have examined the associations of occupational psychosocial factors with the ALI [12]. Yet, no studies have evaluated the associations between work–family conflict and the ALI. We aim to address this knowledge gap by examining potential longitudinal associations of WFC or FWC with the ALI. We do so by drawing on data from workers in Tokyo, Japan, where there is a poor work–life balance, and CVD is the leading cause of death [13].

Materials and methods

Study population

This study uses longitudinal data from the Midlife in Japan (MIDJA) Wave I survey and biomarker study and the Wave II biomarker study [14–16]. The MIDJA Wave I biomarker project was carried out in 2009/2010, followed by the MIDJA Wave II biomarker project in 2013/2014 with a 4-year follow-up period. Two-stage stratified random sampling, considering age and sex, was conducted based on the Basic Resident Register Book in Tokyo, Japan. Participants aged 30–80 were recruited for the MIDJA Wave I survey.

This study includes participants who self-reported having paid employment at MIDJA Wave I and complete data on the variables of interest. The sample selection process is demonstrated in Fig. 1. A total of 1027 participants enrolled in the MIDJA Wave I survey, with a subsample of 382 participants undergoing biological assessment in the biomarker study. Among those, 235 workers had complete data on work–family conflict and covariates, as well as targeted biomarkers at baseline. Subsequently, 153 of them participated in the MIDJA Wave II biomarker study. One participant with invalid targeted biomarkers was excluded from the analysis. The final sample size for this study was 152, reflecting a follow-up rate of 65.11% (153/235), while the overall follow-up rate for the MIDJA biomarker project was 63.61% (243/382).

Work-to-family conflict and family-to-work conflict

This study employed the work–family conflict scale from the MIDJA Wave I survey, which comprised eight items [3]. Each WFC and FWC scale consisted of four items, utilizing a 5-point Likert scale, ranging from "1: none of the time" to "5: most of the time," capturing the nuances of participants' perceptions of WFC and FWC. Examples of questions for WFC are, "How often have you experienced your job reducing the effort you can give to activities at home?" and "How often have you experienced stress at work making you irritable at home?" [14]. Examples of FWC questions are, "How often do responsibilities at home reduce the effort you can devote to your job?" and "How often do personal or family worries and problems distract you when you are at work?" These questions are strain-based WFC and FWC, although they also imply time- and behavior-based [17].

Each score was summed to create continuous WFC and FWC. The total scores for WFC and FWC possibly range from 4 to 20, and higher scores indicate that participants experience more conflicts. These WFC and FWC scores were converted to z-scores to improve statistical analysis. Cronbach's alpha coefficients for WFC and FWC in this study were 0.81 and 0.67, respectively.

Allostatic load index

Following the established approach [11, 18], we selected 13 biomarkers from five biological systems available in the MIDJA Wave I and II biomarker projects. The ALI for this study incorporates the cardiovascular system, which includes the averages of the second and third systolic and diastolic blood pressure [19]; the hypothalamic–pituitary–adrenal (HPA) axis, which includes dehydroepiandrosterone sulfate (DHEA-S); the immune system, which includes CRP, fibrinogen, and IL-6; the metabolic system, which includes TC, TG, LDL-C, HDL-C, and HbA1c; and the anthropometric system, which includes the BMI and waist–hip ratio (WHR).

More than half of these biomarkers do not have established clinical threshold values in Japan. Thus, this study utilized the quartile method to establish cut-off values that have been commonly used in previous studies [11]. In this method, biomarkers that fell into the 75th quartile or higher, or the 25th quartile or lower, would be assigned one point based on whether values above or below these quartiles were considered high risk. Most biomarkers were classified as high risk in the upper quartiles, except for DHEA-S and HDL-C, which were considered high risk in the lower quartiles. The threshold cut-offs at baseline and follow-up were established each time in line with a previous longitudinal study comparing ALI at baseline and follow-up [20]. Participants classified as high risk received one point, while those deemed lower risk received zero points [11].

Regarding the changes in ALI in longitudinal studies, two calculations have been commonly developed. The first method creates two respective ALI scores, ranging from 0 to 13, at baseline and follow-up. In this method, after assigning individual scores (0 or 1) for 13 biomarkers, these scores are summed to create an ALI score at each time point, with a potential range from 0 to 13 [11]. Consequently, changes in ALI are modeled using advanced

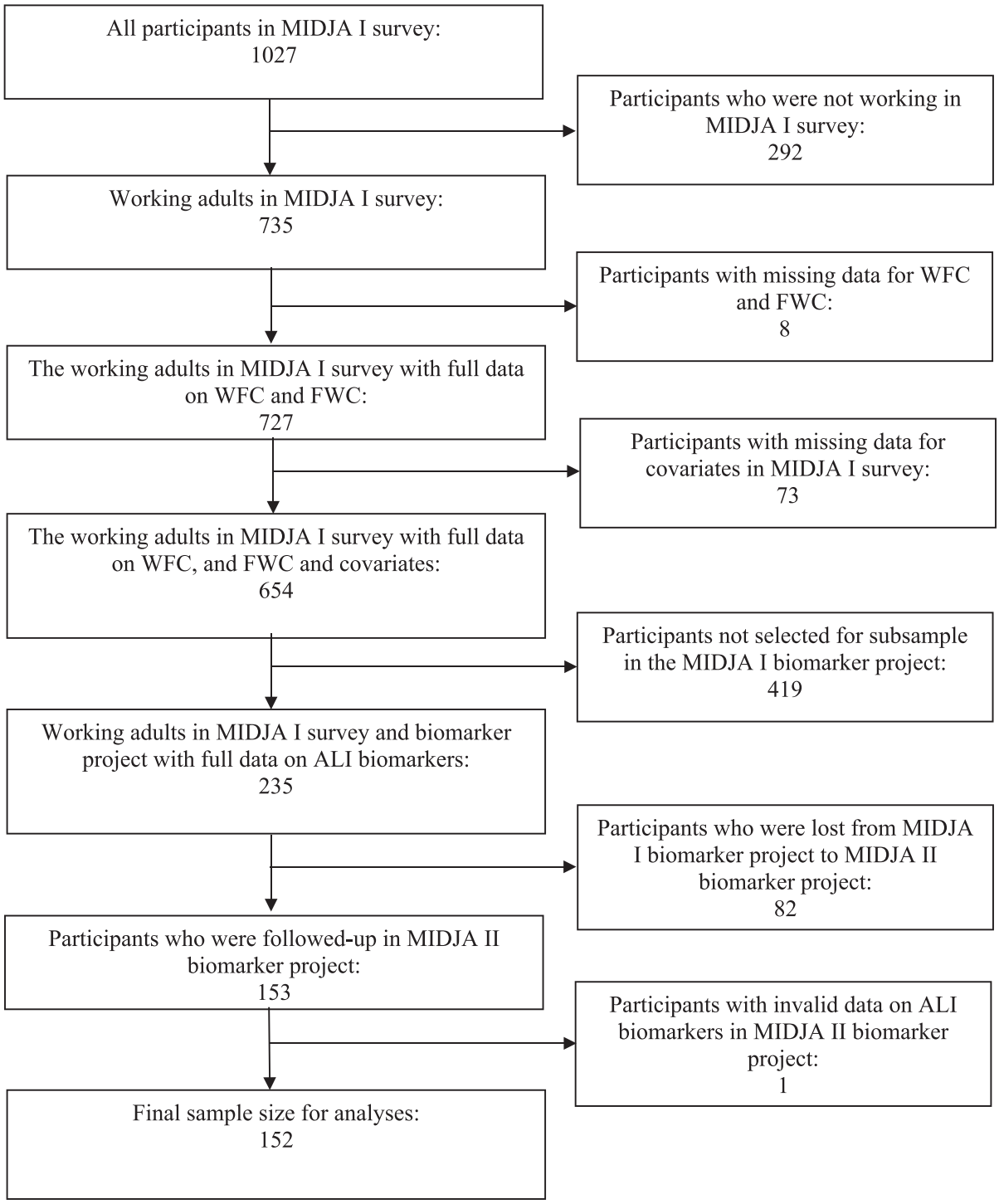

Figure 1 Sample selection. MIDJA, Midlife in Japan; WFC, work–family conflict; FWC, family–work conflict; ALI, allostatic load index

longitudinal regression analysis [20]. This method is labeled the "Two ALI approach" in our study.

Another method creates a single ALI score by considering changes in each biomarker across baseline and follow-up [21]. i.e. using the previously assigned biomarker scores at baseline and follow-up, an ALI change score is created by considering the changes in individual scores of biomarkers. There are four patterns:

i) Baseline = 0 points and follow-up = 0 points, then the longitudinal biomarker score = 0 points;
ii) Baseline = 1 point and follow-up = 0 points, then the longitudinal biomarker score = 1 point;
iii) Baseline = 0 points and follow-up = 1 point, then the longitudinal biomarker score = 2 points; and
iv) Baseline = 1 point and follow-up = 1 point, then the longitudinal biomarker score = 3 points.

Individual longitudinal biomarker scores, ranging from 0 to 3, are summed to create a longitudinal ALI change score, possibly ranging from 0 to 39. This method is labeled as the "One ALI approach" in our study.

To examine the robustness of our findings in light of differing cut-offs to define ALI, we expanded our primary analyses, which were based on the quartile method using absolute cutoffs established at baseline. We also examined the quintiles and tertiles methods based on distribution cut-offs established at baseline and follow-up in two sets of sensitivity analyses.

Covariates

This study included covariates of sociodemographic factors, including age, sex (male and female), educational attainment (high school or less, some college degree, and university degree or more); work- and family-related factors, including management position (yes and no), job demand, which was generated using the Japanese version of the Job Content Questionnaire that was reported continuous variable ranging from 5 to 25 [22], marital status (married, never married, and others), and parental status (yes and no); and health-related lifestyle behaviors, including smoking status (current smoker, former smoker, and never smoker), alcohol consumption (the number of drinks per week, which was logarithmically transformed due to the right-skewed distribution), and physical exercise (yes and no).

Statistical analysis

Initially, we generated descriptive statistics and examined the means with standard deviations (SDs) for the continuous variables, as well as the relative frequencies and percentages for categorical variables. Subsequently, we assessed the correlations between baseline and follow-up using Pearson correlation coefficients for individual biomarkers and Spearman rank correlation coefficients for the ALI.

We used two statistical approaches, including the Two ALI and One ALI approaches, to examine changes in longitudinal ALI scores. In the Two ALI approach, we used generalized estimating equations (GEEs) with a negative binomial distribution to explore the predictive power of WFC and FWC in changes of two ALI scores at baseline and follow-up. The GEE is capable of comparing highly correlated and clustered data to examine changes in repeated measures [23]. Due to the nature of ALI as a count variable, characterized by a right-skewed distribution, because most participants had lower scores, along with overdispersion, the negative binomial distribution was considered suitable for this analysis. For the One ALI approach, we applied a regular negative binomial regression analysis because it already considered changes in biomarkers at baseline and follow-up.

We conducted statistical analyses using a four-step adjustment. Model 0 was crude without adjustment. Model 1 was adjusted for sociodemographic factors, controlling for age, sex, and educational attainment at baseline. Model 2 was further adjusted for work-related and family-related factors, including management position, job demands, marital status, and parental status at baseline. Model 3 was additionally accounted for with health-related lifestyle behaviors, incorporating smoking, alcohol consumption, and physical exercise at baseline.

The results are reported with count ratios (CRs) and 95% confidence intervals (CIs). We used SAS 9.4 statistical software for these analyses.

Results

The characteristics of the study samples are presented in Table 1. The total number of participants was 152. The mean and SD of age were 50.43 ± 11.46. The sex distributions of males and females were fairly equal, including 51.97% of females. Most participants had some college or higher education. For job demands, determined by job demands-control, the mean and SD yielded 12.84 ± 3.44, which can be viewed as reflecting intermediate levels given the potential score range of 5–25. The majority of participants were married and had children. A predominant number of participants were not currently smoking. The median alcohol consumption was 3.5, ranging from 0 to 42 drinks per week. More than half of the participants did not engage in physical exercise. The mean and SD of WFC and FWC were 9.30 ± 3.14 and 7.76 ± 2.38, respectively. The baseline WFC and FWC were highly correlated (correlation coefficient = 0.67; $P = <.0001$) (Supplementary Table 1).

Table 1. Baseline characteristics of the study sample ($n = 152$).

Variables		$n = 152$ (%)
Age	Mean ± SD	50.43 ± 11.46
Sex	Male	73 (48.03%)
	Female	79 (51.97%)
Educational attainment	High school or less	48 (31.58%)
	Some college	43 (28.29%)
	University or higher	61 (40.13%)
Management position	No	107 (70.39%)
	Yes	45 (29.61%)
Job demands	Mean ± SD	12.84 ± 3.44
Marital status	Married	112 (73.68%)
	Never married	25 (16.45%)
	Others	15 (9.87%)
Parental status	No	42 (27.63%)
	Yes	110 (72.37%)
Smoking	Never smoker	57 (37.50%)
	Former smoker	56 (36.84%)
	Current smoker	39 (25.66%)
Alcohol consumption (drinks per week)	Median (range)	3.5 (0.00–42.00)
Physical exercise	No	86 (56.58%)
	Yes	66 (43.42%)
Work–to-family conflict	Mean ± SD	9.30 ± 3.14
Family-to–work conflict	Mean ± SD	7.76 ± 2.38

The means, SDs, correlation coefficients between baseline and follow-up, and high-risk cut-off values at both baseline and follow-up are reported in Table 2. Most of the biomarkers at baseline and follow-up were highly correlated ($P < .001$), except for CRP and HbA1c (Table 2).

Table 3 demonstrates the results of the Two ALI approach. The adjusted models showed a significant association between WFC and changes across the two ALI scores. The CR and 95% CIs for WFC and ALI were 1.15 (1.03, 1.28), whereas FWC did not show a significant association with the CR and 95% CIs at 0.99 (0.89, 1.11).

Table 4 illustrates the results of the One ALI approach. WFC and the One ALI approach showed a significant association in the adjusted models. The CR and 95% CIs for WFC and the One ALI were 1.15 (1.01, 1.32) in the final model. In contrast, there was no significant association between FWC and the One ALI, 0.98 (0.87, 1.11) in the final model.

We conducted sensitivity analyses using various cutoffs, including absolute cutoffs established at baseline, maintaining the quartile method, as well as using quintile and tertile methods with distribution cutoffs established at both baseline and follow-up to create the Two ALI and One ALI. The results from using the absolute cutoffs established at baseline are illustrated in Supplementary Table 2. Our results showed consistent findings

Table 2. The means, standard deviations, and correlations of biomarkers and ALI at baseline and follow-up ($n = 152$).

Variables	At baseline (mean ± SD)	At follow-up (mean ± SD)	Correlations between baseline and follow-up	High-risk cut-offs at baseline	High-risk cut-offs at follow-up
Cardiovascular system					
The mean of second & third systolic blood pressure (mmHg)	120.61 ± 17.83	124.78 ± 19.01	0.70***	≥133.50	≥137.00
The mean of second & third diastolic blood pressure (mmHg)	71.55 ± 11.41	80.09 ± 10.78	0.67***	≥78.00	≥87.00
HPA axis					
DHEA-S (ug/dl)	182.01 ± 111.08	169.34 ± 108.35	0.90***	≤ 97.50	≤ 80.00
Immune system					
CRP (ug/ml)	0.55 ± 0.84	0.94 ± 2.46	0.05	≥ 0.64	≥ 0.78
Fibrinogen (mg/dl)	309.43 ± 61.17	298.82 ± 60.91	0.51***	≥ 347.00	≥ 342.00
Interleukin-6 (pg/ml)	1.24 ± 1.22	1.14 ± 0.87	0.37***	≥ 1.35	≥ 1.40
Metabolic system					
Total cholesterol (mg/dl)	210.76 ± 36.42	213.82 ± 34.31	0.68***	≥ 234.00	≥ 238.50
Triglycerides (mg/dl)	148.26 ± 116.66	138.12 ± 116.34	0.59***	≥ 192.50	≥ 153.00
Low-density lipoprotein cholesterol (mg/dl)	121.16 ± 30.75	123.01 ± 30.29	0.74***	≥ 140.50	≥ 144.00
High-density lipoprotein cholesterol (mg/dl)	66.68 ± 16.63	63.69 ± 13.67	0.73***	≤ 55.00	≤ 55.00
HbA1c (%)	5.05 ± 0.51	5.61 ± 3.66	0.08	≥ 5.20	≥ 5.50
Anthropometric system					
Body mass index	22.91 ± 3.13	22.99 ± 3.14	0.89***	≥ 25.35	≥ 25.01
Waist–hip ratio	0.83 ± 0.08	0.82 ± 0.08	0.84***	≥ 0.90	≥ 0.87
ALI					
Two ALI approach (median and potential range)	3 (0–13)	3 (0–13)	0.67***		
One ALI approach (median and potential range)	9 (0–39)				

Pearson correlation coefficients for continuous variables (biomarkers) and Spearman rank correlation coefficients for count variables (allostatic load index). *$P < .05$, **$P < .01$, ***$P < .001$. SD, standard deviation; HPA, hypothalamic–pituitary–adrenal; DHEA-S, dehydroepiandrosterone sulfate; CRP, C-reactive protein; HbA1c, hemoglobin A1c; ALI, allostatic load index.

Table 3. Longitudinal associations of work-to-family conflict and family-to-work conflict at baseline with the Two ALI approach (CRs and 95% CIs).

	Model 0[a]	Model 1[b]	Model 2[c]	Model 3[d]
Work-to-family conflict				
Two ALI approach	1.02 (0.92, 1.13)	1.20 (1.08, 1.33)***	1.16 (1.04, 1.30)**	1.15 (1.03, 1.28)*
Family-to-work conflict				
Two ALI approach	0.94 (0.83, 1.06)	1.05 (0.92, 1.20)	1.02 (0.90, 1.14)	0.99 (0.89, 1.11)

Note. CI, confidence interval; CRs, count ratios; SD, standard deviation; ALI, allostatic load index. Generalized estimating equation with a negative binomial distribution. Results are reported in the count ratios and 95% confidence intervals. *$P < .05$, **$P < .01$, ***$P < .001$. [a]Model 0: no adjustment; [b]Model 1: adjustment for age, sex, and educational attainment at baseline; [c]Model 2: Model 1 + additional adjustment for management position, job demands, marital status, parental status at baseline; [d]Model 3: Model 2 + additional adjustment for smoking, alcohol consumption, and physical exercise at baseline.

Table 4. Longitudinal associations of work-to-family conflict and family-to-work conflict at baseline with the One ALI approach (CRs and 95% CIs).

	Model 0[a]	Model 1[b]	Model 2[c]	Model 3[d]
Work-to-family conflict				
One ALI approach	1.03 (0.91, 1.17)	1.20 (1.06, 1.35)**	1.16 (1.02, 1.33)*	1.15 (1.01, 1.32)*
Family-to-work conflict				
One ALI approach	0.95 (0.83, 1.07)	1.04 (0.93, 1.17)	1.00 (0.89, 1.13)	0.98 (0.87, 1.11)

Note. CI, confidence interval; CRs, count ratios; SD, standard deviation; ALI, allostatic load index. Negative binomial regression. Results are reported in count ratios and 95% confidence intervals. *$P < .05$, **$P < .01$. [a]Model 0: no adjustment; [b]Model 1: adjustment for age, sex, and educational attainment at baseline; [c]Model 2: Model 1 + additional adjustment for management position, job demands, marital status, parental status at baseline; [d]Model 3: Model 2 + additional adjustment for smoking, alcohol consumption, and physical exercise at baseline.

that WFC was significantly positively associated with ALI, using both the Two and One ALI approaches, comparing absolute cutoffs to our primary analyses using distribution cutoffs. Similarly, FWC was positively associated with ALI, but it did not reach statistical significance in either approach.

We also conducted sensitivity analyses using the quintile and tertile cut-offs established at both baseline and follow-up, as shown in Supplementary Tables 3 and 4. Although associations were attenuated, we still observed consistent positive associations between WFC and both the Two ALI and One ALI approaches in the final model using the quintile cut-offs of 1.17 (1.04, 1.31) and 1.15 (0.99, 1.32), as well as the tertile cut-offs of 1.09 (0.97, 1.22) and 1.10 (0.98, 1.22), respectively. Results related to FWC were likewise similar to those of the primary analyses, although estimates did not reach statistical significance.

Supplementary Table 4 demonstrates the results of the interaction analysis of WFC × WFC in the fully adjusted model. The CRs and 95% CIs of the Two ALI approach and the One ALI approach

were 0.98 (0.87, 1.10) and 0.98 (0.88, 1.08), respectively. These results did not show significance.

Supplementary Table 5 summarizes the characteristics of the study sample at baseline, comparing retained and dropout participants. These groups did not show significant differences.

Discussion

This study examined whether work–family conflict at baseline was associated with changes in ALI over 4 years of follow-up in a sample of Japanese workers. Our results showed that higher WFC was significantly associated with increased ALI in adjusted models, while FWC did not reach statistical significance. We also applied two approaches for ALI change scores, including the Two ALI approach and the One ALI approach, and reported their stable and consistent associations. Therefore, our results suggested that WFC had a more detrimental effect on the biological system among Japanese workers. We also conducted sensitivity analyses using various cutoffs, including a quartile method with absolute cutoffs established at baseline, as well as quintile and tertile methods with distribution cutoffs established at baseline and follow-up. The quartile method, using absolute cutoffs, showed similar effects to those of distribution cutoffs. The quintile and tertile methods showed consistent, but somewhat attenuated, positive associations.

One possible reason for the different effects of WFC and FWC is social norms in Japan. Our results showed that Japanese workers experienced higher WFC, with a mean and SD of 9.30 ± 3.14, compared to FWC at 7.76 ± 2.38. Another Japanese study shows a similar tendency, showing higher WFC than FWC [24]. Interestingly, the government of Japan reported that its survey revealed that Japanese workers were more concerned about the presenteeism of housework than that of their work [25]. These findings support the notion that Japanese workers prioritize their roles at home and experience stress when they cannot fulfill family obligations. This may explain why WFC was significantly associated with increased ALI, while FWC was not.

A similar tendency can be seen in a Brazilian study that examined the associations between WFC/FWC and TC and reported that WFC was associated with TC, but FWC was not [5]. Moreover, a US study reported that WFC was positively associated with a cardiometabolic risk score, while FWC was not associated [26]. This phenomenon may be attributed to the fact that WFC and FWC trigger different psychological and physiological responses.

McEwen stated that chronic anxiety and anticipation can initiate stress cascades [27]. One possible explanation for the different effects of WFC and FWC on ALI is that WFC may induce anticipation or rumination, leading to chronic stress exposure, but FWC does not. WFC stimulates the frontal cortex and limbic system, which fuels the hypothalamus and autonomic nervous system (ANS) activations. A study from Brazil supports this link between WFC and the ANS, highlighting the association between WFC and increased BP, although FWC was not significantly associated with increased BP [5]. Chronic WFC activates the HPA axis, resulting in the production of stress hormones. These stress hormones lead to catabolic reactions to supply glucose to the brain and heart. This mechanism increases glucose uptake, although the biological system tends to favor insulin resistance. Research supports this mechanism, as demonstrated by the associations of WFC with increased BMI in longitudinal studies [7, 8]. Studies also support lipid metabolic dysregulation, indicating associations between WFC and increased TG cross-sectionally [9], as well as decreased HDL-C, both cross-sectionally [9] and longitudinally [7]. Finally, an association between WFC and increased CVD incidents among women is documented, although this association did not reach statistical significance [4]. Since our study utilized biomarkers from the cardiovascular system, HPA axis, immune system, metabolic system, and anthropometric system, we were able to capture changes in AL using a comprehensive biomarker package.

The strengths of this study should be highlighted. Our study used longitudinal data with a 4-year follow-up period to compare baseline and follow-up ALI scores. To our knowledge, this is the first study reporting longitudinal associations between bidirectional work–family conflict (WFC and FWC) and changes in ALI worldwide. The advantage of our longitudinal study period is that it allows us to observe changes in ALI from baseline to follow-up. Our study provided new insights into the long-term effects of work–family conflict on ALI in Japanese workers, as no previous studies have been conducted on this topic. Our study also contributed to expanding the body of knowledge by demonstrating the benefits of using a comprehensive biomarker package, ALI, which can detect physiological changes earlier than single biomarkers, and ultimately facilitate the initiation of primary prevention. Additionally, we applied two statistical approaches to examine the longitudinal associations between WFC/FWC and ALI using repeated measures. Both approaches showed similar results, supporting the robustness of our findings.

We also need to address limitations. Although we were able to examine the longitudinal effects of work–family conflict on changes in ALI over a 4-year interval, we were unable to consider the cumulative effects of work–family conflict, as the MIDJA study collected data at only two time points: baseline and follow-up, without annual surveys and biomarker examinations. Thus, our assumption in this study is that participants had been constantly exposed to work–family conflict throughout the 4-year period. Another limitation of this study was our inability to consider occupation-related information that may influence work–family conflict in greater detail, as MIDJA lacked such data. While we were able to account for data on management positions, we could not consider participants' occupations, industry branches, company sizes, and working hours, which would have been useful. Likewise, we could not account for data on additional family-related stressors (e.g. informal care for the elderly), which were of interest. Our sample size was small, which limited the statistical power. Consequently, we could not (i) conduct sex-stratified analyses, which had been of interest but were reported as poor predictors [28], or (ii) consider the joint effects of WFC and FWC beyond our interaction analysis, which did not show significance. Although work–family conflict scale has three dimensions: strain-based, time-based, and behavior-based [17], the work–family conflict questionnaire in the MIDJA study [14] focused on strain-based conflict, although these questions also nuanced time- and behavior-based strain. Thus, applicability to time- and behavior-based strain of WFC and FWC is limited. The follow-up rate in this study was 65.11%, but our nonresponder analyses suggested attrition bias to be minimal. Lastly, the data are relatively old, and work- and family-related environments may have changed. For example, male roles have shifted toward participating in housework due to shifts in work style, particularly remote work [29]. In recent years, the availability of remote work has increased due to several societal factors, such as the COVID-19 pandemic, according to government reports in Japan. The proportion of Japanese workers with remote work experience increased from 8.5% in 2018 [30] to 27.3% in 2022 [31]. Since the size of the productive age population reached its maximum in 1995, it has

been gradually declining in Japan [32]. New work styles, including remote work, could reduce work–family conflict and enhance work–life balance, while also expanding the possibility for people to participate in the labor force from home.

Our results indicated that exposure to WFC, not FWC, led to increased AL, suggesting that occupational health clinicians and organizations could screen for work–family conflict as part of mental health screening and intervene to reduce WFC. A study reported that interventions to enhance personal resources, such as coping skills and mindfulness, significantly improved work–nonwork conflict [33]. This suggests that interventions supporting workers in improving their personal resources could be beneficial. Additionally, the ALI can serve as an evaluation method for workplace stress intervention programs. A systematic review and meta-analysis study reported that a high AL was linked to increased CVD mortality by 31% [10]. Particularly in Japan, the Industrial Safety and Health Act mandates employers to conduct annual health check-ups [34]. Using data from annual check-ups, it may be beneficial to screen employees using the ALI to assess AL since ALI captures the wear and tear on the biological system at earlier stages, allowing for initiating early interventions prior to developing CVD.

Conclusions

Our study highlighted new knowledge that WFC was associated with long-term biological changes, which were defined by AL among Japanese workers. Further research is recommended to determine how WFC and FWC influence health among workers with large sample sizes in other populations beyond Japan.

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Author contributions

J.L. conceptualized this study. J.L. and M.S. developed the research design and methodology. M.S. conducted data curation and formal analysis. M.S. created visualization materials. M.S. and J.L. drafted the manuscript. M.S., A.L., and J.L. reviewed and edited the manuscript. All authors read and approved the final manuscript.

Supplementary data

Supplementary data are available at *Postgraduate Medical Journal* online.

Conflict of interest statement: None declared.

Ethics approval and consent to participate

The analytic project was conducted in accordance with the Declaration of Helsinki and was determined exempt from review by the Institutional Review Board of the University of California, Los Angeles (IRB#22-000836). All participants gave informed consent prior to data collection.

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Data availability

The data underlying this article are available in the ICPSR repository at https://doi.org/10.3886/ICPSR30822.v3 (MIDJA I survey), https://doi.org/10.3886/ICPSR34969.v4 (MIDJA I Biomarker Project), and https://doi.org/10.3886/ICPSR36530.v4 (MIDJA II Biomarker Project). The authors will make the statistical SAS syntax supporting this article's conclusions available without undue reservation. Requests to access the statistical SAS syntax should be directed to Dr Jian Li (jianli2019@ucla.edu).

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