Journal of the International Neuropsychological Society (2024), **30**, 755–763
doi:10.1017/S1355617724000298

Research Article

Allostatic load and cognitive recall among young adults: Racial, ethnic, and sex-specific variations

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Abstract

Introduction: While factors such as age and education have been associated with persistent differences in functional cognitive decline, they do not fully explain observed variations particularly those between different racial/ethnic and sex groups. The aim of this study was to explore the association between allostatic load (AL) and cognition in a racially diverse cohort of young adults. **Methods:** Utilizing Wave V of the National Longitudinal Study of Adolescent to Adult Health – a nationally representative, longitudinal survey of adults aged 34–44, this study utilized primary data from 10 immune, cardiovascular, and metabolic biomarkers to derive an AL Index. Cognition was previously recorded through word and number recall scores. Regression analysis evaluated the association between cognitive recall, AL, age, sex, and race/ethnicity. **Results:** Regression results indicated statistically higher AL scores among Blacks (IRR = 1.09, CI = 1.01, 1.19) compared to Whites and lower AL score among females compared to males (IRR = 0.76, CI = 0.72, 0.81). At zero AL, Blacks (IRR = 1.2399, CI = 1.2398, 1.24) and Other races (IRR = 1.4523, CI = 1.452, 1.4525) had higher recall while Hispanics (IRR = 0.808, CI = 0.8079, 0.8081) had lower recall compared to Whites. Relative to males, females had higher number recall (IRR = 1.1976, CI = 1.1976, 1.1977). However, at higher, positive levels of AL, Blacks (IRR = 0.9554, CI = 0.9553, 0.9554), Other races (IRR = 0.9479, CI = 0.9479, 0.9479) and females (IRR = 0.9655, CI = 0.9655, 0.9655) had significantly lower number recall than Whites and males respectively. **Conclusions:** Race and sex differences were observed in recall at different levels of AL. Findings demonstrate the need for further exploration of cognition in young adults across diverse populations that includes examination of AL.

Keywords: Recall; health disparity populations; allostasis; ethnicity; social factors; risk factors

(Received 29 September 2023; final revision 2 June 2024; accepted 3 June 2024; First Published online 19 September 2024)

Introduction

Cognitive functioning, mental processes associated with learning and memory, is critical to the ability to complete complex tasks such as problem solving and decision making (Díaz-Venegas et al., 2016). Cognitive decline that does not impact activities of daily living is associated with typical aging. However, racial, ethnic and sex differences in cognition and cognitive decline have been persistently observed (Díaz-Venegas et al., 2016; Marsiske et al., 2013; Zsembik & Peek, 2001) with marginalized populations demonstrating worse performance on cognitive tasks than their White counterparts (Díaz-Venegas et al., 2016). Explanations for these observed differences have consisted of social factors that influence health and cognition such as insurance status and education (Zsembik & Peek, 2001), in addition to biological risk factors such as diabetes (Noble et al., 2012). Furthermore, there is variation on these attenuating factors dependent on race, ethnicity, age, and baseline cognition (Díaz-Venegas et al., 2016; Zahodne et al., 2016). Additionally, females demonstrate greater performance on cognitive tasks yet they experience an increased rate of cognitive decline throughout the lifespan (Levine et al., 2021). However, this association with cognitive decline differs based on their race and ethnicity (Avila et al., 2019). Despite improved understanding of additional factors that influence cognitive functioning, differences persist across the lifespan. This indicates a need to continue exploration of other factors that influence differences in cognitive functioning.

One such factor is allostatic load – the "wear and tear" on physiological systems resulting from cumulative life stress (McEwen, 2005) – which has been associated with a wide array of health outcomes including but not limited to cardiovascular health, mental health and cognitive functioning (Juster et al., 2010). Allostatic load is often measured through a composite score of primary and secondary mediators in the immune, neuroendocrine, metabolic, and cardiovascular systems (Seeman et al., 2001). Evidence suggests that worse health outcomes in Black and Hispanic adults may be attributable to a higher allostatic load burden (Duru et al., 2012; Geronimus et al., 2006). To date, few

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Cite this article: Evans E., Jacobs M., & Ellis C. (2024) Allostatic load and cognitive recall among young adults: Racial, ethnic, and sex-specific variations. *Journal of the International Neuropsychological Society*, **30**: 755–763, https://doi.org/10.1017/S1355617724000298

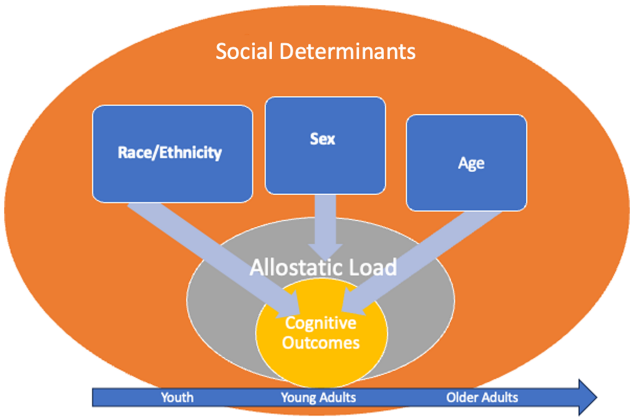

Figure 1. Theoretical model of the multilevel influence of individual characteristics on cognition.

studies have specifically explored the consistency of this finding in cognitive outcomes. Additionally, allostatic load as well as declines in cognitive functioning increases with age. However, research to date has primarily focused on older aged adults with some literature targeting middle aged adults (D'Amico et al., 2020). Richardson et al. (2021) found that early life adversity inhibited the protective power of a college education in Blacks suggesting an interrelationship between allostatic load, education and race that impacts cognitive outcomes. Consequently, there is a need to explore the influence of race/ethnicity on allostatic load in relationship to cognitive outcomes. In addition, there is need to explore this issue in younger age populations which may offer an opportunity to develop preventative interventions to close the racial/ethnic gap in cognitive outcomes. As seen in Figure 1 there is potentially a multilevel influence of individual characteristics such as race/ethnicity and sex on cognition. Additionally, lifespan experiences are associated with cognition. Experiencing adversity throughout the lifespan is associated with increased risk of cognitive decline and impairment (Ahn et al., 2024). Experiencing neglect or living in chronic poverty during childhood are associated with brain development (Blair & Raver, 2016; Luby et al., 2013) and subsequent cognition in adulthood (Evans, 2016). This relationship between life experience in childhood and cognition in adulthood is thought to be partially through stress pathways. Individual characteristics have been shown to result in differences between allostatic load as well as differences in cognition resulting in possible differing individual differences in relationships between allostatic load and cognition.

Despite an observed inverse association between cognition and allostatic load and a higher allostatic load burden in minority populations few studies have examined whether differences in allostatic load partially explain race and ethnic differences in cognition in young adults. Additionally, although men have higher allostatic load gender specific differences in allostatic load have been associated with differences in women's mental health (Kerr et al., 2020) suggesting sex differences in response to chronic stress may explain observed sex differences in cognitive decline. However, similarly to race and ethnicity this association has not been explored in young adults.

Understanding the impact of allostatic load, a representation of the physiological impact of social adversity and social determinants, on cognition in young adults across a diverse population may provide additional insight into preventative targets for cognitive impairment. To determine if a similar relationship between allostatic load and cognition as seen in middle aged and older adults is seen in young adults we will examine the relationship between allostatic load and cognitive recall in a relatively healthy nationally representative young adult population. Additionally, we will explore the relationship between cognition and allostatic load among racial, ethnic and sex groups across a diverse young cohort.

Table 1. Survey, recall, in-home biological measures, and specimen sample sizes

Full Wave V Cohort	All respondents	$N = 12,300$
Word Recall	Delayed, 60 s	$N = 1701$
Word Recall	90 s	$N = 1705$
Digit Recall	Reverse order repeat	$N = 1716$
Demographic-Home Exam	social, environmental, behavioral, health data	$N = 1839$
Cardiovascular	Systolic BP, diastolic BP, pulse rate	$N = 1839$
Anthropometric	weight, height, arm & waist circumference	$N = 1839$
Metabolic	HbA1c, glucose, cholesterol, triglycerides	$N = 1839$
Inflammatory/ Immune	hs-CRP	$N = 1839$
Pharmacologic	prescription medication use & classification	$N = 3883$
Renal function	creatinine, cystatin C	$N = 1839$
Pregnant		$N = 93$

Methods

Data: We used restricted-use data from Wave V of the National Longitudinal Study of Adolescent to Adult Health (Add Health), a longitudinal study of a nationally representative sample of adolescents in grades 7 through 12 during the 1994–1995 school year in the US Wave V was conducted during 2016–2018 when subjects were 31–42 years old to collect social, environmental, behavioral, and biological data with which to track the emergence of chronic disease as the cohort advanced through their fourth decade of life. The full Wave V sample consisted of 12,300 respondents. Relevant ethical approvals were obtained for this study from University of North Carolina and University of Florida institutional review boards. Add Health participants are provided written informed consent for participation in all aspects of ADD Health in accordance with the University of North Carolina School of Public Health Institutional Review Board guidelines. Use of these data required a restricted-use data license and agreement to comply with ethical and privacy standards. All research completed in accordance with the Helsinki Declaration.

Biomarkers: The biomarker collection sample consisted of 5381 respondents who received in-home visits to collect biological measures and specimens including cardiovascular, anthropometric, metabolic, inflammatory/immune, pharmacologic, and renal function indicators (Table 1).

Digit Recall: The digit-span backwards task is a standardized measure that is utilized to assess working memory in the Weschler Adult Intelligence Scale (WAIS-IV). The task involved an interviewer reading strings of numbers aloud, with 1-s intervals between each number. The participant was then asked to recall the string of numbers in reverse order. The task began with a two-number string and consisted of seven levels. At each level, the participant had two trials to recall the number string backwards correctly. If the correct response was given on the first trial, the second trial of that level was not administered, and the interviewer would then move to the number string at the next level. If the

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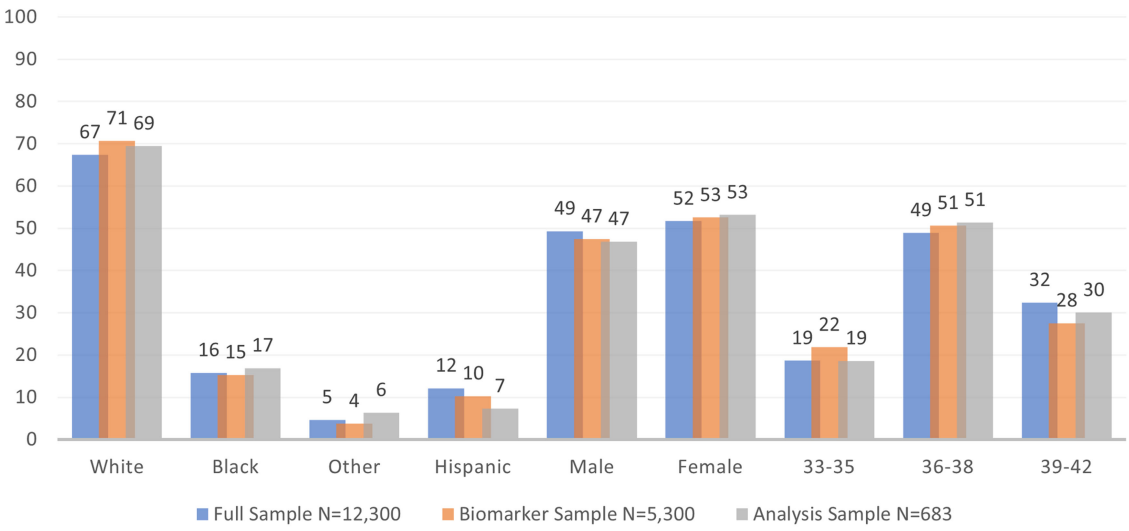

Figure 2. Representation of racial, ethnic and sex subgroups in the study sample.

participant was unable to accurately recall a number string in both trials, the task was concluded. The possible range of scores was from 0 to 7, where higher scores demonstrate better number recall or working memory.

Word Recall: Word recall was determined using the Rey Auditory-Verbal Learning Test (RAVLT). In this task, the interviewer read a list of 15 common words aloud with 1-s intervals between each word. The participants were then instructed to immediately recall as many of the 15 words as possible within 90 s, or until they indicated that they could not remember any other words. The participant received one point for each correct word recalled, and higher scores indicate better immediate word recall or short-term verbal memory. After the first RAVLT list presentation in the immediate recall task, there was a delay after which participants were asked to recall as many of the words from the list as possible within 60 s. The participant received one point for each correct word recalled, with higher scores indicating better delayed word recall or long-term verbal memory.

Sample: Table 1 lists the sample sizes for the full Wave V Add Health Sample as well as the sub samples providing biomarker specimens and performing cognitive recall tasks. The sample consisted of male and female respondents who self-identified as non-Hispanic White, non-Hispanic Black, Hispanic, and Other race/ethnicity in Wave I and had valid sampling weights in Wave V. Respondents who reported more than one race or listed their race as Asian/Pacific Islander, non-Hispanic; American Indian/Native American or other race/ethnicity were combined due to small sample sizes. We excluded female respondents who were pregnant at their Wave V examination because pregnancy may impact several biomarkers for allostatic load toward levels that would be considered high risk. Thus, our final analytic sample consisted of 683 respondents with valid biomarker data and at least one cognitive recall task score. Since the proportion of subjects administered the cognitive recall tasks and from which biomarker specimens were collected differed from the full sample stratification domains, these data required the creation of special sampling weights. To create these sampling weights, post-stratification variables, including gender, age categories and race (Black and non-Black), were used to create subdomains for these response categories and response rates within each domain were calculated. Then the Wave V full sample weight was multiplied by the inverse of these response rates to create a sampling weight for the response cohort used in this analysis. Additional information on the calculation and validation of the Add Health Wave V sample (Harris, Halpern, Biemer, et al., 2019) and Biomarker sample (Chen & Harris, 2020) weights is available. Figure 2 compares the full sample to the sample used in this study illustrating the relative representation of racial, ethnic, and sex subgroups.

Allostatic Load: We calculated an allostatic load score for respondents based on their values for 10 biomarkers of stress and use of biomarker-regulating medications. Following discussion on traditional methods to calculate allostatic load provided by Juster et al. (2010) and examination of our data we used clinically established values for biomarker cutoffs and summing of measures as is traditionally done for our calculation of an allostatic load index. Clinically established values were obtained from relevant organizations and clinical guidelines (Iqbal AM, 2023; National Heart Lung and Blood Institute, 2023; National Kidney Foundation, 2024; Nehring et al., 2023; World Health Organization, 2024) and cross-referenced with clinical values from research examining calculation of allostatic load in minority racial and ethnic groups (Rodriquez et al., 2019). First, based on clinically established guidelines, we assigned respondents a score of 0, 1, or 2 for each biomarker indicating a value suggesting low, medium, or high risk of an adverse health event or condition. Specifically, respondents received a point for having values of diastolic blood pressure (DBP), systolic blood pressure (SBP), pulse rate, hemoglobin A1c (HbA1c), C-reactive protein (CRP), triglycerides, estimated glomerular filtration rate (eGFR), glucose, high-density lipoprotein (HDL) cholesterol, and low-density lipoprotein (LDL) cholesterol. Clinical values corresponding to score assignments are listed in Table 2. Second, among respondents who were not already identified as high risk on a particular biomarker using the sample-based cutoffs, we assigned a score of two for SBP and DBP if a respondent reported taking antihypertensive medication; HDL if a respondent reported taking antihyperlipidemic medication; and A1C if a respondent reported taking anti-diabetic medication. This approach to account for biomarker-related medication usage reflects our assumption that respondents who were on medication and had biomarker values within healthy ranges were successful in controlling them but would have otherwise experienced the same wear and tear on their

https://doi.org/10.1017/S1355617724000298

Table 2. Allostatic load scoring criteria

	Score values and clinical ranges		
Biomarker	0	1	2
CRP	0.0–0.999	1.000–10.000	10.001 & above
Pulse Rate	<100.0		≥100.0
LDL	≤100.0	≥100.1, ≤129.9	≥130.0
HDL	≥60.0	≥10.0, ≤59.9	≤40.0
Triglycerides	≤149.9	≥150.0, ≤199.9	≥200.0
A1C	≤5.7	>5.8, ≤6.4	≥6.5
Glucose	≤99.9	≥100.0, ≤125.9	≥126.0
eGFR	≥90.000	≥60.000, ≤89.999	≤59.999
SBP	≤119.9	≥120.0, ≤139.9	≥140.0
DBP	≤79.9	≥80.0, ≤89.9	≥90.0

regulatory systems as unmedicated respondents who had biomarker values in the unhealthy ranges. Finally, to calculate allostatic load, we summed the points assigned due to biomarker levels and medication use resulting in a single score for each respondent.

Statistical Analysis: These data were evaluated in three stages. First, we calculated mean and frequency values for allostatic load, cognition measures, and demographic characteristics for the full sample as well as racial/ethnic subsamples. Statistically significant differences between subsamples were tested using F- and chi-square test for continuous and categorical variables, respectively. Second, a negative binomial regression evaluated differences in allostatic load between sexes and racial/ethnic groups and sex of the participant adjusting for age. This analytic approach aligns with previous studies of allostatic load and cognition and will allow for comparison of findings utilizing similar approaches allostatic load (Chyu & Upchurch, 2011, 2018; Graves & Nowakowski, 2017; Rainisch & Upchurch, 2013). Third, we assessed the association between the three measures of cognitive recall and allostatic load, age, sex, and race/ethnicity. These regression analyses were first specified with only allostatic load and the demographic characteristics then adding interactions between allostatic load and demographic characteristics. The three measures of cognition represent a total count of the word or numbers that respondents were able to remember within a given time frame. Since these data represent discrete, count values as non-negative integers, a Poisson regression was used to model all three cognitive outcomes. In addition to coefficient estimates, we also reported incidence rate ratios (IRRs) for the negative binomial and Poisson regressions. An IRR, which is calculated by exponentiating a log-rate coefficient, is the ratio of the allostatic load scores for one group (e.g., Blacks) compared to the scores of another group, typically the reference group (e.g., Whites). We used SAS version 9.4 (Cary, NC) and accounted for Add Health's complex survey design (including sampling weights) in all analyses (Harris, Halpern, Whitsel, et al., 2019).

Results

Table 3 provides means and frequency values for all sample characteristics and outcome variables as well as F- and chi-square tests evaluating subgroup differences. Respondents were 38 years old (SD = 1.83) on average and 53% were female and 47% were male. The sample was 70% White, 22% Black, 6% Other races, and 13% Hispanic. Subgroups showed no statistically significant differences in the sex composition ($\chi^2 = 4.83$, $p = 0.1851$) or average age ($F = 2.3$, $p = 0.0759$). allostatic load values ranged between zero and 16 with an average of 5.49 (SD = 2.94) and

Table 3. Sample characteristics and outcome variables

	Full Sample				White		Black		Other		Hispanic			
	N	Mean	Std Dev	Range	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	*F*-Statistic	*p*-Value
Age	683	38.12	1.83	34–44	38.10	1.83	38.33	1.84	37.55	1.62	38.20	1.89	2.30	0.0759
Allostatic Load Index	683	5.49	2.94	0–16	5.37	2.90	5.82	3.04	5.61	2.93	5.05	2.86	0.94	0.4216
Number Recall Score	683	4.27	1.58	0–7	4.41	1.58	3.89	1.58	4.30	1.55	3.79	1.55	4.45	0.0041
Word Recall Score 60 s	681	4.77	2.02	0–14	4.92	1.99	4.28	2.04	4.95	2.00	4.26	1.88	4.31	0.005
Word Recall Score 90 s	683	6.34	1.96	1–15	6.40	1.94	6.19	1.95	6.39	2.23	5.53	1.93	0.43	0.7351
	N	Percent			*N*	Percent	*N*	Percent	*N*	Percent	*N*	Percent	χ^2	*p*-Value
Male	320	46.85			232	48.23	58	39.46	22	50.00	45	51.72	4.83	0.1851
Female	363	53.15			249	51.77	89	60.54	22	50.00	42	48.28		
White	481	70.42												
Black	147	21.52												
Other	44	6.44												
Hispanic	87	12.74												

https://doi.org/10.1017/S1355617724000298

Table 4. Association between allostatic load and demographic characteristics

N	683								
Pearson Chi-Square	1015.502								
Log Likelihood	2679.32								
	Estimate	Std Err	95% CI		Chi-Square	Pr > ChiSq	IRR	95% CI	
Intercept	**1.30**	0.34	0.63	1.98	14.27	0.0002			
Age	0.01	0.01	0.00	0.03	2.35	0.1252	1.01	1.00	1.03
Black	**0.09**	0.04	0.01	0.16	4.65	0.0311	1.09	1.01	1.18
Other	0.05	0.07	−0.08	0.18	0.49	0.4859	1.05	0.92	1.19
Hispanic	−0.10	0.05	−0.20	0.01	3.47	0.0626	0.91	0.82	1.01
Female	**−0.27**	0.03	−0.34	−0.21	67.62	<0.0001	0.76	0.72	0.81

Dependent Variable: Allostatic Load Index.
Reference group: Race (White), Ethnicity (Non-Hispanic), Sex (Male).
Indicates significant at the 95% confidence level.
Estimates are weighted to reflect representative population.
Modeling framework adjusts for survey stratification and respondent clustering.

Table 5. Relationship between 60-s number recall, allostatic load, and demographic characteristics

	683												
N	Estimate	Std Err	Chi-Square	Pr > ChiSq	IRR	95% CI		Estimate	Std Err	Chi-Square	Pr > ChiSq	IRR	95% CI	
Intercept	**0.9324**	0.0001	631	<0.0001				**0.7916**	0.0001	4418	<0.0001			
Allostatic load	**−0.0066**	0.0000	1097	<0.0001	0.9934	0.9934	0.9934	**−0.0176**	0.0000	35,660	<0.0001	0.9823	0.9823	0.9823
Age	**0.0138**	0.0000	2018	<0.0001	1.0139	1.0139	1.0139	**0.0137**	0.0000	1944	<0.0001	1.0138	1.0138	1.0138
Black	**−0.0569**	0.0000	1394	<0.0001	0.9447	0.9446	0.9447	**0.215**	0.0000	38,250	<0.0001	1.2399	1.2398	1.24
Other	**0.0239**	0.0000	1035	<0.0001	1.0242	1.0242	1.0242	**0.3731**	0.0001	2722	<0.0001	1.4523	1.452	1.4525
Hispanic	**−0.1846**	0.0000	630	<0.0001	0.8314	0.8314	0.8315	**−0.2132**	0.0000	217	<0.0001	0.808	0.8079	0.8081
Female	**−0.0179**	0.0000	237	<0.0001	0.9822	0.9822	0.9823	**0.1803**	0.0000	4948	<0.0001	1.1976	1.1976	1.1977
Black*allostatic load								**−0.0457**	0.0000	7099	<0.0001	0.9554	0.9553	0.9554
Other*allostatic load								**−0.0535**	0.0000	2966	<0.0001	0.9479	0.9479	0.9479
Hispanic*allostatic load								**0.0064**	0.0000	5197	<0.0001	1.0064	1.0064	1.0064
Female*allostatic load								**−0.0351**	0.0000	7415	<0.0001	0.9655	0.9655	0.9655

Dependent Variable: 60-s number recall score.
Reference group: Race (White), Ethnicity (Non-Hispanic), Sex (Male).
Indicates significant at the 95% confidence level.
Estimates are weighted to reflect representative population.
Modeling framework adjusts for survey stratification and respondent clustering.

averages were not significantly different between subgroups ($F = 0.94$, $p = 0.4216$). Number recall scores ranged from zero to seven with an average of 4.27 (SD = 1.58) and showed variation between racial and ethnic groups ($F = 4.45$, $p = 0.0041$). Sixty and 90s word recall ranged between zero and 15 and averaged 4.77 (SD = 2.02) and 6.34 (SD = 1.96) respectively. While 60-s recall scores varied significantly between groups ($F = 4.31$, $p = 0.005$), 90-s recall scores did not ($F = 0.43$, $p = 0.7351$).

Table 4 lists results from the negative binomial model estimating the association between allostatic load and sex, race, ethnicity, and age. Relative to Whites, Blacks have significantly higher allostatic load (IRR = 1.09, CI = 1.01, 1.18), while females had substantially lower allostatic load relative to their male counterparts (IRR = 0.76, CI = 0.72, 0.81). Regression estimates were also used to generate hypothetical age specific allostatic load index scores.

Table 5 lists results from the Poisson model estimating the association between 60-s number recall, allostatic load, and demographic characteristics. Results are presented with and without interaction terms, but we will focus on results from the estimation including interaction terms. Number recall increased with age (IRR = 1.0138, CI = 1.0138, 1.0138), but decreased with each additional point of allostatic load (IRR = 0.9823, CI = 0.9823, 0.9823). Demographic characteristics were included as binary variables as well as interaction terms. The un-interacted binary characteristics can be interpreted as the differential between the subgroup and the reference group that exists when allostatic load is zero for both groups. The interaction term represents the relative group scores at positive values of allostatic load. At zero allostatic load, Blacks (IRR = 1.2399, CI = 1.2398, 1.24) and Other (IRR = 1.4523, CI = 1.452, 1.4525) racial groups have higher digit-span recall relative to Whites and Hispanics (IRR = 0.808, CI = 0.8079, 0.8081) have lower digit-span recall. Additionally, at zero allostatic load females (IRR = 1.1976, CI = 1.1976, 1.1977) have higher digit-span recall than males. However, at positive allostatic load values, Blacks (IRR = 0.9554, CI = 0.9553, 0.9554), Other (IRR = 0.9479, CI = 0.9479, 0.9479) racial groups, and females (IRR = 0.9655, CI = 0.9655, 0.9655) have lower digit-span recall than the reference group, while Hispanics have higher (IRR = 1.0064, CI = 1.0064, 1.0064) relative to Whites.

Table 6 lists results from the Poisson model estimating the association between 60-s word recall, allostatic load, and demographic characteristics. At zero allostatic load, Blacks (IRR = 1.0834, CI = 1.0833, 1.0835), Hispanics (IRR = 1.4574,

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Table 6. Relationship between 60-s word recall, allostatic load, and demographic characteristics

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N	Estimate	Std Err	Chi-Square	Pr > ChiSq	IRR	95% CI		Estimate	Std Err	Chi-Square	Pr > ChiSq	IRR	95% CI	
Intercept	**−0.0112**	0.0001	10,129	<0.0001	0.8434	0.8434	0.8435	**−0.0813**	0.0001	5159	<0.0001			
Allostatic load	−0.0211	0.0000	1243	<0.0001	0.9792	0.9792	0.9792	**−0.0165**	0.0000	3411	<0.0001	0.9836	0.9836	0.9836
Age	0.0431	0.0000	2193	<0.0001	1.044	1.044	1.044	**0.0442**	0.0000	2262	<0.0001	1.0452	1.0452	1.0452
Black	**−0.1703**	0.0000	1317	<0.0001	0.8434	0.8434	0.8435	**0.0801**	0.0000	557	<0.0001	1.0834	1.0833	1.0835
Other	0.036	0.0000	2461	<0.0001	1.0366	1.0366	1.0367	**0.3766**	0.0001	337	<0.0001	1.4574	1.4572	1.4575
Hispanic	**−0.1775**	0.0000	6752	<0.0001	0.8374	0.8373	0.8374	**−0.2796**	0.0000	4298	<0.0001	0.7561	0.756	0.7562
Female	**0.0816**	0.0000	555	<0.0001	1.085	1.085	1.085	**0.0519**	0.0000	4719	<0.0001	1.0532	1.0532	1.0533
Black*allostatic load								**−0.0433**	0.0000	643	<0.0001	0.9576	0.9576	0.9576
Other*allostatic load								**−0.0498**	0.0000	3007	<0.0001	0.9514	0.9514	0.9514
Hispanic*allostatic load								**0.0263**	0.0000	1005	<0.0001	1.0266	1.0266	1.0267
Female*allostatic load								**0.0059**	0.0000	2378	<0.0001	1.0059	1.0059	1.0059

Dependent Variable: 60-s word recall score.
Reference group: Race (White), Ethnicity (Non-Hispanic), Sex (Male).
Indicates significant at the 95% confidence level.
Estimates are weighted to reflect representative population.
Modeling framework adjusts for survey stratification and respondent clustering.

Table 7. Relationship between 90-s word recall, allostatic load, and demographic characteristics

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N	Estimate	Std Err	Chi-Square	Pr > ChiSq	IRR	95% CI		Estimate	Std Err	Chi-Square	Pr > ChiSq	IRR	95% CI	
Intercept	**1.0028**	0.0001	1114	<0.0001				**0.8286**	0.0001	7373	<0.0001			
Allostatic load	**−0.0118**	0.0000	5282	<0.0001	0.9883	0.9883	0.9883	**0.014**	0.0000	336	<0.0001	1.0141	1.0141	1.0141
Age	**0.0227**	0.0000	833	<0.0001	1.0229	1.0229	1.0229	**0.0232**	0.0000	8548	<0.0001	1.0235	1.0235	1.0235
Black	**0.0199**	0.0000	2726	<0.0001	1.0201	1.02	1.0201	**0.3363**	0.0000	1512	<0.0001	1.3997	1.3996	1.3998
Other	**−0.0654**	0.0000	1038	<0.0001	0.9367	0.9367	0.9368	**0.3521**	0.0001	3503	<0.0001	1.422	1.4218	1.4222
Hispanic	**−0.1637**	0.0000	7658	<0.0001	0.849	0.849	0.849	**−0.2164**	0.0000	348	<0.0001	0.8054	0.8054	0.8055
Female	**0.0503**	0.0000	2877	<0.0001	1.0516	1.0516	1.0516	**0.2418**	0.0000	1367	<0.0001	1.2736	1.2735	1.2736
Black*allostatic load								**−0.0537**	0.0000	1549	<0.0001	0.9477	0.9477	0.9477
Other*allostatic load								**−0.0639**	0.0000	600	<0.0001	0.9381	0.9381	0.9381
Hispanic*allostatic load								**0.0125**	0.0000	305	<0.0001	1.0126	1.0126	1.0126
Female*allostatic load								**−0.0338**	0.0000	1051	<0.0001	0.9668	0.9668	0.9668

Dependent Variable: 60-s word recall score.
Reference group: Race (White), Ethnicity (Non-Hispanic), Sex (Male).
Indicates significant at the 95% confidence level.
Estimates are weighted to reflect representative population.
Modeling framework adjusts for survey stratification and respondent clustering.

CI = 1.4572, 1.4575), and females (IRR = 1.0532, CI = 1.0532, 1.0533) had higher word recall relative to Whites and males respectively, while Hispanics (IRR = 0.7561, CI = 0.756, 0.7562) had lower relative to Whites. At higher allostatic load, Blacks (IRR = 0.9576, CI = 0.9576, 0.9576) and Other (IRR = 0.9514, CI = 0.9514, 0.9514) races have significantly lower word recall relative to Whites. However, at these higher allostatic load values Hispanics (IRR = 1.0266, CI = 1.0266, 1.0267) and females (IRR = 1.0059, CI = 1.0059, 1.0059) have higher words recall compared to Whites and males.

Table 7 lists results from the Poisson model estimating the association between 90-s word recall, allostatic load, and demographic characteristics. Results were similar in direction and magnitude for age, sex, and racial/ethnic groups and the interaction terms. However, the un-interacted allostatic load coefficient is positive (IRR = 1.0141, CI = 1.0141, 1.0141) indicating a direct relationship between 90-s word recall and allostatic load. While IRR value was small, this variation between the 90- and 60-s recall tasks may indicate a compensatory time effect.

Discussion

While many studies have examined the relationship between allostatic load and health outcomes, few studies have explored how the relationship between allostatic load and cognitive outcomes differs by race, ethnicity and sex. In this study examining the relationship between allostatic load and cognitive recall among young adults, we found allostatic load to have an inverse relationship with cognitive recall. However, this relationship was complex and not consistent when examining differences among race, ethnicity, and sex. Blacks had significantly higher allostatic load compared to their White counterparts whereas females had significantly lower allostatic load compared to their male counterparts. Additionally, worse performance on these cognitive

https://doi.org/10.1017/S1355617724000298

tasks correlated with higher allostatic load. However, at positive allostatic load indices there were race, ethnicity, and sex differences in cognitive performance. Blacks performed worse on word and number recall at higher allostatic load indices whereas Hispanics performed higher on digit-span recall and word recall relative to Whites. Females performed higher on word recall but lower on digit-span recall compared to males at higher allostatic load indices.

Allostatic load, sex, race, ethnicity, and cognition

These findings are particularly important given the increasing interest in allostatic load as a predictor of risk of cognitive outcomes (D'Amico et al., 2020). Concurrently, studies have consistently shown that Blacks experience greater cognitive decline over time in both disease and normally aging populations (Gupta, 2021; Weuve et al., 2018; Zahodne et al., 2016; Zsembik & Peek, 2001). Therefore, an understanding of the markers of risk of cognitive decline such as allostatic load at earlier ages is particularly important for Black adults and allostatic load is one such promising marker. However, our findings suggest there may be variation in the relationship between allostatic load and cognitive outcomes dependent on race and ethnicity. These differences in cognition by allostatic load indices suggest that allostatic load in isolation of other sociocultural factors may not provide similar representation of cognitive risk among all racial and ethnic groups.

The second key finding of this study was females performed better on word recall but performed worse on digit-span recall at higher allostatic load indices. Regarding sex differences and cognition, women have demonstrated improved performance on verbal tasks than men similar to our findings (Nooyens et al., 2022). The explanation for worse performance in the digit-span task among females is unclear as previous work has demonstrated no gender differences on digit-span performance (Piccardi et al., 2019). A possible explanation for findings within higher allostatic load indices is that the digit-span task does not benefit from improved semantic memory skills which is a memory skill in which females demonstrate higher skills (Herlitz & Rehnman, 2008; Loprinzi & Frith, 2018). Sex differences in cognition and memory are less understood and future research is necessary to examine these differences, particularly in young adults.

Allostatic load and cognition

While a review by D'Amico et al. (2020) observed a significant effect of allostatic load on global cognition, the authors did not find a similar association between allostatic load and memory. Reasoning for the difference in our findings may be due to the variation in performance across the memory tasks. Although additional exploration is needed, the findings presented herein indicate a relationship between allostatic load and memory in adults aged 34–44 supporting previous literature demonstrating allostatic load influences on health outcomes early in the lifespan.

Our findings align with previous literature (1) showing differences in cognitive performance between racial and ethnic cohorts of young adults and (2) age-dependent variation in cognition (Zahodne et al., 2016). This growing body of literature highlights the role interventions targeting chronic stress at earlier stages of life may play on reducing cognitive decline.

Allostatic load, sex, race, and ethnicity

Aligning with previous literature allostatic load was higher among Black adults compared to their White counterparts (Moore et al., 2021; Richardson et al., 2021) and allostatic load was higher among males than females (Kerr et al., 2020). It is important to note that despite Black-White differences, we did not observe a difference in allostatic load between Hispanics and their Non-Hispanic counterparts. Richardson et al. (2021) suggest an explanation for a lack of difference in the Add Health data between Mexican Americans and Whites may be due to many participants being US-born and therefore reflect broader assimilation that translates into health outcomes that align more with White Americans rather than foreign born Hispanic populations. Sex differences in allostatic load may be partially explained by differences in relevant and significant biomarkers and systems that differ between women and men (Longpré-Poirier et al., 2022). Kerr et al. (2020) recommend gender specific analyses that include clinical cutoffs and consideration of sex-specific hormones in addition to examination of sex-gender interactions such as gender identify when examining sex-specific differences in allostatic load. Further, women show higher allostatic load variation dependent on sociodemographic and stress-related factors compared to men. In other words, allostatic load in females is primarily seen in systems associated with social factors such as the immune system whereas men demonstrate increases in systems associated with behavior risk factors such as the cardiovascular and metabolic system (Longpré-Poirier et al., 2022).

Allostatic load and intersectionality

Additionally, while females often demonstrate lower levels of allostatic load this is not retained when examining race in conjunction with sex in which Black women have been demonstrated to have higher levels of allostatic load compared to their White counterparts (Chyu & Upchurch, 2011). The "weathering" theory may partially explain higher allostatic load levels among minoritized groups. The weathering theory posited by Geronimus et al. (2006) suggests a reason for decreased health outcomes in minoritized groups is due to lifelong adversity. This is supported by increased immune response allostatic load patterns in Blacks compared to Whites (Howard & Sparks, 2016) as social adversity is associated with increased inflammation (Leschak & Eisenberger, 2019; Morey et al., 2015).

Findings from this study should be understood with the following limitations in mind. First, our allostatic load index was limited to biomarkers available in the Add Health data and does not consist of any primary mediators from the neuroendocrine system. Additionally, while we reviewed articles focusing on allostatic load markers specific to racial/ethnic minority groups (Rodriquez et al., 2019) and sex differences (Yang & Kozloski, 2011) to inform our marker cutoffs our analysis did not include different allostatic load calculations or cutoffs for different groups. Although a single index for allostatic load has been shown to be appropriate to measure allostatic load, race differences in the biological pathways that make up allostatic load suggest markers should be differentially weighted across race and ethnicity (Howard & Sparks, 2016). While biomarkers and cognition batteries were both collected from robust samples of Add Health participants, less than 700 (40%) of respondents appeared in both subsamples thereby limiting the sample eligible for this study. Additionally, Add Health contains a variety of individual, social, and environmental information on both respondents and their

https://doi.org/10.1017/S1355617724000298

families. To maintain focus on the subgroups, this information was not included in the current study. However, this we plan to explore this information in our future research. Lastly, our measures of cognition were brief cognitive recall tasks that do not span the breadth of cognition. Future research should examine allostatic load with more complex cognitive tasks.

Conclusion

We observed racial, ethnic and sex differences in allostatic load and the relationship between allostatic load and cognition in young adults. Furthermore, we saw cognitive differences that are not fully explained by differences in allostatic load suggesting that while allostatic load is a critical marker to include, analysis of racial, ethnic and sex differences in cognition must include comprehensive examination of impacting factors. There is a need for multi-pronged approach to reduce differences in cognitive impairment that examines both social determinants and physiological differences resulting from social determinants such as social and contextual factors. Persistent health disparities necessitate examination of health determinants that consist of a wide array of variables. Furthermore, clear differences in cognition in young adults suggest the benefits of early intervention. The addition of allostatic load as a determinant influencing health provides a pathway towards a target for early intervention to improve disparities in cognition throughout the lifespan.

Acknowledgements. This research uses data from ADD Health, funded by grant P01-HD31921 (Harris) from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 23 other federal agencies and foundations. ADD Health is currently directed by Robert A. Hummer and funded by the National Institute on Aging cooperative agreements U01 AG071448 (Hummer) and U01AG071450 (Aiello and Hummer) at the University of North Carolina at Chapel Hill. ADD Health was designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris at the University of North Carolina at Chapel Hill. No direct support was received from grant P01-HD31921 or cooperative agreements U01 AG071448 and U01AG071450. This work was supported in part by the US National Institutes of Health via predoctoral fellowship funding for first author under grant T32 HD043730.

Competing interests. None.

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