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Computer use and cardiovascular risk biomarkers in midlife and older adults

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ABSTRACT

With increased computer usage amongst midlife and older adults, concerns are emerging with regards to the potential adverse health effects of computer use given the sedentary habits it may encourage. The current study aims to investigate the relationship between computer use and cardiovascular risk in midlife and older adults. From the National Survey of Midlife Development in the United States II: Biomarker Project (2004–2009) and the National Survey of Midlife Development in the United States (MIDUS II), 2004–2006, we examined five cardiovascular risk biomarkers—high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, interleukin-6, and C-reactive protein—in relation to self-reported general computer use frequency and computer use at work frequency. Our results show that general computer use frequency and computer use at work frequency were not significant predictors of any of the five cardiovascular risk biomarkers—HDL cholesterol, LDL cholesterol, triglycerides, interleukin-6, and C-reactive protein. However, our exploratory analysis showed that employment status significantly moderated the relationship between general computer use frequency and LDL cholesterol. Our study highlights the importance of a more nuanced approach to understanding the health implications of computer use and sedentary behaviour in general.

1. Introduction

Digital technology, especially the regular use of computers, has profoundly shaped all facets of modern life, revolutionising the way we work, communicate, and access information (Gell et al., 2015; Graham & Dutton, 2019; Keegan, 2012; Srinivasan, 2018; Tully, 2003). While often associated with younger generations, research indicates that midlife and older adults have also begun to adopt computer use for its utility in work, communication, and leisure activities (Carpenter & Buday, 2007; Nimrod, 2020; Wagner et al., 2010). With increased computer usage, growing concerns are emerging with regards to the potential adverse health effects of widespread computer use in midlife and older adults, especially given the sedentary habits it may encourage (Fotheringham et al., 2000; Gatto & Tak, 2008; Harvey et al., 2013). This focus is particularly relevant for older adults, who often face more susceptibility to health-related issues, including cardiovascular diseases (Lakatta, 2002; Mittelmark et al., 1993; North & Sinclair, 2012).

Despite the concern regarding the adverse health implications of computer use in midlife and older adults, research findings on the relationship between computer use and health outcomes remain inconclusive. On one hand, several existing studies have shown that computer use is negatively associated with health outcomes, such as an increased risk of being overweight or obese (Aghasi et al., 2020; Vandelanotte et al., 2009), reduced levels of physical activity (Fotheringham et al., 2000), potential sleep problems when used during leisure time (Andersen & Garde, 2015), and the likelihood of experiencing eye strain (Basnet et al., 2022). On the other hand, recent studies have also reported that computer use enables individuals to engage in health-promoting activities (Stephenson et al., 2017), experience improved cognitive funtioning (Almeida et al., 2012; Kamin & Lang, 2020) and foster greater social connections that improve overall well-being (Fingerman et al., 2020; Petersen et al., 2023). Interestingly, one study found that while computer users reported higher subjective health through self-reported measures, there were no significant links between computer use and physical activity or objective health outcomes, such as body mass index and number of chronic diseases (Hartanto et al., 2020).

However, it is noteworthy that most of the existing studies focused

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on subjective health outcomes, which may contribute to the mixed findings (e.g., Fotheringham et al., 2000; Slegers et al., 2008). Thus, it is imperative to shift the focus to objective health biomarkers, which offer a more consistent and precise measure of physiological changes in individuals (Molenaar et al., 2007; Okura et al., 2004). This is particularly pertinent to cardiovascular health, the leading causes of mortality globally (Amini et al., 2021), which often manifest silently, with physiological changes developing unnoticed for years before overt symptoms emerge (Greenland et al., 2004; Soliman, 2019).

Given the mixed findings and global prominence of cardiovascular diseases (Lindstrom et al., 2022), the current study aimed to investigate the association between computer use and its health implications with cardiovascular risk biomarkers. To provide a comprehensive assessment, computer use was operationalised as both general computer use frequency and computer use at work frequency. Five well-established biomarkers linked to cardiovascular risk were included in the current study (Gilstrap & Wang, 2012; Hartanto et al., 2022, 2024; Ridker et al., 2000). The first biomarker, high-density lipoprotein (HDL) cholesterol was included due to its protective role in cardiovascular health by facilitating the removal of excess cholesterol (Kosmas et al., 2018; Trimarco et al., 2022). The second biomarker, low-density lipoprotein (LDL) cholesterol – often referred to as "bad" cholesterol due to its role in transporting cholesterol to the arteries – was included, as it promotes blood clot formation and contributes to increased cardiovascular risk (Jung et al., 2022; Pereira, 2017; Stanciulescu et al., 2023). The third biomarker, triglycerides – types of fat found in the blood that store excess energy from the diet – were included because elevated levels of triglycerides are a well-known risk factor for coronary heart disease (Assmann et al., 1998; Sarwar et al., 2007). Lastly, we also included interleukin-6, a cytokine that plays a central role in the body's immune response (Tanaka et al., 2014), and C-reactive protein, a protein produced by the liver in response to inflammation (Mouliou, 2023). Both have shown to be critical in the development and progression of cardiovascular diseases (Amezcua-Castillo et al., 2023; Feng et al., 2022; Kuppa et al., 2023; Mossmann et al., 2022). By including these specific biomarkers, this study provides a comprehensive evaluation of cardiovascular risk.

We hypothesised positive relationships between computer use and higher cardiovascular risk in midlife and older adults. This is because prolonged computer use often leads to extended periods of physical inactivity, which may contribute to sedentary behavior (Bertuol et al., 2023; Harvey et al., 2013). Sedentary behaviour has been linked to an increased risk of developing cardiovascular diseases (Bakker et al., 2021; Bezerra et al., 2023) as it promotes obesity, hypertension and insulin resistance, all of which are established risk factors for cardiovascular disease (Kim et al., 2018; Zhang et al., 2022).

2. Materials and methods

2.1. Participants

This cross-sectional study involved 1054 adults from the National Survey of Midlife Development in the United States II (MIDUS II): Biomarker Project (Ryff et al., 2010) and the National Survey of Midlife Development in the United States (MIDUS II), 2004–2006 (Ryff et al., 2021). The MIDUS II: Biomarker Project, conducted between 2004 and 2009, is a subset of a broader, long-term research initiative stemming from the original MIDUS I survey launched in 1995. To be eligible for MIDUS II, participants had to be aged 25 to 74 during the original MIDUS survey and have completed the initial MIDUS I interview (Ryff et al., 2021). For MIDUS II: Biomarker Project, participants were required to have completed the MIDUS II Project 1 Survey (Ryff et al., 2010). Within this study, participants aged 35 to 65 were classified as midlife adults, while those aged above 65 years old were categorised as older adults (Hartanto et al., 2020; Infurna et al., 2020; Kang & Kim, 2022).

In MIDUS I, researchers recruited 7108 noninstitutionalized adults through random digit sampling across all 48 contiguous states. In the context of the Biomarker Project, participants underwent an overnight stay at one of three general clinical research centres situated in the United States, which included the University of California, Los Angeles, Georgetown University, and the University of Wisconsin-Madison. A comprehensive physical examination was conducted during participants' stay, encompassing the collection of fasting blood samples before breakfast on the second day of their hospital visit (Love et al., 2010). Data collection was carried out in strict adherence to approved guidelines and regulations, receiving approval from the Health Sciences Institutional Review Boards at the University of Wisconsin-Madison (H-2008-0060). Prior to their involvement, all participants provided written informed consent. Table 1 provides a detailed breakdown of the sample's demographics and key variables. Tables 2 and 3 presents the zero-order correlation of the variables examined in this study.

2.2. Measures

2.2.1. General computer use frequency

Participants' computer use was assessed by: "*How often do you use a computer (such as to send e-mail or search the internet)*". Participants rated their frequency of involvement on a scale of 1 (*daily*) to 6 (*never*).

2.2.2. Computer use at work frequency

Participants' computer use at work frequency was assessed by: "*Please indicate how often, during your work-shift, you do each of the following. If you are not currently working, but were employed over the past*

Table 1
Participants' characteristics.

Variable	*N*	*M (SD)*	Range
Demographics			
Age	1054	58.04 (11.62)	35.00–86.00
Gender (% male)	1054	0.45 (0.50)	0.00–1.00
Race (% white)	1051	0.94 (0.24)	0.00–1.00
Education Attainment	1051	7.74 (2.45)	1.00–12.00
Income (in thousands)	1032	76.67 (60.41)	0.00–300.00
Employment Status	1052	0.52 (0.50)	0.00–2.00
Health Status and Behaviours			
Alcohol consumption (drinks per month)	1054	2.53 (1.58)	1.00–6.00
Exercise (exercise regularly)	1054	0.79 (0.41)	0.00–1.00
Smoking (current smoker)	1054	0.11 (0.32)	0.00–1.00
Hypertension	1054	0.26 (0.44)	0.00–1.00
Diabetes	1054	0.09 (0.28)	0.00–1.00
Stroke	1054	0.00 (0.07)	0.00–1.00
Antihyperlipidemic Agent Medication	1053	0.31 (0.46)	0.00–1.00
Predictors			
General computer use frequency	1048	4.62 (1.92)	1.00–6.00
Computer use at work frequency	554	3.42 (1.37)	1.00–5.00
Cardiovascular Risk Biomarkers			
HDL cholesterol (mg/dL)	1043	54.58 (17.43)	19.00–107.42
LDL cholesterol (mg/dL)	1043	106.17 (34.62)	16.00–211.77
Triglycerides (mg/mL)	1045	130.92 (78.33)	25.00–554.76
Interleukin-6 (pg/mL)	1044	2.66 (2.17)	0.16–11.15
C-reactive protein (ug/mL)	1040	2.50 (3.00)	0.03–15.55

Note. Values shown are before imputation and winsorization. Education attainment was rated on a scale of 1 (*No school*) to 12 (*PhD, EdD, MD, LLB, LLD, JD, or other professional degree*). HDL = high-density lipoprotein, LDL = low-density lipoprotein. Alcohol consumption was measured based on participants' frequency of drinking in the past month (1 = *Never drinks,* 6 = *Everyday*). Smoking habits was measured based on whether participants currently smoked regularly (0 = *No,* 1 = *Yes*). Exercise frequency was measured based on whether they engaged in regular exercise, or activity, for at least 20 min, three times per week (0 = *No,* 1 = *Yes*). Only participants who were employed at the time of the study were included in the descriptive analyses related to computer use at work frequency.

Table 2
Correlation matrix of the study variables for the main sample (N = 1054).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. General computer use frequency																			
2. HDL Cholesterol	0.02																		
3. LDL Cholesterol	−0.03	−0.11[b]																	
4. Triglycerides	−0.07[a]	−0.50[b]	0.16[b]																
5. Interleukin-6	−0.13[b]	−0.14[b]	−0.07[a]	0.13[b]															
6. C-reactive Protein	−0.01	−0.11[b]	0.05	0.10[a]	0.47[b]														
7. Age	−0.23[b]	0.06[a]	−0.14[b]	−0.04	0.20[b]	−0.01													
8. Gender (% Male)	−0.04	−0.41[b]	−0.03	0.21[b]	−0.03	−0.15[b]	0.05												
9. Race (% White)	0.05	−0.01	−0.03	0.04	0.01	0.00	0.11[b]	−0.01											
10. Education Attainment	0.34[b]	0.03	−0.07[a]	−0.07[a]	−0.10[a]	−0.09[a]	−0.07[a]	0.09[a]	0.04										
11. Income (in thousands)	0.26[b]	−0.03	−0.07[a]	−0.07[a]	−0.10[a]	−0.05	−0.22[b]	0.08[a]	0.04	0.28[b]									
12. Employment status	0.19[b]	−0.03	0.06[a]	−0.03	−0.13[b]	−0.02	−0.42[b]	0.05	−0.06	0.15[b]	0.22[b]								
13. Alcohol consumption	0.10[a]	0.18[b]	−0.03	−0.01	−0.06	−0.08[a]	0.07*	0.18[b]	0.03	0.11[b]	0.13[b]	0.02							
14. Exercise	0.07[a]	0.11[b]	0.01	−0.11[b]	−0.15[b]	−0.17[b]	−0.05	−0.01	0.07[a]	0.09[a]	0.06	0.04	0.04						
15. Smoking	−0.09[a]	−0.12[b]	0.10[a]	0.05	0.04	0.04	−0.13[b]	0.01	−0.02	−0.15[b]	−0.08[a]	0.00	−0.03	−0.06[a]					
16. Hypertension	−0.11[b]	−0.10[b]	−0.10[a]	0.14[b]	0.21[b]	0.13[b]	0.22[b]	0.01	0.01	−0.03	−0.06[a]	−0.12[b]	0.04	−0.05	−0.03				
17. Diabetes	−0.09[a]	−0.10[b]	−0.12[b]	0.12[b]	0.11[b]	0.10[a]	0.09[a]	0.05	0.00	−0.03	−0.03	−0.10[a]	−0.11[b]	−0.08[a]	−0.02	0.22[b]			
18. Stroke	−0.01	−0.02	−0.05	0.03	0.08[a]	0.08[a]	0.05	0.02	0.02	0.02	0.07[a]	−0.05	−0.01	0.00	0.02	0.09[a]	0.08[a]		
19. Antihyperlipidemic Agent Medication	0.00	−0.11[b]	−0.36[b]	0.05	0.11[b]	−0.03	0.30[b]	0.14[b]	0.04	−0.01	0.03	−0.12[b]	0.07[a]	−0.04	−0.05	0.23[b]	0.16[b]	0.04	

Note.
HDL = high-density lipoprotein, LDL = low-density lipoprotein. Education attainment was rated on a scale of 1 (*No school*) to 12 (*PhD, EdD, MD, LLB, LLD, JD, or other professional degree*). Alcohol consumption was measured based on participants' frequency of drinking in the past month (1 = *Never drinks,* 6 = *Everyday*). Smoking habits was measured based on whether participants currently smoked regularly (0 = *No,* 1 = *Yes*). Exercise frequency was measured based on whether they engaged in regular exercise, or activity, for at least 20 min, three times per week (0 = *No,* 1 = *Yes*).

[a] $p < .05$.

[b] $p < .001$.

10 years, please tell us about your most recent job – How often does your job require you to work on a computer?". Participants rated their frequency of computer use at work frequency on a scale of 1 (*All of the time)* to 5 (*Never)*.

2.2.3. Serum lipid

Enzymatic colorimetric assays were used to determine total cholesterol, HDL cholesterol and triglyceride levels. The inter-assay and intra-assay coefficients of variability for total cholesterol were 2.65% and 0.51–0.81%. while for HDL cholesterol, it is 6.52% and 1.1–1.4%. As for the triglycerides levels, the inter-assay and intra-assay coefficient of variability were 1.01% and 1.6%. Low-density was estimated using the Friedewald formula (Friedewald et al., 1972). Triglycerides levels above 400 mg/dl were replaced with 400 mg/dl to calculate LDL cholesterol levels. Lastly, the inter-assay coefficient of variability for LDL cholesterol was 10.11%. Higher levels of HDL cholesterol indicates lower levels of cardiovascular risk (Kosmas et al., 2018; Trimarco et al., 2022), while higher levels of LDL cholesterol and triglycerides levels indicates higher levels of cardiovascular risk (Aberra et al., 2020; Harchaoui et al., 2009; Jung et al., 2022; Stanciulescu et al., 2023).

2.2.4. C-reactive protein

BNII nephelometer (N Antiserum to Human Fibrinogen; Dade Behring, Inc., Deerfield, IL) was used to measure C-reactive protein with a particle-enhanced immunonepholometric assay range of 0.175–1100 μg/mL (reference range <3 μg/ml). Samples falling below the assay range for CRP by this method were re-assayed by immunoelectrochemiluminescence using a high-sensitivity assay kit (Meso Scale Diagnostics #K151STG). The laboratory intra- and inter-assay coefficients of variance for CRP were in acceptable ranges, with the ranges of the intra-assay variance coefficient between 2.3% and 4.4% and the interassay variance between 2.1% and 5.7%. Higher levels of C-reactive protein indicates higher levels of cardiovascular risk (Amezcua-Castillo et al., 2023; Kuppa et al., 2023).

2.2.5. Interleukin-6

Interleukin-6 was measured using the Quantikine® High-sensitivity enzyme-linked immunosorbent assay (ELISA) kit #HS600B (R&D Systems, Minneapolis, MN), with an assay range of 0.156–10 pg/mL. All samples were tested in duplicate. The laboratory intra-assay and inter-assay coefficients of variance for interleukin-6 were 3.25% and 12.31%, respectively. The reference range spanned from 0.45 to 9.96 pg/mL. Higher levels of interleukin-6 indicates higher levels of cardiovascular risk (Feng et al., 2022; Mossmann et al., 2022).

2.2.6. Demographics

Age, education, income were mean-centered while gender, race, employment status were dichotomized (gender: 0 = *Female,* 1 = *Male*; race: 0 = *White,* 1 = *Non-white;* employment status: 0 = *Employed,* 1 = *Unemployed*).

2.2.7. Health status and related behaviours

Health status and behaviours of participants was measured through a series of questions. Hypertension, diabetes, stroke history were evaluated and coded by asking participants whether they had experienced or been treated for these conditions in the past twelve months (0 = *No,* 1 = *Yes*). Smoking habits of participants were evaluated and coded by asking participants whether participants currently smoked cigarettes regularly (0 = *No,* 1 = *Yes*). Alcohol consumption was measured and coded based on the participants' frequency of drinking in the past month (1 = *Never drinks,* 6 = *Everyday*). Exercise frequency was measured and coded by asking participants on whether they engaged in regular exercise, or activity, for at least 20 min, three times per week (0 = *No,* 1 = *Yes*). Lastly, participants' use of antihyperlipidmeric agent medication was measured and coded based on whether any type of antihyperlipidmerdic agent medication was used such as HMG-CoA reductase inhibitor, fibric

Table 3
Correlation matrix of the study variables for the employed-only sample (N = 573).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Computer use at work frequency	−0.02																	
2. HDL Cholesterol	0.00	−0.15[b]																
3. LDL Cholesterol	−0.02	−0.51[b]	0.24[b]															
4. Triglycerides	−0.04	−0.13[a]	−0.08	0.06														
5. Interleukin-6	0.04	−0.08	0.06	0.06	0.47													
6. C-reactive Protein	−0.12[a]	0.12[a]	−0.13[a]	−0.07	0.13[a]	−0.04												
7. Age	−0.09[a]	−0.41[a]	0.05	0.27	−0.04	−0.22[b]	−0.03											
8. Gender (% Male)	−0.05	−0.02	0.01	0.05	−0.02	−0.04	0.09[a]	−0.02										
9. Race (% White)	0.24[b]	0.03	−0.05	−0.03	−0.06	−0.09[a]	−0.06	0.00	0.06									
10. Education Attainment	0.23[b]	−0.06	−0.07	−0.03	−0.04	−0.03[a]	−0.07	0.09[a]	0.05	0.28[b]								
11. Income (in thousands)	0.04	0.18[b]	−0.01	0.01	−0.09[a]	−0.15[b]	0.07	0.21[b]	0.04	0.06	0.15[b]							
12. Alcohol consumption	0.04	0.10[a]	0.03	−0.05	−0.18	−0.17[b]	−0.03	0.01	0.08	0.10[a]	0.07	0.02						
13. Exercise	−0.15[b]	−0.12[a]	0.11[a]	0.07	0.03	0.01	−0.07	0.08	−0.04	−0.11[a]	−0.08	0.00	−0.08					
14. Smoking	0.02	−0.06	−0.09[a]	0.08[a]	0.14	0.07	0.23[b]	−0.04	−0.02	−0.03	−0.03	0.02	0.00	−0.07				
15. Hypertension	0.00	−0.07	−0.11[a]	0.02	0.11[a]	0.14[a]	0.06	0.00	−0.01	−0.02	0.01	−0.07	−0.13[a]	0.02	0.24[b]			
16. Diabetes	0.02	0.06	0.02	0.00	−0.01	0.06	0.05	−0.04	0.01	−0.04	0.01	0.01	0.02	−0.01	0.08	−0.01		
17. Stroke	0.04	0.13[a]	−0.30[b]	0.01	0.13[a]	−0.04	0.34[b]	0.08[a]	0.00	−0.01	0.06	0.05	−0.05	−0.05	0.23[b]	0.18[b]	−0.02	
18. Antihyperlipidemic Agent Medication																		

Note.
HDL = high-density lipoprotein, LDL = low-density lipoprotein. Education attainment was rated on a scale of 1 (*No school)* to 12 (*PhD, EdD, MD, LLB, LLD, JD, or other professional degree)*. Alcohol consumption was measured based on participants' frequency of drinking in the past month (1 = *Never drinks,* 6 = *Everyday)*. Smoking habits was measured based on whether participants currently smoked regularly (0 = *No,* 1 = *Yes*). Exercise frequency was measured based on whether they engaged in regular exercise, or activity, for at least 20 min, three times per week (0 = *No,* 1 = *Yes*).
[a] $p < .05$.
[b] $p < .001$.

Table 4
Standardized regression coefficients of general computer use frequency on cardiovascular risk biomarkers.

	HDL Cholesterol				LDL Cholesterol				Triglycerides				Interleukin-6				C-reactive Protein			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	β	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*
Predictor																				
General Computer Use Frequency	−0.00	−0.00 (0.28)	−0.03	−0.32 (0.27)	−0.04	−0.67 (0.61)	−0.01	−0.20 (0.58)	−0.04	−1.46 (1.35)	−0.02	−0.73 (1.34)	−0.06	−0.07 (0.04)	−0.04	−0.04 (0.04)	0.01	0.02 (0.05)	0.04	0.06 (0.05)
Covariates																				
Age	0.10	0.16 (0.05)[a]	0.11	0.16 (0.05)[a]	−0.17	−0.49 (0.01)[b]	−0.04	−0.12 (0.10)	−0.10	−0.69 (0.23)[a]	−0.13	−0.90 (0.24)[b]	0.17	0.03 (0.01)[b]	0.13	0.02 (0.01)[b]	−0.01	−0.00 (0.01)	−0.02	−0.01 (0.01)
Gender (% Male)	−0.42	−14.81 (0.99)[b]	−0.45	−15.82 (0.96)[b]	−0.01	−0.70 (2.14)	0.03	2.29 (2.06)	0.22	35.33 (4.77)[b]	0.22	34.73 (4.81)[b]	−0.03	−0.15 (0.13)	−0.04	−0.16 (0.13)	−0.14	−0.82 (0.19)[b]	−0.13	−0.79 (0.19)[b]
Race (% White)	−0.02	−1.55 (2.05)	−0.03	−2.22 (1.94)	−0.00	−0.68 (4.41)	−0.01	−1.05 (4.17)	0.06	18.30 (9.85)	0.06	21.11 (9.70)*	−0.00	−0.04 (0.28)	0.01	0.05 (0.27)	0.00	0.02 (0.38)	0.01	0.18 (0.37)
Education Attainment	0.07	0.53 (0.22)[a]	0.05	0.33 (0.21)	−0.05	−0.65 (0.47)	−0.05	−0.76 (0.45)	−0.06	−1.92 (1.05)	−0.05	−1.67 (1.04)	−0.05	−0.05 (0.03)	−0.04	−0.03 (0.03)	−0.08	−0.10 (0.04)[a]	−0.07	−0.09 (0.04)[a]
Income	0.00	0.00 (0.01)	−0.02	−0.01 (0.01)	−0.09	−0.05 (0.02)[a]	−0.05	−0.03 (0.02)	−0.07	−0.10 (0.04)[a]	−0.07	−0.09 (0.04)[a]	−0.03	−0.00 (0.00)	−0.02	−0.00 (0.00)	−0.02	−0.00 (0.00)	−0.01	−0.00 (0.00)
Employment Status	0.02	0.76 (1.10)	0.01	0.30 (1.04)	0.03	1.74 (2.37)	0.01	1.00 (2.24)	−0.05	−7.63 (5.29)	−0.04	−5.73 (5.22)	−0.03	−0.12 (0.15)	−0.01	−0.06 (0.14)	−0.01	−0.04 (0.21)	0.01	0.04 (0.20)
Alcohol Consumption			0.25	2.80 (0.30)[b]			−0.00	−0.10 (0.65)			−0.02	−1.04 (1.52)			−0.05	−0.06 (0.04)			−0.04	−0.07 (0.06)
Exercise frequency			0.09	3.91 (1.14)[b]			0.00	0.38 (2.45)			−0.09	−17.13 (5.71)[a]			−0.12	−0.66 (0.16)[b]			−0.15	−1.13 (0.22)[b]
Smoking			−0.09	−4.89 (1.49)[a]			0.06	6.81 (3.20)[a]			0.02	4.84 (7.46)			0.04	0.28 (0.21)			0.02	0.20 (0.30)
Hypertension			−0.11	−4.42 (1.13)[b]			0.01	0.46 (2.42)			0.13	24.09 (5.63)[b]			0.15	0.74 (0.16)[b]			0.12	0.83 (0.22)[b]
Diabetes			−0.02	−1.54 (1.70)			−0.06	−7.40 (3.66)[a]			0.07	18.56 (8.52)[a]			0.04	0.32 (0.24)			0.07	0.74 (0.33)[a]
Stroke			−0.00	−0.64 (6.77)			−0.03	−14.99 (14.54)			0.02	23.12 (33.88)			0.06	1.75 (0.94)			0.07	3.03 (1.31)[a]
Antihyperlipidemic Agent Medication			−0.07	−2.50 (1.09)[a]			−0.34	−25.46 (2.33)[b]			0.01	2.44 (5.44)			0.03	0.16 (0.15)			−0.05	−0.32 (0.21)

Note. β = standardized regression coefficient.
Demographics controlled in Model 1. Demographics and health-related behaviours controlled in Model 2. Alcohol consumption was measured based on participants' frequency of drinking in the past month (1 = *Never drinks*, 6 = *Everyday*). Smoking habits was measured based on whether participants currently smoked regularly (0 = *No*, 1 = *Yes*). Exercise frequency was measured based on whether they engaged in regular exercise, or activity, for at least 20 min, three times per week (0 = *No*, 1 = *Yes*). HDL = high-density lipoprotein, LDL = low-density lipoprotein.
[a] $p < .05$.
[b] $p < .001$.

Fig. 1. Forest Plot of General Computer Use Frequency on Cardiovascular Risk Biomarkers
Note. Position of each square indicates the effect size contributed by the cardiovascular risk biomarker on general computer use frequency. Size of each square indicates sample size. Whiskers indicate 95% confidence intervals.

acid derivatives, bile acid sequestrants, cholesterol absorption inhibitors (0 = *No,* 1 = *Yes*).

2.3. Data analysis

The primary aim of the current study was to investigate the relationship between general computer use frequency, computer use at work frequency and cardiovascular risk biomarkers, specifically HDL cholesterol, LDL cholesterol, triglycerides, interleukin-6, and C-reactive protein. The predictor variables were taken from the National Survey of Midlife Development in the United States (MIDUS II), 2004–2006 (Ryff et al., 2021) while the cardiovascular risk biomarkers were taken from the National Survey of Midlife Development in the United States II (MIDUS II): Biomarker Project (Ryff et al., 2010). We employed ordinary least squares regression to examine this association, using general computer use frequency and computer use at work frequency as the predictor variables. The full dataset was used to analyse the relationship between general computer use frequency and cardiovascular risk biomarkers ($N = 1054$) while the dataset used to analyse the relationship between computer use at work frequency and cardiovascular risk biomarkers only included participants who were employed at the time of the study ($N = 573$). Two models were estimated for each cardiovascular risk biomarker. In the first model, we controlled for demographic variables including age, gender, education level, household income, race, and employment status which have previously shown associations with cardiovascular risk in existing research (Carson et al., 2009; Hartanto et al., 2021; Hoeymans et al., 1996; Li et al., 2016; Roth et al., 2015; Strand & Tverdal, 2004; Walsemann et al., 2016). However, for the analysis of the relationship between computer use at work and cardiovascular risk biomarkers, employment status was not included as a covariate given that all the participants were employed. The second model included additional controls for health-related variables and behaviours known to impact cardiovascular health, such as smoking status, alcohol consumption, regular exercise frequency, and the use of anti-hyperlipidemic medications (Gastaldelli et al., 2010; Loprinzi et al., 2016; Mozaffarian et al., 2008). Additionally, an exploratory moderation analysis was conducted to examine whether age and employment status could moderate the relationship between general computer use frequency and cardiovascular risk biomarkers. An exploratory mediation analysis was also carried out to determine whether exercise frequency could mediate the relationship between general computer use frequency, computer use at work frequency and cardiovascular risk biomarkers. Specifically, we were interested in the indirect effect of general computer use frequency, computer use at work frequency on cardiovascular risk biomarkers through exercise frequency. To mitigate the influence of extreme outliers, cardiovascular risk biomarker indices underwent winsorization to three standard deviations. Any missing values, accounting for less than 0.54% on any variable, were imputed using the expectation-maximisation (EM) algorithm. All analyses were conducted in R version 4.3.1 (R Core Team, 2023). Descriptive statistics was computed via *psych* version 2.4.6 (Revelle, 2021). The main analyses and exploratory moderation analysis was conducted with *lme4* version 1.1–35.1 (Bates et al., 2015) while the exploratory moderation analysis was conducted with mediation analysis was conducted with *lavaan* version 0.6–17 (Rosseel, 2012). Visualisations was created with *metafor* version 4.6.0 (Viechtbauer, 2010).

3. Results

3.1. Main analyses

3.1.1. General computer use frequency

After controlling for demographics in Model 1, as seen in Table 4 and Fig. 1, we found that there was no significant relationship between general computer use frequency and HDL cholesterol ($\beta = -0.00$, $b = -0.00$, $SE = 0.28$, 95% CI = [−0.56, 0.55], $p = .987$), LDL cholesterol ($\beta = -0.04$, $b = -0.67$, $SE = 0.61$, 95% CI = [−1.86, 0.52], $p = .267$), triglycerides ($\beta = -0.04$, $b = -1.46$, $SE = 1.35$, 95% CI = [−4.11, 1.19], $p = .279$), interleukin-6 ($\beta = -0.06$, $b = -0.07$, $SE = 0.04$, 95% CI = [−0.14, 0.01], $p = .071$) and C-reactive protein ($\beta = 0.01$, $b = 0.02$, $SE = 0.05$, 95% CI = [−0.08, 0.12], $p = .695$).

After controlling for demographics and health-related behaviours in Model 2, as seen in Table 4 and Fig. 1, we found that there was no significant relationship between general computer use frequency and HDL cholesterol ($\beta = -0.03$, $b = -0.32$, $SE = 0.27$, 95% CI = [−0.84, 0.21], $p = .240$), LDL cholesterol ($\beta = -0.01$, $b = -0.20$, $SE = 0.58$, 95% CI = [−1.33, 0.93], $p = .729$), triglycerides ($\beta = -0.02$, $b = -0.73$, $SE = 1.34$, 95% CI = [−3.36, 1.91], $p = .589$), interleukin-6 ($\beta = -0.04$, $b = -0.04$, $SE = 0.04$, 95% CI = [−0.12, 0.03], $p = .233$) and C-reactive protein ($\beta = 0.04$, $b = 0.06$, $SE = 0.05$, 95% CI = [−0.04, 0.16], $p = .234$).

3.1.2. Computer use at work frequency

After controlling for demographics in Model 1, as seen in Table 5 and Fig. 2, we found that there was no significant relationship between computer use at work frequency and HDL cholesterol ($\beta = -0.06$, $b = -0.74$, $SE = 0.50$, 95% CI = [−1.72, 0.25], $p = .143$), LDL cholesterol ($\beta = 0.02$, $b = 0.43$, $SE = 1.06$, 95% CI = [−1.66, 2.52], $p = .688$), triglycerides ($\beta = 0.02$, $b = 1.00$, $SE = 2.35$, 95% CI = [−3.61, 5.62], $p = .670$), interleukin-6 ($\beta = -0.01$, $b = -0.02$, $SE = 0.06$, 95% CI = [−0.14, 0.10], $p = .750$) and C-reactive protein ($\beta = 0.03$, $b = 0.07$, $SE = 0.09$, 95% CI = [−0.11, 0.26], $p = .427$).

After controlling for demographics and health-related behaviours in Model 2, as seen in Table 5 and Fig. 2, we found that there was no significant relationship between computer use at work frequency and HDL cholesterol ($\beta = -0.07$, $b = -0.89$, $SE = 0.47$, 95% CI = [−1.82, 0.04], $p = .061$), LDL cholesterol ($\beta = 0.05$, $b = 1.32$, $SE = 1.03$, 95% CI = [−0.72, 3.35], $p = .204$), triglycerides ($\beta = 0.02$, $b = 1.18$, $SE = 2.37$, 95% CI = [−3.48, 5.84], $p = .619$), interleukin-6 ($\beta = -0.01$, $b = -0.02$, $SE = 0.06$, 95% CI = [−0.14, 0.10], $p = .737$) and C-reactive protein ($\beta = 0.04$, $b = 0.09$, $SE = 0.09$, 95% CI = [−0.09, 0.27], $p = .344$).

Table 5
Standardized Regression Coefficients of Computer Use at Work Frequency on Cardiovascular risk Biomarkers.

	HDL Cholesterol				LDL Cholesterol				Triglycerides				Interleukin-6				C-reactive Protein			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	β	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*	*β*	*b (SE)*
Predictor																				
Computer Use at Work Frequency	−0.06	−0.74 (0.50)	−0.07	−0.89 (0.47)	0.02	0.43 (1.06)	0.05	1.32 (1.03)	0.02	1.00 (2.35)	0.02	1.18 (2.37)	−0.01	−0.02 (0.06)	−0.01	−0.02 (0.06)	0.03	0.07 (0.09)	0.04	0.09 (0.09)
Covariates																				
Age	0.10	0.19 (0.07) [a]	0.14	0.25 (0.07) [b]	−0.13	−0.48 (0.15) [a]	−0.02	−0.07 (0.16)	−0.07	−0.59 (0.34)	−0.09	−0.75 (0.37) [a]	0.12	0.03 (0.01) [a]	0.08	0.02 (0.01)	−0.04	−0.01 (0.01)	−0.04	−0.01 (0.01)
Gender (% Male)	−0.41	−14.19 (1.32) [b]	−0.45	−15.61 (1.26) [b]	0.06	3.75 (2.79)	0.08	5.30 (2.76)	0.28	42.04 (6.17) [b]	0.29	43.29 (6.33) [b]	−0.04	−0.15 (0.16)	−0.03	−0.11 (0.16)	−0.22	−1.30 (0.25) [b]	−0.19	−1.14 (0.25) [b]
Race (% White)	−0.04	−2.63 (2.49)	−0.07	−4.28 (2.33)	0.03	3.43 (5.28)	−0.02	2.59 (5.09)	0.07	20.28 (11.66)	0.08	23.26 (11.67) [a]	−0.03	−0.19 (0.30)	−0.00	−0.03 (0.30)	−0.03	−0.33 (0.46)	−0.01	−0.15 (0.46)
Education Attainment	0.06	0.40 (0.29) [a]	0.03	0.22 (0.27)	−0.05	−0.62 (0.61)	−0.05	−0.68 (0.58)	−0.02	−0.68 (1.34)	−0.01	−0.32 (1.34)	−0.05	−0.04 (0.03)	−0.02	−0.02 (0.03)	−0.10	−0.13 (0.05) [a]	−0.08	−0.10 (0.05) [a]
Income	−0.01	−0.00 (0.01)	−0.05	−0.01 (0.01)	−0.08	−0.04 (0.02)	−0.05	−0.03 (0.02)	−0.06	−0.08 (0.05)	−0.05	−0.07 (0.05)	−0.01	−0.00 (0.00)	0.01	0.00 (0.00)	0.00	0.00 (0.00)	0.02	0.00 (0.00)
Alcohol Consumption			0.28	3.17 (0.41) [b]			−0.01	−0.12 (0.90)			−0.04	−1.76 (2.06)			−0.09	−0.11 (0.05) [a]			−0.09	−0.18 (0.08) [a]
Exercise			0.10	4.26 (1.56) [a]			0.01	1.18 (3.41)			−0.05	−9.46 (7.82)			−0.16	−0.75 (0.20) [b]			−0.15	−1.12 (0.31) [b]
Smoking			−0.10	−5.37 (1.96) [a]			0.09	9.41 (4.28) [a]			0.05	12.4 (9.80)			0.04	0.21 (0.25)			0.01	0.13 (0.38)
Hypertension			−0.10	−4.09 (1.60) [a]			0.00	0.02 (3.50)			0.12	22.8 (8.04) [a]			0.11	0.49 (0.20) [a]			0.06	0.43 (0.31)
Diabetes			0.01	0.48 (2.62)			−0.06	−8.00 (5.73)			−0.01	−2.61 (13.15)			0.04	0.32 (0.33)			0.11	1.30 (0.51) [a]
Stroke			0.04	14.41 (14.60)			0.01	9.77 (31.91)			0.01	13.49 (73.19)			−0.02	−0.95 (1.85)			0.05	3.29 (2.86)
Antihyperlipidemic Agent Medication			−0.12	−4.72 (1.52) [a]			−0.29	−21.86 (3.33) [b]			−0.01	−0.99 (7.63)			0.07	0.29 (0.19)			−0.05	−0.33 (0.30)

Note. β = standardized regression coefficient.
Demographics controlled in Model 1. Demographics and health-related behaviours controlled in Model 2. Alcohol consumption was measured based on participants' frequency of drinking in the past month (1 = *Never drinks,* 6 = *Everyday*). Smoking habits was measured based on whether participants currently smoked regularly (0 = *No,* 1 = *Yes*). Exercise frequency was measured based on whether they engaged in regular exercise, or activity, for at least 20 min, three times per week (0 = *No,* 1 = *Yes*). HDL = high-density lipoprotein, LDL = low-density lipoprotein.
[a] $p < .05$.
[b] $p < .001$.

Fig. 2. Forest Plot of Computer Use at Work Frequency on Cardiovascular Risk Biomarkers
Note. Position of each square indicates the effect size contributed by the cardiovascular risk biomarker on computer use at work frequency. Size of each square indicates sample size. Whiskers indicate 95% confidence intervals.

3.2. Exploratory moderation analysis

3.2.1. General computer use frequency

Age. In Model 1, we found that age did not moderate the relationship between general computer use frequency and HDL cholesterol ($\beta = 0.01$, $b = 0.01$, $SE = 0.02$, 95% CI = [−0.04, 0.05], $p = .783$), LDL cholesterol ($\beta = -0.03$, $b = -0.05$, $SE = 0.05$, 95% CI = [−0.14, 0.05], $p = .315$), triglycerides ($\beta = 0.00$, $b = 0.01$, $SE = 0.11$, 95% CI = [−0.21, 0.22], $p = .942$), interleukin-6 ($\beta = -0.03$, $b = -0.00$, $SE = 0.00$, 95% CI = [−0.01, 0.00], $p = .322$) and C-reactive protein ($\beta = 0.00$, $b = 0.00$, $SE = 0.00$, 95% CI = [−0.01, 0.01], $p = .878$). Similarly, in Model 2, we found that age was not a significant moderator in the relationship between general computer use frequency and HDL cholesterol ($\beta = 0.02$, $b = 0.01$, $SE = 0.02$, 95% CI = [−0.03, 0.06], $p = .540$), LDL cholesterol ($\beta = -0.02$, $b = -0.04$, $SE = 0.05$, 95% CI = [−0.13, 0.05], $p = .428$), triglycerides ($\beta = 0.01$, $b = 0.03$, $SE = 0.11$, 95% CI = [−0.19, 0.25], $p = .780$), interleukin-6 ($\beta = -0.03$, $b = -0.00$, $SE = 0.00$, 95% CI = [−0.01, 0.00], $p = .399$) and C-reactive protein ($\beta = -0.01$, $b = -0.00$, $SE = 0.00$, 95% CI = [−0.01, 0.01], $p = .772$).

Employment Status. In Model 1, we found that employment status did not significantly moderate the relationship between general computer use frequency and HDL cholesterol ($\beta = -0.04$, $b = -0.68$, $SE = 0.57$, 95% CI = [−1.80, 0.44], $p = .233$), triglycerides ($\beta = 0.06$, $b = 5.15$, $SE = 2.73$, 95% CI = [−0.20, 10.50], $p = .059$), interleukin-6 ($\beta = 0.01$, $b = 0.03$, $SE = 0.08$, 95% CI = [−0.12, 0.18], $p = .698$) and C-reactive protein ($\beta = -0.03$, $b = -0.10$, $SE = 0.11$, 95% CI = [−0.31, 0.11], $p = .357$). Similar to Model 1, in Model 2, employment status was not a significant moderator in the relationship between general computer use frequency and HDL cholesterol ($\beta = -0.04$, $b = -0.79$, $SE = 0.54$, 95% CI = [−1.85, 0.28], $p = .148$), triglycerides ($\beta = 0.06$, $b = 4.90$, $SE = 2.71$, 95% CI = [−0.42, 10.22], $p = .071$), interleukin-6 ($\beta = 0.01$, $b = 0.02$, $SE = 0.08$, 95% CI = [−0.13, 0.17], $p = .775$) and C-reactive protein ($\beta = -0.03$, $b = -0.11$, $SE = 0.10$, 95% CI = [−0.31, 0.10], $p = .309$).

However, in Model 1, employment status significantly moderated between general computer use frequency and LDL cholesterol ($\beta = 0.09$, $b = 3.09$, $SE = 1.22$, 95% CI = [0.69, 5.48], $p = .012$). Similarly, in Model 2, employment status was a significant moderator between general computer use frequency and LDL cholesterol ($\beta = 0.08$, $b = 2.71$, $SE = 1.17$, 95% CI = [0.42, 5.00], $p = .021$). The simple slope analysis indicated that for unemployed participants, there was no significant relationship between general computer use frequency and LDL cholesterol ($b = -1.15$, $SE = 0.73$, $p = .120$). For employed participants, there was also no significant relationship between general computer use frequency and LDL cholesterol ($b = 1.55$, $SE = 0.92$, $p = .090$). Nevertheless, the correlation between general computer use frequency and LDL cholesterol became positive for participants who are employed.

3.2.2. Computer use at work frequency

Age. In Model 1, we found that age did not significantly moderate the relationship between computer use at work frequency and HDL cholesterol ($\beta = 0.01$, $b = 0.01$, $SE = 0.05$, 95% CI = [−0.09, 0.11], $p = .774$), LDL cholesterol ($\beta = -0.02$, $b = -0.06$, $SE = 0.11$, 95% CI = [−0.27, 0.15], $p = .594$), triglycerides ($\beta = 0.03$, $b = 0.18$, $SE = 0.24$, 95% CI = [−0.28, 0.65], $p = .440$), interleukin-6 ($\beta = 0.00$, $b = 0.00$, $SE = 0.01$, 95% CI = [−0.01, 0.02], $p = .531$) and C-reactive protein ($\beta = -0.00$, $b = -0.00$, $SE = 0.01$, 95% CI = [−0.02, 0.02], $p = .957$). Similarly, in Model 2, we found that age did not significantly moderate the relationship between computer use at work frequency HDL cholesterol ($\beta = 0.01$, $b = 0.02$, $SE = 0.05$, 95% CI = [−0.08, 0.11], $p = .726$), LDL cholesterol ($\beta = -0.02$, $b = -0.04$, $SE = 0.11$, 95% CI = [−0.25, 0.16], $p = .679$), triglycerides ($\beta = 0.03$, $b = 0.17$, $SE = 0.24$, 95% CI = [−0.30, 0.65], $p = .481$), interleukin-6 ($\beta = 0.03$, $b = 0.01$, $SE = 0.01$, 95% CI = [−0.01, 0.02], $p = .398$) and C-reactive protein ($\beta = -0.00$, $b = -0.00$, $SE = 0.01$, 95% CI = [−0.02, 0.02], $p = .908$).

3.3. Exploratory mediation analysis

An exploratory mediation analysis was conducted with cardiovascular risk biomarkers as the outcome variable, general computer use frequency and computer use at work frequency as predictor variables and exercise frequency as the mediator. Demographics such as age and gender were controlled in Model 1, while both demographics and health-related behaviours such as hypertension and diabetes were controlled for in Model 2. The bias-corrected resampling method (1000 sample) showed that exercise frequency was not a significant mediator between general computer use frequency and any of the cardiovascular risk biomarkers. Exercise frequency was also not a significant mediator between computer use at work frequency and any of the cardiovascular risk biomarkers.

3.3.1. General computer use frequency

In Model 1, exercise frequency was not a significant mediator between general computer use frequency and HDL cholesterol ($\beta = 0.00$, $b = 0.03$, $SE = 0.04$, 95% CI = [−0.04, 0.09], $p = .461$), LDL cholesterol ($\beta = 0.00$, $b = 0.01$, $SE = 0.02$, 95% CI = [−0.03, 0.04], $p = .696$), triglycerides ($\beta = -0.00$, $b = -0.10$, $SE = 0.14$, 95% CI = [−0.38, 0.17], $p = .464$), interleukin-6 ($\beta = -0.00$, $b = -0.00$, $SE = 0.01$, 95% CI = [−0.01, 0.01], $p = .459$) and C-reactive protein ($\beta = -0.00$, $b = -0.01$, $SE = 0.01$, 95% CI = [−0.02, 0.01], $p = .457$). In Model 2, exercise frequency was also not a significant mediator between general computer use frequency and HDL cholesterol ($\beta = 0.00$, $b = 0.01$, $SE = 0.03$, 95% CI = [−0.04, 0.07], $p = .668$), LDL cholesterol ($\beta = 0.00$, $b = 0.00$, $SE = 0.01$, 95% CI = [−0.02, 0.02], $p = .882$), triglycerides ($\beta = -0.00$, $b = -0.05$, $SE = 0.13$, 95% CI = [−0.30, 0.19], $p = .669$), interleukin-6 ($\beta = -0.00$, $b = -0.00$, $SE = 0.01$, 95% CI = [−0.01, 0.01], $p = .668$) and C-reactive Protein ($\beta = -0.00$, $b = -0.00$, $SE = 0.01$, 95% CI = [−0.02, 0.01], $p = .667$).

3.3.2. Computer use at work frequency

In Model 1, exercise frequency was not a significant mediator between computer use at work frequency and HDL cholesterol ($\beta = 0.00$, b

= 0.02, SE = 0.06, 95% CI = [−0.10, 0.14], p = .770), LDL cholesterol (β = 0.00, b = 0.01, SE = 0.04, 95% CI = [−0.06, 0.08], p = .785), triglycerides (β = −0.00, b = −0.04, SE = 0.12, 95% CI = [−0.28, 0.21], p = .775), interleukin-6 (β = −0.00, b = −0.00, SE = 0.01, 95% CI = [−0.02, 0.02], p = .770) and C-reactive protein (β = −0.00, b = −0.00, SE = 0.02, 95% CI = [−0.03, 0.03], p = .770). In Model 2, exercise frequency was also not a significant mediator between computer use at work frequency and HDL cholesterol (β = 0.00, b = 0.01, SE = 0.05, 95% CI = [−0.10, 0.12], p = .865), LDL cholesterol (β = 0.00, b = 0.00, SE = 0.02, 95% CI = [−0.03, 0.04], p = .878), triglycerides (β = −0.00, b = −0.02, SE = 0.12, 95% CI = [−0.26, 0.22], p = .866), interleukin-6 (β = −0.00, b = −0.00, SE = 0.01, 95% CI = [−0.02, 0.02], p = .865) and C-reactive protein (β = −0.00, b = −0.00, SE = 0.01, 95% CI = [−0.03, 0.03], p = .865).

4. Discussion

In the present study, we examined the relationship between computer use and cardiovascular biomarkers in midlife and older adults to assess potential cardiovascular risk implications. We consistently found that neither general computer use frequency and computer use at work frequency was significantly associated with any of the 5 cardiovascular risk biomarkers included in the current study. Overall, our main findings do not support the hypothesis that computer use is positively associated with heightened cardiovascular risk in this demographic, challenging the concerns that sedentary behaviour related to computer use may negatively affect cardiovascular health.

The absence of significant relationships between computer use and any of the cardiovascular biomarkers suggests that frequent computer use may not be a reliable indicator of sedentary lifestyle. While this might contradict existing research on the relationship between sedentary lifestyle and cardiovascular health (Fotheringham et al., 2000; Gatto & Tak, 2008; Harvey et al., 2013), it highlights the possibility that computer use alone does not fully capture the complexity of sedentary behaviour. This is further supported by our exploratory mediation analysis, which showed that exercise frequency did not significantly mediate the relationship between computer use and cardiovascular risk. This suggests that computer use and cardiovascular risk is not directly affected by exercise frequency alone. In fact, we found a significant positive zero-order correlation between general computer use frequency and exercise frequency (see Table 2), indicating that computer users may engage in regular exercise. This could be explained by how older adults who use computers regularly may be more health-conscious and proactive about mitigating potential health risks (Hunsaker et al., 2021; Wan et al., 2022). Furthermore, the evolving technology landscape has introduced a wide range of tools and apps, such as physical trackers like FitBit and online coaching platforms, that may have been integrated into the daily routines of computer users to help them maintain an active lifestyle (Hurling et al., 2007; Longhini et al., 2024; Newbold et al., 2021; Petersen et al., 2020).

Our exploratory moderation further reinforces the complexity behind the relationship between computer use and cardiovascular risk. This analysis revealed that employment status significantly moderated the relationship between general computer use frequency and LDL cholesterol. Although the simple slope analysis did not find a significant relationship for participants regardless of employment status, we found that the correlation between general computer use frequency and LDL cholesterol became positive among employed participants. Work-related factors may play a role in influencing cardiovascular risks associated with computer use at work as individuals are more likely to spend extended amounts of time in front of a computer with fewer opportunities for movement or breaks (Parry & Straker, 2013; Smith et al., 2015). However, future studies should replicate these findings using larger samples to confirm the robustness of this relationship. These findings have important implications for public health recommendations and interventions, especially in midlife and older adults. Firstly, public health strategies should emphasize the importance of taking regular breaks and reducing prolonged periods of sitting across multiple contexts. Furthermore, given the complexity of computer use, public health strategies should adopt a more holistic approach, considering other activities associated with sedentary behaviour such as television viewing (Karkauskiene et al., 2023; Katzmarzyk & Lee, 2012; Thorp et al., 2011).

Our study has several limitations that should be acknowledged. Firstly, the cross-sectional nature of this study limits our ability to draw causal conclusions, making the results susceptible to reverse causation (Kramer, 1988; Wang & Cheng, 2020). Future studies should adopt a longitudinal design to better understand the relationship between computer use and cardiovascular risk in midlife and older adults. Secondly, our study utilizes self-reported measures of computer use frequency, which may lack validity (Kastelic & Sarabon, 2019; Parry et al., 2021). This limitation could explain the observed lack of association between both forms of computer use frequency and cardiovascular biomarkers as evidence suggests that self-reported computer use frequency often fails to reflect actual usage patterns (Kramer, 1988; Wang & Cheng, 2020). Moreover, self-reported measures may oversimplify the complexity of computer use behaviour, failing to capture important factors such as the context, purpose and intensity of use, possibly leading to inconsistencies when compared with more objective data on computer use frequency (Araujo et al., 2017). To overcome these limitations, future research could adopt more objective measures such as wearable sensors that can track screen time and movement or continuous biomarker monitoring, offering a more detailed understanding of how computer use may impact cardiovascular health (Group, 2021; Li et al., 2022).

In conclusion, our study's findings highlight the complexity of the relationship between computer use and cardiovascular health among midlife and older adults. While our results do not support a straightforward link between computer use and heightened cardiovascular risk, they encourage further investigation into the diverse factors at play, including the nature of computer use, the context in computer use occurs, and the individual characteristics and behaviours of computer users. This nuanced approach will contribute to a more comprehensive understanding of how technology and sedentary behaviour intersect with cardiovascular health in the modern age.

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CRediT authorship contribution statement

Meilan Hu: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Shu Fen Diong:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **K.T. A. Sandeeshwara Kasturiratna:** Writing – review & editing, Formal analysis. **Andree Hartanto:** Writing – review & editing, Supervision, Investigation, Formal analysis, Conceptualization.

Declaration of competing Interest

The authors declare no conflict of interest.

Data availability

All MIDUS datasets and documentation are archived and publicly available at the ICPSR repository (http://www.icpsr.umich.edu/) at the University of Michigan.

References

Aberra, T., Peterson, E. D., Pagidipati, N. J., Mulder, H., Wojdyla, D. M., Philip, S., Granowitz, C., & Navar, A. M. (2020). The association between triglycerides and incident cardiovascular disease: What is "optimal". *Journal of Clinical Lipidology, 14*(4), 438–447.e3. https://doi.org/10.1016/j.jacl.2020.04.009

Aghasi, M., Matinfar, A., Golzarand, M., Salari-Moghaddam, A., & Ebrahimpour-Koujan, S. (2020). Internet use in relation to overweight and obesity: A systematic review and meta-analysis of cross-sectional studies. *Advances in Nutrition, 11*(2), 349–356. https://doi.org/10.1093/advances/nmz073

Almeida, O. P., Yeap, B. B., Alfonso, H., Hankey, G. J., Flicker, L., & Norman, P. E. (2012). Older men who use computers have lower risk of dementia. *PLoS One, 7*(8), Article e44239. https://doi.org/10.1371/journal.pone.0044239

Amezcua-Castillo, E., González-Pacheco, H., Sáenz-San Martín, A., Méndez-Ocampo, P., Gutierrez-Moctezuma, I., Massó, F., Sierra-Lara, D., Springall, R., Rodríguez, E., Arias-Mendoza, A., & Amezcua-Guerra, L. M. (2023). C-reactive protein: The quintessential marker of systemic inflammation in coronary artery disease—Advancing toward precision medicine. *Biomedicines, 11*(9), 2444. https://doi.org/10.3390/biomedicines11092444

Amini, M., Zayeri, F., & Salehi, M. (2021). Trend analysis of cardiovascular disease mortality, incidence, and mortality-to-incidence ratio: Results from global burden of disease study 2017. *BMC Public Health, 21*(1), 401. https://doi.org/10.1186/s12889-021-10429-0

Andersen, L. L., & Garde, A. H. (2015). Sleep problems and computer use during work and leisure: Cross-sectional study among 7800 adults. *Chronobiology International, 32*(10), 1367–1372. https://doi.org/10.3109/07420528.2015.1095202

Araujo, T., Wonneberger, A., Neijens, P., & de Vreese, C. (2017). How much time do you spend online? Understanding and improving the accuracy of self-reported measures of internet use. *Communication Methods and Measures, 11*(3), 173–190. https://doi.org/10.1080/19312458.2017.1317337

Assmann, G., Schulte, H., Funke, H., & von Eckardstein, A. (1998). The emergence of triglycerides as a significant independent risk factor in coronary artery disease. *European Heart Journal, 19*(Suppl M), M8–M14.

Bakker, E. A., van Bakel, B. M. A., Aengevaeren, W. R. M., Meindersma, E. P., Snoek, J. A., Waskowsky, W. M., van Kuijk, A. A., Jacobs, M. M. L. M., Hopman, M. T. E., Thijssen, D. H. J., & Eijsvogels, T. M. H. (2021). Sedentary behaviour in cardiovascular disease patients: Risk group identification and the impact of cardiac rehabilitation. *International Journal of Cardiology, 326*, 194–201. https://doi.org/10.1016/j.ijcard.2020.11.014

Basnet, A., Pathak, S. B., Marasini, A., Pandit, R., & Pradhan, A. (2022). Digital eye strain among adults presenting to tertiary care hospital in the era of COVID-19 pandemic: A descriptive cross-sectional study. *JNMA: Journal of the Nepal Medical Association, 60*(245), 22–25. https://doi.org/10.31729/jnma.7092

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Bertuol, C., da Silveira, M. H. C., Krug, R. de R., Kupske, J. W., Mielke, G. I., & Del Duca, G. F. (2023). Use of electronic devices in leisure time modifies the prevalence and factors associated with sedentary behavior derived exclusively from excessive television viewing among Brazilian adults. *BMC Public Health, 23*(1), 1602. https://doi.org/10.1186/s12889-023-16517-7

Bezerra, T., Souza Filho, A., Quirino, N., Bandeira, P., Cabral, L., Reuter, C., Martins, C., & Carvalho, F. (2023). Physical activity, sedentary behaviour and cardiovascular risk factors in overweight low-income schoolchildren: A complex system perspective. *Obesities, 3*(1). https://doi.org/10.3390/obesities3010008. Article 1.

Carpenter, B. D., & Buday, S. (2007). Computer use among older adults in a naturally occurring retirement community. *Computers in Human Behavior, 23*(6), 3012–3024. https://doi.org/10.1016/j.chb.2006.08.015

Carson, A. P., Rose, K. M., Catellier, D. J., Diez-Roux, A. V., Muntaner, C., & Wyatt, S. B. (2009). Employment status, coronary heart disease, and stroke among women. *Annals of Epidemiology, 19*(9), 630–636. https://doi.org/10.1016/j.annepidem.2009.04.008

Feng, Y., Ye, D., Wang, Z., Pan, H., Lu, X., Wang, M., Xu, Y., Yu, J., Zhang, J., Zhao, M., Xu, S., Pan, W., Yin, Z., Ye, J., & Wan, J. (2022). The role of interleukin-6 family members in cardiovascular diseases. *Frontiers in Cardiovascular Medicine, 9*. https://doi.org/10.3389/fcvm.2022.818890

Fingerman, K. L., Birditt, K. S., & Umberson, D. J. (2020). Use of technologies for social connectedness and well-being and as a tool for research data collection in older adults. In *Mobile technology for adaptive aging: Proceedings of a workshop*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK563112/.

Fotheringham, M. J., Wonnacott, R. L., & Owen, N. (2000). Computer use and physical inactivity in young adults: Public health perils and potentials of new information technologies. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine, 22*(4), 269–275. https://doi.org/10.1007/BF02895662

Friedewald, W. T., Levy, R. I., & Fredrickson, D. S. (1972). Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clinical Chemistry, 18*(6), 499–502.

Gastaldelli, A., Folli, F., & Maffei, S. (2010). Impact of tobacco smoking on lipid metabolism, body weight and cardiometabolic risk. *Current Pharmaceutical Design, 16*(23), 2526–2530. https://doi.org/10.2174/138161210792062858

Gatto, S. L., & Tak, S. H. (2008). Computer, internet, and e-mail use among older adults: Benefits and barriers. *Educational Gerontology, 34*(9), 800–811. https://doi.org/10.1080/03601270802243697

Gell, N. M., Rosenberg, D. E., Demiris, G., LaCroix, A. Z., & Patel, K. V. (2015). Patterns of technology use among older adults with and without disabilities. *The Gerontologist, 55*(3), 412–421. https://doi.org/10.1093/geront/gnt166

Gilstrap, L. G., & Wang, T. J. (2012). Biomarkers and cardiovascular risk assessment for primary prevention: An update. *Clinical Chemistry, 58*(1), 72–82. https://doi.org/10.1373/clinchem.2011.165712

Graham, M., & Dutton, W. H. (2019). *Society and the internet: How networks of information and communication are changing our lives*. Oxford University Press.

Greenland, P., LaBree, L., Azen, S. P., Doherty, T. M., & Detrano, R. C. (2004). Coronary artery calcium score combined with Framingham score for risk prediction in asymptomatic individuals. *JAMA, 291*(2), 210–215. https://doi.org/10.1001/jama.291.2.210

Group, F.-N. B. W. (2021). Monitoring biomarker. In *BEST (biomarkers, EndpointS, and other tools) resource*. Food and Drug Administration (US) *[Internet]* https://www.ncbi.nlm.nih.gov/books/NBK402282/.

Harchaoui, K. E. L., Visser, M. E., Kastelein, J. J. P., Stroes, E. S., & Dallinga-Thie, G. M. (2009). Triglycerides and cardiovascular risk. *Current Cardiology Reviews, 5*(3), 216–222. https://doi.org/10.2174/157340309788970315

Hartanto, A., Majeed, N. M., Lua, V. Y., Wong, J., & Chen, N. R. (2022). Dispositional gratitude, health-related factors, and lipid profiles in midlife: a biomarker study. *Scientific Reports, 12*(1), 6034. https://doi.org/10.1038/s41598-022-09960-w.

Hartanto, A., Majeed, N. M., Ng, W. Q., Chai, C. K. N., & Lua, V. Y. Q. (2021). Subjective age and inflammation risk in midlife adults: Findings from the Midlife in the United States (MIDUS) studies. *Comprehensive Psychoneuroendocrinology, 7*, Article 100072. https://doi.org/10.1016/j.cpnec.2021.100072

Hartanto, A., Kasturiratna, K. S., Hu, M., Diong, S. F., & Lua, V. Y. (2024). Negative work-to-family spillover stress and heightened cardiovascular risk biomarkers in midlife and older adults. *Journal of Psychosomatic Research, 178*, 111594. https://doi.org/10.1016/j.jpsychores.2024.111594.

Hartanto, A., Yong, J. C., Toh, W. X., Lee, S. T. H., Tng, G. Y. Q., & Tov, W. (2020). Cognitive, social, emotional, and subjective health benefits of computer use in adults: A 9-year longitudinal study from the midlife in the United States (MIDUS). *Computers in Human Behavior, 104*, Article 106179. https://doi.org/10.1016/j.chb.2019.106179

Harvey, J. A., Chastin, S. F. M., & Skelton, D. A. (2013). Prevalence of sedentary behavior in older adults: A systematic review. *International Journal of Environmental Research and Public Health, 10*(12), 6645–6661. https://doi.org/10.3390/ijerph10126645

Hoeymans, N., Smit, H. A., Verkleij, H., & Kromhout, D. (1996). Cardiovascular risk factors in relation to educational level in 36 000 men and women in The Netherlands. *European Heart Journal, 17*(4), 518–525. https://doi.org/10.1093/oxfordjournals.eurheartj.a014903

Hunsaker, A., Hargittai, E., & Micheli, M. (2021). Relationship between internet use and change in health status: Panel Study of Young Adults. *Journal of Medical Internet Research, 23*(1), Article e22051. https://doi.org/10.2196/22051

Hurling, R., Catt, M., De Boni, M., Fairley, B. W., Hurst, T., Murray, P., Richardson, A., & Sodhi, J. S. (2007). Using internet and mobile phone technology to deliver an automated physical activity program: Randomized controlled trial. *Journal of Medical Internet Research, 9*(2), e7. https://doi.org/10.2196/jmir.9.2.e7

Infurna, F. J., Gerstorf, D., & Lachman, M. E. (2020). Midlife in the 2020s: Opportunities and challenges. *American Psychologist, 75*(4), 470–485. https://doi.org/10.1037/amp0000591

Jung, E., Kong, S. Y., Ro, Y. S., Ryu, H. H., & Shin, S. D. (2022). Serum cholesterol levels and risk of cardiovascular death: A systematic review and a dose-response meta-analysis of prospective cohort studies. *International Journal of Environmental Research and Public Health, 19*(14), 8272. https://doi.org/10.3390/ijerph19148272

Kamin, S. T., & Lang, F. R. (2020). Internet use and cognitive functioning in late adulthood: Longitudinal findings from the survey of health, ageing and retirement in Europe (SHARE). *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 75*(3), 534–539. https://doi.org/10.1093/geronb/gby123

Kang, H., & Kim, H. (2022). Ageism and psychological well-being among older adults: A systematic review. *Gerontology and Geriatric Medicine, 8*, Article 23337214221087023. https://doi.org/10.1177/23337214221087023

Karkauskiene, E., Tully, M. A., Dudoniene, V., Giné-Garriga, M., Escribà-Salvans, A., Font-Jutglà, C., & Jerez-Roig, J. (2023). Effectiveness of interventions for reducing sedentary behaviour in older adults living in long-term care facilities: A protocol for a systematic review. *Healthcare, 11*(14), 1976. https://doi.org/10.3390/healthcare11141976

Kastelic, K., & Sarabon, N. (2019). Comparison of self-reported sedentary time on weekdays with an objective measure (activPAL). *Measurement in Physical Education and Exercise Science, 23*, 1–10. https://doi.org/10.1080/1091367X.2019.1603153

Katzmarzyk, P. T., & Lee, I.-M. (2012). Sedentary behaviour and life expectancy in the USA: A cause-deleted life table analysis. *BMJ Open, 2*(4), Article e000828. https://doi.org/10.1136/bmjopen-2012-000828

Keegan, S. (2012). Digital technologies are re-shaping our brains: What are the implications for society and the research industry? *Qualitative Market Research: An International Journal, 15*(3), 328–346. https://doi.org/10.1108/13522751211232012

Kim, K. S., Kim, S. J., Kim, S., Choi, D.-W., Ju, Y. J., & Park, E.-C. (2018). Association of self-reported sedentary time with insulin resistance among Korean adults without

diabetes mellitus: A cross-sectional study. *BMC Public Health, 18*(1), 1335. https://doi.org/10.1186/s12889-018-6237-4

Kosmas, C. E., Martinez, I., Sourlas, A., Bouza, K. V., Campos, F. N., Torres, V., Montan, P. D., & Guzman, E. (2018). High-density lipoprotein (HDL) functionality and its relevance to atherosclerotic cardiovascular disease. *Drugs in Context, 7*, Article 212525. https://doi.org/10.7573/dic.212525

Kramer, M. S. (1988). Cross-sectional studies. In M. S. Kramer (Ed.), *Clinical epidemiology and biostatistics: A primer for clinical investigators and decision-makers* (pp. 113–117). Springer. https://doi.org/10.1007/978-3-642-61372-2_9.

Kuppa, A., Tripathi, H., Al-Darraji, A., Tarhuni, W. M., & Abdel-Latif, A. (2023). C-Reactive protein levels and risk of cardiovascular diseases: A two-sample bidirectional mendelian randomization study. *International Journal of Molecular Sciences, 24*(11). https://doi.org/10.3390/ijms24119129. Article 11.

Lakatta, E. G. (2002). Age-associated cardiovascular changes in health: Impact on cardiovascular disease in older persons. *Heart Failure Reviews, 7*(1), 29–49. https://doi.org/10.1023/a:1013797722156

Li, X., Holiday, S., Cribbet, M., Bharadwaj, A., White, S., Sazonov, E., & Gan, Y. (2022). Non-invasive screen exposure time assessment using wearable sensor and object detection. *Annual international conference of the IEEE engineering in medicine and biology society* (pp. 4917–4920). IEEE Engineering in Medicine and Biology Society. Annual International Conference. https://doi.org/10.1109/EMBC48229.2022.9871903, 2022.

Li, J., Loerbroks, A., Bosma, H., & Angerer, P. (2016). Work stress and cardiovascular disease: A life course perspective. *Journal of Occupational Health, 58*(2), 216–219.

Lindstrom, M., DeCleene, N., Dorsey, H., Fuster, V., Johnson, C. O., LeGrand, K. E., Mensah, G. A., Razo, C., Stark, B., Varieur Turco, J., & Roth, G. A. (2022). Global burden of cardiovascular diseases and risks collaboration, 1990-2021. *Journal of the American College of Cardiology, 80*(25), 2372–2425. https://doi.org/10.1016/j.jacc.2022.11.001

Longhini, J., Marzaro, C., Bargeri, S., Palese, A., Dell'Isola, A., Turolla, A., Pillastrini, P., Battista, S., Castellini, G., Cook, C., Gianola, S., & Rossettini, G. (2024). Wearable devices to improve physical activity and reduce sedentary behaviour: An umbrella review. *Sports Medicine - Open, 10*(1), 9. https://doi.org/10.1186/s40798-024-00678-9

Loprinzi, P. D., Branscum, A., Hanks, J., & Smit, E. (2016). Healthy lifestyle characteristics and their joint association with cardiovascular disease biomarkers in US adults. *Mayo Clinic Proceedings, 91*(4), 432–442. https://doi.org/10.1016/j.mayocp.2016.01.009

Love, G. D., Seeman, T. E., Weinstein, M., & Ryff, C. D. (2010). Bioindicators in the MIDUS National Study: Protocol, Measures, Sample, and Comparative Context. *Journal of Aging and Health, 22*(8), 1059–1080. https://doi.org/10.1177/0898264310374355.

Mittelmark, M., Psaty, B. M., Rautaharju, P. M., Fried, L. P., Borhani, N. O., Tracy, R. P., Gardin, J. M., O'Leary, D. H., & Kronmal, R. (1993). Prevalence of cardiovascular diseases among older adults: The cardiovascular health study. *American Journal of Epidemiology, 137*(3), 311–317. https://doi.org/10.1093/oxfordjournals.aje.a116678

Molenaar, E. A., Ameijden, E. J. C. V., Grobbee, D. E., & Numans, M. E. (2007). Comparison of routine care self-reported and biometrical data on hypertension and diabetes: Results of the Utrecht Health Project. *The European Journal of Public Health, 17*(2), 199–205. https://doi.org/10.1093/eurpub/ckl113

Mossmann, M., Wainstein, M. V., Mariani, S., Machado, G. P., de Araújo, G. N., Andrades, M., Gonçalves, S. C., & Bertoluci, M. C. (2022). Increased serum IL-6 is predictive of long-term cardiovascular events in high-risk patients submitted to coronary angiography: An observational study. *Diabetology & Metabolic Syndrome, 14*(1), 125. https://doi.org/10.1186/s13098-022-00891-0

Mouliou, D. S. (2023). C-reactive protein: Pathophysiology, diagnosis, false test results and a novel diagnostic algorithm for clinicians. *Diseases, 11*(4), 132. https://doi.org/10.3390/diseases11040132

Mozaffarian, D., Wilson, P. W. F., & Kannel, W. B. (2008). Beyond established and novel risk factors. *Circulation, 117*(23), 3031–3038. https://doi.org/10.1161/CIRCULATIONAHA.107.738732

Newbold, J. W., Rudnicka, A., & Cox, A. (2021). Staying active while staying home: The use of physical activity technologies during life disruptions. *Frontiers in Digital Health, 3*, Article 753115. https://doi.org/10.3389/fdgth.2021.753115

Nimrod, G. (2020). Changes in internet use when coping with stress: Older adults during the COVID-19 pandemic. *American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry, 28*(10), 1020–1024. https://doi.org/10.1016/j.jagp.2020.07.010

North, B. J., & Sinclair, D. A. (2012). The intersection between aging and cardiovascular disease. *Circulation Research, 110*(8), 1097–1108. https://doi.org/10.1161/CIRCRESAHA.111.246876

Okura, Y., Urban, L. H., Mahoney, D. W., Jacobsen, S. J., & Rodeheffer, R. J. (2004). Agreement between self-report questionnaires and medical record data was substantial for diabetes, hypertension, myocardial infarction and stroke but not for heart failure. *Journal of Clinical Epidemiology, 57*(10), 1096–1103. https://doi.org/10.1016/j.jclinepi.2004.04.005

Parry, D. A., Davidson, B. I., Sewall, C. J. R., Fisher, J. T., Mieczkowski, H., & Quintana, D. S. (2021). A systematic review and meta-analysis of discrepancies between logged and self-reported digital media use. *Nature Human Behaviour, 5*(11). https://doi.org/10.1038/s41562-021-01117-5. Article 11.

Parry, S., & Straker, L. (2013). The contribution of office work to sedentary behaviour associated risk. *BMC Public Health, 13*(1), 296. https://doi.org/10.1186/1471-2458-13-296

Pereira, H. (2017). The importance of cholesterol in psychopathology: A review of recent contributions. *Indian Journal of Psychological Medicine, 39*(2), 109–113. https://doi.org/10.4103/0253-7176.203117

Petersen, J. M., Kemps, E., Lewis, L. K., & Prichard, I. (2020). Associations between commercial app use and physical activity: Cross-sectional study. *Journal of Medical Internet Research, 22*(6), Article e17152. https://doi.org/10.2196/17152

Petersen, B., Khalili-Mahani, N., Murphy, C., Sawchuk, K., Phillips, N., Li, K. Z. H., & Hebblethwaite, S. (2023). The association between information and communication technologies, loneliness and social connectedness: A scoping review. *Frontiers in Psychology, 14*. https://doi.org/10.3389/fpsyg.2023.1063146

R Core Team. (2023). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, 4.3.1), [Computer software] https://www.Rproject.org/.

Revelle, W. (2021). *psych: Procedures for psychological, psychometric, and personality research*. Northwestern University, 2.3.9) [R].

Ridker, P. M., Hennekens, C. H., Buring, J. E., & Rifai, N. (2000). C-reactive protein and other markers of inflammation in the prediction of cardiovascular disease in women. *New England Journal of Medicine, 342*(12), 836–843. https://doi.org/10.1056/NEJM200003233421202

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software, 48*(2). https://doi.org/10.18637/jss.v048.i02

Roth, G. A., Forouzanfar, M. H., Moran, A. E., Barber, R., Nguyen, G., Feigin, V. L., Naghavi, M., Mensah, G. A., & Murray, C. J. L. (2015). Demographic and epidemiologic drivers of global cardiovascular mortality. *New England Journal of Medicine, 372*(14), 1333–1341. https://doi.org/10.1056/NEJMoa1406656

Ryff, C. D., Almeida, D. M., Ayanian, J. Z., Carr, D. S., Cleary, P. D., Coe, C., Davidson, R. J., Krueger, R. F., Lachman, M. E., Marks, N. F., Mroczek, D. K., Seeman, T. E., Seltzer, M. M., Singer, B. H., Sloan, R. P., Tun, P. A., Weinstein, M., & Williams, D. R. (2021). Midlife in the United States (MIDUS 2), 2004-2006. *Inter-university Consortium for Political and Social Research [distributor]*. https://doi.org/10.3886/ICPSR04652.v8.

Ryff, C. D., Seeman, T., & Weinstein, M. (2010). *Midlife in the United States (MIDUS 2): Biomarker project, 2004-2009: Version 10* (version v10). *ICPSR - Interuniversity Consortium for Political and Social Research*. https://doi.org/10.3886/ICPSR29282.V10.

Sarwar, N., Danesh, J., Eiriksdottir, G., Sigurdsson, G., Wareham, N., Bingham, S., Boekholdt, S. M., Khaw, K.-T., & Gudnason, V. (2007). Triglycerides and the risk of coronary heart disease: 10,158 incident cases among 262,525 participants in 29 western prospective studies. *Circulation, 115*(4), 450–458. https://doi.org/10.1161/CIRCULATIONAHA.106.637793

Slegers, K., van Boxtel, M. P. J., & Jolles, J. (2008). Effects of computer training and internet usage on the well-being and quality of life of older adults: A randomized, controlled study. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 63*(3), P176–P184. https://doi.org/10.1093/geronb/63.3.p176

Smith, L., Hamer, M., Ucci, M., Marmot, A., Gardner, B., Sawyer, A., Wardle, J., & Fisher, A. (2015). Weekday and weekend patterns of objectively measured sitting, standing, and stepping in a sample of office-based workers: The active buildings study. *BMC Public Health, 15*, 9. https://doi.org/10.1186/s12889-014-1338-1

Soliman, G. A. (2019). Dietary fiber, atherosclerosis, and cardiovascular disease. *Nutrients, 11*(5), 1155. https://doi.org/10.3390/nu11051155

Srinivasan, R. (2018). *Whose global village?. Rethinking how technology shapes our world*. NYU Press.

Stanciulescu, L. A., Scafa-Udriste, A., & Dorobantu, M. (2023). Exploring the association between low-density lipoprotein subfractions and major adverse cardiovascular outcomes—a comprehensive review. *International Journal of Molecular Sciences, 24*(7), 6669. https://doi.org/10.3390/ijms24076669

Stephenson, A., McDonough, S. M., Murphy, M. H., Nugent, C. D., & Mair, J. L. (2017). Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 105. https://doi.org/10.1186/s12966-017-0561-4

Strand, B. H., & Tverdal, A. (2004). Can cardiovascular risk factors and lifestyle explain the educational inequalities in mortality from ischaemic heart disease and from other heart diseases? 26 year follow up of 50,000 Norwegian men and women. *Journal of Epidemiology & Community Health, 58*(8), 705–709. https://doi.org/10.1136/jech.2003.014563

Tanaka, T., Narazaki, M., & Kishimoto, T. (2014). IL-6 in inflammation, immunity, and disease. *Cold Spring Harbor Perspectives in Biology, 6*(10), a016295. https://doi.org/10.1101/cshperspect.a016295

Thorp, A. A., Owen, N., Neuhaus, M., & Dunstan, D. W. (2011). Sedentary behaviors and subsequent health outcomes in adults: A systematic review of longitudinal studies, 1996–2011. *American Journal of Preventive Medicine, 41*(2), 207–215. https://doi.org/10.1016/j.amepre.2011.05.004

Trimarco, V., Izzo, R., Morisco, C., Mone, P., Virginia Manzi, M., Falco, A., Pacella, D., Gallo, P., Lembo, M., Santulli, G., & Trimarco, B. (2022). High HDL (High-Density Lipoprotein) cholesterol increases cardiovascular risk in hypertensive patients. *Hypertension, 79*(10), 2355–2363. https://doi.org/10.1161/HYPERTENSIONAHA.122.19912

Tully, C. J. (2003). Growing up in technological worlds: How modern technologies shape the everyday lives of young people. *Bulletin of Science, Technology & Society, 23*(6), 444–456. https://doi.org/10.1177/0270467603260812

Vandelanotte, C., Sugiyama, T., Gardiner, P., & Owen, N. (2009). Associations of leisure-time internet and computer use with overweight and obesity, physical activity and sedentary behaviors: Cross-sectional study. *Journal of Medical Internet Research, 11*(3), Article e1084. https://doi.org/10.2196/jmir.1084

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1–48. https://doi.org/10.18637/jss.v036.i03

Wagner, N., Hassanein, K., & Head, M. (2010). Computer use by older adults: A multi-disciplinary review. *Computers in Human Behavior, 26*(5), 870–882. https://doi.org/10.1016/j.chb.2010.03.029

Walsemann, K. M., Goosby, B. J., & Farr, D. (2016). Life course SES and cardiovascular risk: Heterogeneity across race/ethnicity and gender. *Social Science & Medicine, 152*, 147–155. https://doi.org/10.1016/j.socscimed.2016.01.038

Wan, X., Lighthall, N. R., & Paulson, D. (2022). Subjective markers of successful aging and change in Internet use among older adults: The distinctive role of subjective health. *Computers in Human Behavior, 127*, Article 107064. https://doi.org/10.1016/j.chb.2021.107064

Wang, X., & Cheng, Z. (2020). Cross-sectional studies: Strengths, weaknesses, and recommendations. *Chest, 158*, S65–S71. https://doi.org/10.1016/j.chest.2020.03.012, 1, Supplement.

Zhang, K., Huang, S., Feng, D., Lang, X., Wang, Q., & Liu, Y. (2022). Sedentary behavioral studies of young and middle-aged adults with hypertension in the framework of behavioral epidemiology: A scoping review. *International Journal of Environmental Research and Public Health, 19*(24), Article 16796. https://doi.org/10.3390/ijerph192416796