Financial Strain and Impaired Fasting Glucose: The Moderating Role of Physical Activity in the Coronary Artery Risk Development in Young Adults Study

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Objectives: Physical activity and financial strain are independent, and opposite, predictors of disease. This study examines whether physical activity modifies the concurrent and prospective relation between financial strain and impaired fasting glucose. **Methods:** Participants were part of the Coronary Artery Risk Development in Young Adults study, a prospective study examining the development of disease. Participants were recruited in 1985 to 1986 and followed up for 20 years. The outcome measures were fasting glucose (FG) levels at Years 7 and 20. FG was available at Years 7 and 20 from 3991 and 3500 participants, respectively. **Results:** The effects of financial strain on elevated glucose levels differed by physical activity levels as indicated by the significant interaction terms for the analyses of covariance at Year 7 (p = .02) and Year 20 (p = .04). Planned contrast comparisons demonstrated that FG levels in financially strained participants who were physically inactive were significantly different from financially strained participants who were active, and all participants with low financial strain. Specifically, in less active participants, the adjusted mean FG levels were higher in financially strained participants (2.27 mg/dL at Year 7 and 5.86 mg/dL at Year 20). In active participants, these differences were −1.78 mg/dL at Year 7 and negligible at Year 20. **Conclusions:** In adults burdened by financial strain, physical activity is associated with a reduced risk of developing impaired FG up to 13 years later. This adds to a growing literature showing the potential of physical activity to moderate stress-related disease processes. **Key Words:** financial strain, physical activity, CARDIA, fasting glucose.

CVD = cardiovascular disease; **FG** = fasting glucose; **SES** = socioeconomic status; **CARDIA** = Coronary Artery Risk Development in Young Adults; **PAH** = Physical Activity History; **EU** = exercise units; **BMI** = body mass index.

INTRODUCTION

Preventable diseases account for a large proportion of overall morbidity and mortality in industrialized nations. Nearly 10% of U.S. adults have diagnosed or undiagnosed diabetes (1), and cardiovascular disease (CVD) is the leading cause of death in the United States, accounting for approximately 35% of all deaths (2). Impaired fasting glucose (FG; >100 mg/dL) is a risk factor for cardiovascular disease (3,4) and Type 2 diabetes (5,6) and thus serves as an early marker of both diseases.

A significant predictor of preventable diseases and mortality is socioeconomic status (SES) (7,8). Poorer individuals, the unemployed, and the less educated have higher incidences of Type 2 diabetes and CVD (9,10). Accumulating evidence suggests that underlying the effects of lower SES on health is the stress of not being able to meet one's basic living demands and lack of control experienced by these individuals (11). Difficulty in meeting basic financial needs imposes psychological stress on low-SES individuals, which can affect both physical and mental health (12,13).

Individuals lower in SES and experiencing financial strain are less likely to engage in health-enhancing behaviors. However, health behaviors do not completely mediate the impact of SES on health (14,15). There is relatively little work on whether health behaviors *moderate* the associations of SES and health. Physical activity and fitness levels may protect those experiencing financial strain from developing disease. To date, this has not been examined. Laboratory studies with rodents provide evidence of reduced antibody suppression for physically active animals undergoing laboratory-induced stress compared to animals that are not active (16,17). Less active human adults, compared with more active ones, react to mental stress with higher cortisol (17), and have higher levels of proinflammatory cytokines (18), both increasingly considered to foster disease development (19,20). If physical activity can buffer stress responses, it may particularly benefit those experiencing financial strain associated with low SES and protect them from developing disease.

Given the evidence that more physically active animals, including humans, have attenuated physiological responses to laboratory-induced stress, the present study examined whether financially strained yet physically active individuals have similar levels of FG to those not financially strained, both concurrently and prospectively. We tested this question using the Coronary Artery Risk Development in Young Adults (CARDIA) study, a prospective, ongoing, multisite study examining psychological, behavioral, physical, and biochemical factors associated with the development of CVD. We examined (1) whether reporting having difficulty paying for one's basic living expenses at baseline was associated with FG levels concurrently and prospectively (13 years later) and (2) whether those financially strained individuals who were physically active at baseline had lower levels of FG, comparable to those not strained.

METHODS

CARDIA recruited participants in 1985 to 1986 at four sites (Birmingham, AL, Chicago, IL, Minneapolis, MN, and Oakland, CA). Recruitment at each of the site balanced race (black, white), sex, age (18–24 and 25–30 years), and education (high school graduate or less, more than high school graduate). Participants were examined at study entry and at Years 2, 5, 7, 10, 15, and 20, with a reexamination rate of 71.8% among surviving cohort members at Year 20. A total of 4086 participants (80.6% of original sample) completed Year 7 examination, considered as baseline for this analysis since it was the first year where both income level and economic strain were assessed during

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the same examination. Participants in CARDIA at Year 7 compared with those who did not participate that year were more likely to be white, to have more years of education, and less likely to smoke at baseline. Thirteen years of follow-up (from Year 7 to Year 20) were available. FG was available at Years 7 and 20 from 3991 and 3500 participants, respectively (15). Institutional review committee approval from each site and informed consent were obtained.

MATERIALS

Primary Outcome Variable

Fasting Glucose (mg/dL)

Participants fasted overnight and avoided smoking and heavy physical activity for 2 hours before laboratory examination. Blood was drawn into vacutainers containing no preservative. Serum was separated by centrifugation at 4°C within 60 minutes, stored in cryovials, and frozen at −70°C within 90 minutes until analysis. FG was measured by the hexokinase method at every examination (21). We excluded data in our analyses for participants who fasted less than 8 hours and more than 24 hours at either baseline (Year 7) and at the 13-year follow-up (Year 20). As a result, data from 2607 participants were included in the current study.

Independent (or Exposure) Variables

Financial Strain

Financial strain was assessed by the question, "How hard is it for you (and your family) to pay for the very basics like food, medical care, and heating?" Participants selected from a choice of 1 = very hard, 2 = hard, 3 = somewhat hard, 4 = not very hard, and 5 = do not know. Responses for financial strain were significantly skewed (skewness statistic = 2.1). Accordingly, financial strain was recoded into a binary variable, in which very hard and hard were considered high financial strain (and scored 1), and somewhat hard and not very hard were considered low financial strain (and scored 0). "Do not know" responses were recoded as missing. Financial strain provides an assessment of the balance between income and demands and provides a more direct measure of psychological stress inherent in the difficulty meeting demands than does a measure of income alone. Similar questions have been used in previous studies examining financial strain (11,12,22,23).

Household Income

Household income is a covariate related to financial strain and a possible alternative hypothesis (see later paragraphs). Income was first reported in the seventh year of CARDIA and was examined as a predictor of FG instead of financial strain. Participants selected from nine categories of past-year family income ranging from 1 = less than U.S. $5000 to 8 = greater than U.S. $75,000, and the categories were included in the analyses as an ordinal variable. We computed a household income score by dividing household income by number of participants reported living in the household. "Do not know" responses were recoded as missing.

Physical Activity History

Participants completed the Physical Activity History (PAH) at baseline (Year 7 of CARDIA study), which assessed levels of vigorous (≥5 METs)[1] and moderate (3–4 METs) physical activity during the previous 12-month period. Participants' reported the number of months in which they engaged in each of 13 categories of mostly exercise and recreational sport activity (see Appendix A) for a minimal monthly and weekly duration. Responses were then multiplied by the intensity of the activity and a weighting factor applied to the months of more frequent weekly participation, summed over all activities, and expressed as exercise units (EUs). The PAH is a valid and reliable measure of physical activity and is significantly related to measures of fitness, anthropometrics, and biological outcomes (24). We used a total physical activity score in the study. EU scores were significantly skewed (skewness statistic = 2.8) and thus defined participants with an activity score of 300 EU or more as "more active," and those with a score below 300 EU as "less active." This split was based on previous CARDIA analyses comparing activity levels in CARDIA and Centers for Disease Control and Prevention recommendations for activity per week (25).

Covariates

Year 7 analyses adjusted for age, sex, race, Year 7 body mass index (BMI), and years of education. In addition, we examined baseline (Year 7) physical illness diagnosis of diabetes that could confound financial strain and physical activity. At Year 20, we included baseline FG and Year 20 BMI as covariates.

Statistical Analyses

SPSS 18.0 (IBM; Armonk, NY) was used to analyze the data. First, t and χ^2 tests were used to examine differences between high and low financial strain in the covariates, physical activity and FG levels. Next, we examined a two-by-two analysis of covariance in which the interaction between physical activity (0 versus 1) and financial strain was examined (0 versus 1).[2] We built our model by first including only the two characteristics of a priori interest, financial strain and physical activity (Model A; Table 2) and then added age, race, sex, and education (Model B; Table 2), and a final model including income, BMI, and a diagnosis of diabetes at baseline (Model C; Table 2). Prospective analyses also included baseline FG levels as a covariate. Given we had an a priori hypothesis that financially strained less active individuals would have elevated FG levels compared to those strained and active and to those nonstrained, we followed up our interaction analyses with planned contrasts analysis of variance. We conducted planned comparisons where we expected financially strained and less active participants to have significantly higher mean FG levels than financially strained and active, and all non–financially strained participants. Second, we also examined whether differences existed between those financially strained and active and those not financially strained,

[1]METs are defined as multiples of 1 kcal/kg per hour, commonly used as the amount of energy expenditure in adults at rest.

[2]Analyses were repeated with the skewed raw data for financial strain and physical activity. Models were consistent in direction and significance with those reported in the main text. However, we report results based on dichotomized predictors for easier interpretability and comparison to previous work (11,12,23).

both active and less active. Sample size limited any meaningful assessment of race and sex interactions.

RESULTS

Overall, 2591 of 2607 participants responded to the question on financial strain. Of these, 282 (10.9%) were classified as having high financial strain at Year 7 (Table 1). Participants with high financial strain, compared with those with low strain, were less educated ($p < .001$), had lower family income ($p < .001$), had higher BMI ($p = .005$), and had significantly higher FG scores at 13-year follow-up (103.1 versus 99.0, $p = .047$). Forty percent of financially strained participants were active, and 46% of nonstrained were active ($p = .07$). Furthermore, 62% and 60% of black and white men were active compared with 25% and 41% of black and white women, respectively. At baseline (Year 7), fewer participants with diabetes compared with patients without diabetes (25% versus 47%, $p < .001$) reported being active. In addition, reports of diabetes were related to higher levels of FG at baseline (mean FG, 117.3 versus 90.3, $p < .001$) and 13-year follow-up (mean FG, 126.2 versus 98.7, $p < .001$). Finally, baseline and 13-year FG values were not significantly correlated with physical activity ($p > .10$).

Primary Analyses

Financial Strain and Physical Activity on FG

Table 2 presents the direct associations of financial strain (high versus low) on mean FG at baseline and 13-year follow-up, covarying baseline FG (see columns labeled ALL). High and low financially strained participants did not have significant mean differences in FG levels at baseline, but significant differences were apparent at follow-up (mean FG difference, 3.36, $p = .02$ in the model covarying baseline FG versus 3.17, $p = .03$ in the fully adjusted model). Next, analyses of covariance suggest that physical activity significantly attenuates the relationship between financial strain and FG at baseline (interaction effect, $p = .02$) and at follow-up (interaction effect, $p = .04$). In the adjusted baseline analyses, a mean FG difference of 2.27 was observed between those financially strained and those low in strain who were less active. In those active, the difference is −1.56. For the 13-year follow-up, the difference was 5.86 in those financially strained and less active compared with those less active but not strained. For those active, the mean FG difference was −0.03 (final adjusted model interaction effect, $p = .04$). See Figures 1A and B for representations of these effects. Next, a priori planned comparisons revealed that financially strained and less active participants ($n = 163$) had significantly higher baseline mean FG levels compared with financially strained and active ($n = 114$, $p = .02$) as well as those with low financial strain ($n = 1218$ and $n = 1074$ for less and more active, respectively; $p = .02$). Similar significant differences existed during follow-up. At follow-up, results indicated that financially strained and less active participants had significantly higher mean FG levels compared with financially strained and active ($p = .01$) as well as those with low financial strain ($p = .01$). Planned comparisons for baseline and follow-up analyses also revealed no significant difference between low-strained active and less active ($p > .10$) or between high-strained active and those low in strain who were either more or less active ($p > .10$).

TABLE 1. Year 7 Characteristics of Participants in CARDIA Sample by Financial Strain

	Baseline Financial Strain		
	All ($n = 2591$)	Low ($n = 2309$)	High ($n = 282$)
Demographics			
Age, M (SD)	32.2 (3.6)	32.2 (3.6)	32.3 (3.6)
Male sex, *n* (%)	1159 (44.6)	1048 (45.4)	111 (39.4)
White, *n* (%)	1483 (57.2)	1341 (58.1)	142 (50.4)
Education, M (SD)	14.9 (2.5)	15.0 (2.5)	13.7 (2.2)
Body mass index, M (SD)	26.5 (5.86)	26.4 (5.8)	27.6 (6.6)
Comorbid conditions, *n* (%)			
Diabetes	75 (2.9)	67 (2.9)	8 (2.8)
Heart problems	268 (10.3)	234 (10.2)	34 (12.1)
Hypertension	237 (9.1)	204 (8.9)	33 (11.7)
Asthma	260 (10.0)	226 (9.8)	34 (12.1)
Total physical activity (more active), *n* (%)	1188 (45.8)	1074 (46.5)	114 (40.4)
Fasting glucose, M (SD), mg/dL			
Baseline	91.1 (14.9)	91.0 (14.7)	92.0 (16.9)
Follow-up	99.5 (24.5)	99.0 (23.0)	103.1 (33.2)

CARDIA = Coronary Artery Risk Development in Young Adults; M = mean; SD = standard deviation.

Household Income as Alternative Hypothesis

To examine the possibility that financial strain is simply a marker of lower income, we tested whether the moderating effects of physical activity would be similar for household income level but did not find such effects ($p > .10$).

DISCUSSION

The current study contributes to the growing literature that experiencing financial strain is related to the subsequent development of poor health and mortality (11,22). Our study is unique in its findings that perceived financial strain, independent of an objective marker of SES such as income, is associated with impaired FG during a 13-year period among young adults, even after adjusting for age, race, sex, education, BMI, a diagnosis of diabetes, and baseline levels of FG. The inherent stress associated with economic difficulties may be a salient feature of the previously identified relationships between SES and health (26). Financial strain serves as a potent psychological stressor. Recent works suggest that financially strained women report less perceived control over their lives, trend toward more stressful daily experiences (11), demonstrate higher systolic blood pressure over time (12), and have more recurring cardiac events (11). Further investigation should also examine the differential impact of economic difficulties that are immediate but short lived versus those that are long term.

TABLE 2. Direct Effects of Financial Strain and Interaction Effects With Physical Activity on Baseline and Follow-Up FG (mg/dL) for (A) Raw Model; (B) Adjusted for Age, Race, Sex, Education; and (C) Additional Adjustment for BMI, DB, and Household Income

	FG at Baseline			Follow-Up FG Adjusted for Baseline FG		
Financial Strain	All	Less Active	Active	All	Less Active	Active
(A) Bivariate (Crude)						
Low, M [SE]	90.99 [0.31]	90.86 [0.42]	90.95 [0.45]	99.08 [0.46]	98.96 [0.64]	99.03 [0.68]
High, M [SE]	92.02 [1.01]	93.65 [1.16]	89.57 [1.39]	102.44 [1.33]	104.54 [39.35]	99.82 [2.09]
Mean difference (high − low)	1.03	2.79	−1.38	3.36	5.58	0.79
p	.27			.02		
Interaction *p*		.03			.09	
(B) Adjusted for age, race, sex, and education						
Low, M [SE]	91.01 [0.30]	91.50 [0.42]	90.32 [0.45]	99.01 [0.46]	99.20 [0.65]	98.81 [0.69]
High, M [SE]	91.80 [0.88]	93.95 [1.16]	88.84 [1.36]	102.29 [1.34]	104.50 [1.76]	99.42 [2.08]
Mean difference (high − low)	0.79	2.45	−1.48	3.28	5.30	0.61
p	.41			.02		
Interaction *p*		.04			.10	
(C) Also adjusted for BMI, DB, and household income						
Low, M [SE]	91.14 [0.29]	91.23 [0.40]	90.83 [0.43]	99.13 [0.46]	98.99 [0.65]	99.09 [0.69]
High, M [SE]	91.54 [0.86]	93.50 [1.12]	89.05 [1.29]	102.30 [1.38]	104.85 [1.81]	99.12 [2.10]
Mean difference (high − low)	0.40	2.27	−1.78	3.17	5.86	0.03
p	.67			.03		
Interaction *p*		.02			.04	

FG = fasting glucose; BMI = body mass index; DB = diabetes at baseline; M = mean; SE = standard error.
High financial strain–less active, $n = 163$; High financially strain–active, $n = 114$: Low financial strain–less active, $n = 1218$; Low financial strain–active, $n = 1074$. Baseline FG included in all prospective analyses.

In the present study, financially strained participants had higher levels of concurrent FG but only if they reported lower levels of physical activity at baseline. Reduced physical activity levels seem to exacerbate the positive association between financial strain and concurrent FG levels. In prospective analyses, controlling for baseline glucose, physical activity seemed to act as a stress moderator. Prospectively, financially strained individuals at baseline were more likely to have higher FG levels over a decade later, yet physical activity moderated these effects. Only those financially strained and less active had significant increases in FG compared with individuals strained and more active and all those not financially strained. Importantly, while previous work has linked financial difficulties to disease independent of the effects of health behaviors, this is the first study to indicate that physical activity may be particularly beneficial for those burdened by financial strain. At follow-up, those both financially strained and less active would have, on average, been diagnosed with impaired FG, whereas individuals in the other groups, on average, fell slightly short of diagnosis. Our findings highlight the importance of maintaining regular participation in physical activity even—and especially—when undergoing financial stress. This is especially important in the current economic environment when financial strain is widespread and affecting a range of people, not just those at the lowest levels of income.

The mechanisms of the observed effects are unknown and unexplored in the present study but likely function through multiple pathways. Activity may dampen the impact of chronic

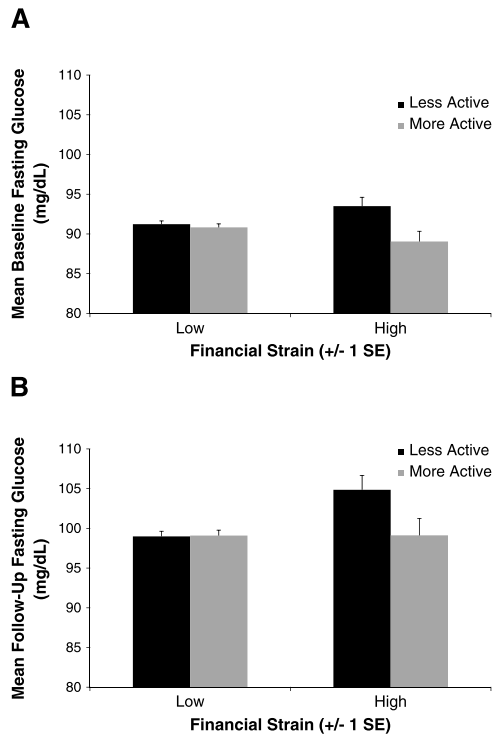

Figure 1. A, Fasting glucose at baseline for low and high financial strain in less active and active participants. B, Fasting glucose at 13-year follow-up for low and high financial strain in less active and active participants. SE = standard error.

stress, by acting on peripheral metabolic and immune regulation (27,28), delaying telomeric shortening (29), by acting directly on the brain and cognition (30,31), and by reducing visceral fat specifically (32). We have recently demonstrated the buffering effects of being active on the association between stress and telomere length, thus providing initial support for a likely mechanism through cell dynamics (29).

The present study has several strengths, including the large sample size, the longitudinal and prospective approach to the analyses, and the inclusion of several potentially confounding factors such as BMI and a diagnosis of diabetes. Furthermore, the present study was able to examine effects of perceived financial strain on health, independent from the direct effects of objective markers of SES such as income and education level. The present study adds to previous work demonstrating long-term effects of financial strain on health and the potential of physical activity to act as a stress buffer.

The present study also has some limitations. First, we used the seventh year of the study as the baseline since that was the first year both income and financial strain were reported in the same year, thus potentially limiting our findings to the effects of financial strain and physical activity levels during the mid 30s. Second, we assume, as other researchers do (11,12,33), that the psychological strain from financial difficulties may be a particularly active component of low income affecting health. Yet, future studies should explicitly examine this by purposefully measuring psychological stress from financial strain. Third, Year 7 participants were more educated and more white than the initial sample recruited into the study. As a result, findings might be limited to more educated or white samples.

An important limitation to our study is our restricted measurement battery. In the current study, financial strain was captured with a one-item question—physical activity with a measure developed for the CARDIA Study—and income was rated on an ordinal scale. Others have used more detailed financial strain questionnaires that should be used in future studies (32), although previous findings with categorical data are consistent with the current study (11,23). In addition, based on a previous study (25), we dichotomized participants into active and less active categories. However, the CARDIA physical activity questionnaire does not directly measure duration, and thus, EUs cannot be directly translated into a meaningful precise amount of activity. This may likely have resulted in lack of direct associations between physical activity and glucose levels. Furthermore, objective measures of physical fitness are stronger predictors of biological outcomes than self-reported physical activity (34). Thus, it is difficult to state explicitly that 300 EU meets physical activity recommendations for health benefits. Future studies should measure a more precise dose of physical activity to determine how much activity is needed to buffer the impact of financial strain on impaired FG.

The finding that a more active lifestyle can attenuate the risk financially strained individuals have of future development of impaired FG suggests the need for future research to examine better ways to engage those under financial stress in exercise. As well, reducing financial strain in individuals and the psychological damage that it may have is an important area for future studies and public health policy. Clinicians are increasingly aware that the health needs of low-SES individuals in general require particular attention. The current study suggests that clinicians should more specifically target patients experiencing financial strain, placing greater emphasis on promoting physical activity in these patients and reducing the psychological impact of financial difficulties. Future research should also identify factors among those with financial strain that predict physical activity, to assist with tailoring interventions. These data suggest that promoting physical activity may alleviate the damaging health consequences of financial stress. In turn, this could dampen the social and economic costs to the individuals and to society.

REFERENCES

1. Cowie CC, Rust KF, Burd-Holt DD, Eberhardt MS, Flegal KM, Engelgau MM, Saydah SH, Williams DE, Geiss LS, Gree EW. Prevalence of diabetes and impaired fasting glucose in adults in the US population—National Health and Nutrition Examination Survey 1999–2002. Diabetes Care 2006;29:1263–8.
2. Heron M, Tejada-Vera B. Deaths: leading causes for 2005. Natl Vital Stat Rep 2009;58:1–97.
3. Lorenzo C, Williams K, Hunt KJ, Haffner SM. The National Cholesterol Education Program – Adult Treatment Panel III, International Diabetes Federation, and World Health Organization definitions of the metabolic syndrome as predictors of incident cardiovascular disease and diabetes. Diabetes Care 2007;30:8–13.
4. Barr ELM, Zimmet PZ, Welborn TA, Jolley D, Magliano DJ, Dunstan DW, et al. Risk of cardiovascular and all-cause mortality in individuals with diabetes mellitus, impaired fasting glucose, and impaired glucose tolerance—the Australian Diabetes, Obesity, and Lifestyle Study (AusDiab). Circulation 2007;116:151–7.
5. Edelstein SL, Knowler WC, Bain RP, Andres R, BarrettConnor EL, Dowse GK, et al. Predictors of progression from impaired glucose tolerance to NIDDM—an analysis of six prospective studies. Diabetes 1997;46:701–10.
6. Unwin N, Shaw J, Zimmet P, Alberti K. Impaired glucose tolerance and impaired fasting glycaemia: the current status on definition and intervention. Diabet Med 2002;19:708–23.
7. Lidfeldt J, Li TY, Hu FB, Manson JE, Kawachi I. A prospective study of childhood and adult socioeconomic status and incidence of Type 2 diabetes in women. Am J Epidemiol 2007;165:882–9.
8. Adler NE, Boyce T, Chesney MA, Cohen S, Folkman S, Kahn RL, et al. Socioeconomic status and health: the challenge of the gradient. Am Psychol 1994;49:15–24.
9. Larranaga I, Arteagoitia JM, Rodriguez JL, Gonzalez F, Esnaola S, Pinies JA, et al. Socio-economic inequalities in the prevalence of Type 2 diabetes, cardiovascular risk factors and chronic diabetic complications in the Basque Country, Spain. Diabet Med 2005;22:1047–53.
10. Adler NE, Ostrove JM. Socioeconomic status and health: what we know and what we don't. In: Adler NE, Marmot M, McEwen B, Stewart J, editors. New York, NY: New York Academy of Sciences; 1999:3–15.
11. Georgiades A, Janszky I, Blom M, Laszlo KD, Ahnve S. Financial strain predicts recurrent events among women with coronary artery disease. Int J Cardiol 2009;135:175–83.
12. Steptoe A, Brydon L, Kunz-Ebrecht S. Changes in financial strain over three years, ambulatory blood pressure, and cortisol responses to awakening. Psychosom Med 2005;67:281–7.
13. Kessler RC, Turner JB, House JS. Intervening processes in the relationship between unemployment and health. Psychol Med 1987;17:949–61.
14. Lantz PM, House JS, Lepkowski JM, Williams DR, Mero RP, Chen JM. Socioeconomic factors, health behaviors, and mortality—results from a nationally representative prospective study of US adults. JAMA 1998;279:1703–8.
15. Cohen S, Schwartz JE, Epel E, Kirschbaum C, Sidney S, Seeman T. Socioeconomic status, race, and diurnal cortisol decline in the Coronary

Artery Risk Development in Young Adults (CARDIA) study. Psychosom Med 2006;68:41–50.
16. Dishman RK, Warren JM, Hong S, Bunnell BN, Mougey EH, Meyerhoff JL, et al. Treadmill exercise training blunts suppression of splenic natural killer cell cytolysis after footshock. J Appl Physiol 2000;88:2176–82.
17. Rimmele U, Zellweger BC, Marti B, Seiler R, Mohiyeddini C, Ehlert U, et al. Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. Psychoneuroendocrinology 2007;32:627–35.
18. Hamer M, Steptoe A. Association between physical fitness, parasympathetic control, and proinflammatory responses to mental stress. Psychosom Med 2007;69:660–6.
19. Matthews K, Schwartz J, Cohen S, Seeman T. Diurnal cortisol decline is related to coronary calcification: CARDIA study. Psychosom Med 2006; 68:657–61.
20. Pradhan AD, Manson JE, Rifai N, Buring JE, Ridker PM. C-reactive protein, interleukin 6, and risk of developing Type 2 diabetes mellitus. JAMA 2001;286:327–34.
21. Pereira MA, Kartashov AI, Ebbeling CB, Van Horn L, Slattery M, Jacobs DR, et al. Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. Lancet 2005;365:36–42.
22. Szanton SL, Allen JK, Thorpe RJ, Seeman T, Bandeen-Roche K, Fried LP. Effect of financial strain on mortality in community-dwelling older women. J Gerontol B Psychol Sci Soc Sci 2008;63:S369–74.
23. Szanton SL, Thorpe RJ, Whitfield K. Life-course financial strain and health in African-Americans. Soc Sci Med 2010;71:259–65.
24. Jacobs DR, Hahn LP, Haskell WL, Pirie P, Sidney S. Validity and reliability of short physical activity history: CARDIA and the Minnesota Heart Health Program. J Cardiopulm Rehabil Prev 1989;9:448–59.
25. Parker ED, Schmitz KH, Jacobs DR, Dengel DR, Schreiner PJ. Physical activity in young adults and incident hypertension over 15 years of follow-up: the CARDIA study. Am J Public Health 2007;97:703–9.
26. Kumari M, Badrick E, Chandola T, Adler NE, Epel E, Seeman T, et al. Measures of social position and cortisol secretion in an aging population: findings from the Whitehall II study. Psychosom Med 2010;72:27–34.
27. Fleshner M, Campisi J, Deak T, Greenwood BN, Kintzel JA, Leem TH, et al. Acute stressor exposure facilitates innate immunity more in physically active than in sedentary rats. Am J Physiol Regul Integr Comp Physiol 2002;282:R1680–6.
28. Traustadottir T, Bosch PR, Matt KS. The HPA axis response to stress in women: effects of aging and fitness. Psychoneuroendocrinology 2005;30: 392–402.
29. Puterman E, Lin J, Blackburn E, O'Donovan A, Adler N, Epel E. The power of exercise: buffering the effect of chronic stress on telomere length. PLos One 2010;5:e10837.
30. Wolkowitz OM, Epel ES, Reus VI, Mellon SH. Depression gets old fast: do stress and depression accelerate cell aging? Depress Anxiety 2010;27: 327–38.
31. McEwen BS. Physiology and neurobiology of stress and adaptation: central role of the brain. Physiol Rev 2007;87:873–904.
32. Kay SJ, Singh MAF. The influence of physical activity on abdominal fat: a systematic review of the literature. Obes Rev 2006;7:183–200.
33. Rios RRR, Zautra AJ. Socioeconomic disparities in pain: the role of economic hardship and daily financial worry. Health Psychol 2011;30:58–66.
34. Sternfeld B, Sidney S, JacobsJr DR, Sadler MC, Haskell WL, Schreiner PJ. Seven-year changes in physical fitness, physical activity, and lipid profile in the CARDIA study. Ann Epidemiol 1999;9:25–33.

APPENDIX A. Activity Categories in the CARDIA Physical Activity Questionnaire (34)

Vigorous activities
Running, jogging
Vigorous racquet sports, including tennis, badminton, paddleball, racquetball, handball
Bicycle, faster than 10 mph, hard exercise on exercise bicycle, rowing machine
Swim vigorous exercise class or vigorous dancing, including jazzercise, Jane Fonda–type workout, aerobic dancing, ballet
Vigorous job activity such as lifting, carrying, digging
Home or leisure activity such as snow shoveling, moving heavy objects, or weight lifting
Strenuous sports such as basketball, football, skating, or skiing
Moderate activities
Nonstrenuous sports such as softball, shooting baskets, volleyball, ping pong, leisurely jogging, swimming, or hiking
Walking, hiking, walking to work
Bowling, golf
Home exercises, calisthenics
Home maintenance gardening, including carpentry, painting, raking, or mowing