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Psychological resources and incident hypertension in the Coronary Artery Risk Development in Young Adults (CARDIA) study

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Abstract

Objective: Examining factors that may protect against the development of hypertension is critical, as hypertension is a major public health concern. We examined the individual and combined associations of psychological resources (optimism and mastery) on incident hypertension over 15-years.

Methods: We used data from four exams of the Coronary Artery Risk Development in Young Adults (CARDIA) study over 15-years (CARDIA exam years 15 – 30). Optimism and mastery were standardized to a *z*-score separately and summed to generate a psychological resources score. We examined incidence of hypertension (stages 1 and 2; SBP ≥ 130 mmHg or DBP ≥ 80 mmHg) and stage 2 hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) among participants without hypertension at baseline. Multivariable logistic regressions adjusted for sociodemographic factors, behavioral factors, and depressive symptoms.

Results: Of 2,927 participants, 58% were women, 42% were Black, and the average age at study baseline was 40 years (3.63). A higher psychological resources score was associated with lower odds of developing hypertension (stages 1 and 2) (OR: 0.89, 95% CI: −0.21, −0.03, $p <$ .01) and stage 2 hypertension (OR: 0.88, 95% CI: −0.21, −0.04, $p <$ .01), after adjustment for

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sociodemographic factors. However, following adjustment for behavioral factors and depressive symptoms, the associations for hypertension (stages 1 and 2) and stage 2 hypertension were no longer statistically significant.

Conclusions: Greater psychological resources are associated with lower odds of hypertension. Associations were attenuated after additional adjustment for behavioral factors, indicating these factors may be important confounders or mediators.

Keywords

hypertension; cardiovascular diseases; optimism; perceived control

Introduction

Hypertension is a major public health concern, both globally and within the United States in particular. According to the Centers for Disease Control and Prevention (CDC), hypertension was the primary or contributing cause to nearly 500,000 deaths in 2018 (CDC, 2018). Indeed, hypertension is a risk factor for heart disease and stroke, two of the leading causes of death in the United States (Virani et al., 2021). Sometimes referred to as the “silent killer,” hypertension is particularly worrisome given it often lacks noticeable warning signs or symptoms. Hypertension is also associated with reduced health-related quality of life and functional impairment (Taichman et al., 2005; Trevisol et al., 2011) and an increased risk of psychological problems, such as anxiety and depression (Meng et al., 2012; Pan et al., 2015). Given the physical and psychological consequences of this condition, examining factors that may protect against the development of hypertension is critical.

Psychological resources are factors that have beneficial associations with physical and mental health outcomes (Taylor & Broffman, 2011). Two commonly studied psychological resources are optimism and a sense of mastery and personal control (henceforth referred to as mastery). *Optimism* is conceptualized as generally having positive expectations for future outcomes (Carver et al., 2010) while *mastery* is considered the extent to which one feels they have personal control in outcomes, or the way things turn out (Pearlin et al., 1981). These two constructs are associated with one another (Ruthig & Chipperfield, 2007; Ruthig et al., 2007), but are thought to be theoretically and empirically distinct from one another. Prior literature suggests that these two psychological resources are related to approach-oriented coping rather than avoidant coping (Taylor & Broffman, 2011). That is, when faced with a stressor or threat, individuals high on optimism or mastery may be more likely to use coping responses such as problem solving (or problem-focused coping) and emotional expression (or emotion-focused coping). With problem-focused coping, individuals may attempt to cope with a situation through behavioral efforts to change what they can about the stressful situation; alternatively, with emotion-focused coping, individuals may seek out emotional social support to talk about the stressful situation (Ketcher et al., 2021). Continued use of such approach-oriented coping in response to stressors or threats may guard individuals from harmful stress exposure over time (Taylor & Seeman, 1999). It is possible having psychological resources for adaptive coping responses acts as a *protective factor* against hypertension disease development.

Although the relation between psychological resources and physical health outcomes has been well-established, few studies have examined associations with hypertension specifically. For example, a meta-analysis found that optimism was significantly associated with physical well-being, a pattern particularly relevant for cardiac patients (Rasmussen et al., 2009). However, of the 83 included studies, only one examined the association between optimism and hypertension. Similarly, a systematic review found that greater mastery was associated with better cardiometabolic health and lower risk for cardiovascular disease and death, but no studies in the review examined hypertension as a metric of cardiovascular health (Roepke & Grant, 2011). As such, there appears to be a lack of research examining psychological resources and hypertension specifically.

There are also methodological limitations concerning existing studies that have examined the relation between psychological resources and hypertension. For example, previous studies have relied on cross-sectional designs or non-validated single-item measures for psychological resources (Conway et al., 2008; Trudel-Fitzgerald et al., 2014). More longitudinal studies with validated measures of psychological resources are needed to further examine these associations. Two recent longitudinal studies reported associations between greater optimism and lower risk of hypertension (Boehm et al., 2020; Kubzansky et al., 2020). However, there is a paucity of longitudinal investigations on the associations between mastery and incident hypertension, or examinations into the combined effect of psychological resources with hypertension.

To address these limitations, the present study investigated the individual and combined prospective associations of psychological resources with incident hypertension over a 15-year period. The combined association was examined to see if the association with incident hypertension was stronger when having higher levels of both psychological resources. Because the American Heart Association created two new stages of hypertension in 2017 (stage 1 and stage 2) (Whelton et al., 2018), the current study investigates the association of psychological resources on different stages of hypertension. It was hypothesized that higher levels of psychological resources (optimism and mastery, assessed individually and as a composite measure) would be associated with lower odds of developing incident hypertension.

Method

Participants and Procedures

Data were used from the longitudinal Coronary Artery Risk Development in Young Adults (CARDIA) study. Requests to access the data, study materials, and analytic methods may be sent to the CARDIA Study Coordinating Center (CARDIA, 2022). CARDIA started in 1985–86 and included healthy White or Black men and women (N = 5,115) between the ages of 18 and 30 years. Participants were enrolled from four sites across the United States (Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA), and recruitment was balanced for age, sex, race, and education (Friedman et al., 1988). Follow-up assessments were completed at study years 2, 5, 7, 10, 15, 20, 25, and 30. Original study approval was obtained from the Institutional Review Boards across all four participating institutions

(University of Alabama at Birmingham; Northwestern University; University of Minnesota; and Kaiser Permanente).

The present study uses data from 4 exams corresponding to years 15 (2000–01, ages 33–45), 20 (2005–06, ages 38–50), 25 (2010–11, ages 43–55), and 30 (2015–16, ages 48–60). Retention rates from the original surviving cohort were 74%, 72%, 72%, and 71%, respectively. Exam year 15 henceforth will be referred to as baseline, while exam years 20, 25, and 30 will be referred to as the 5-, 10- and 15-year follow-up, respectively. Year 15 was selected as baseline, as the measures that make up psychological resources were only included in the year 15 questionnaire battery. As year 15 is the study baseline, the current study includes participants whose ages ranged from 33–45 at baseline, to ages 48–60 at the last follow-up.

Stage 1 hypertension is defined as systolic blood pressure (SBP) 130–139 mmHg or diastolic blood pressure (DBP) 80–89 mmHg, while stage 2 hypertension is defined as SBP ≥140 mmHg or DBP ≥90 mmHg (Whelton et al., 2018). Hypertension is characterized as stage 1 and stage 2 hypertension. The current study examined hypertension (stages 1 and stage 2) first, followed by stage 2 hypertension. Stage 2 hypertension was examined separately, and served as the primary outcome of interest, as it is a more serious condition, putting individuals with blood pressure within this range at greater risk for cardiovascular (CVD) events, such as fatal and nonfatal coronary heart disease, stroke, or hospitalization for heart failure, compared to individuals with normal blood pressure or stage 1 hypertension (Yano et al., 2018). Further, increased SBP and DBP has shown greater associations with myocardial infarction, angina, peripheral arterial disease, and abdominal aortic aneurysm (Rapsomaniki et al., 2014). Having hypertension (stages 1 and 2) at baseline was an exclusion criterion for the hypertension (stages 1 and 2) analyses, while stage 2 hypertension at baseline was an exclusion criterion for the stage 2 hypertension analyses. Stage 1 hypertension alone was not examined in the current study, as the number of patients meeting criteria for stage 1 hypertension during follow-ups was a relatively small sample, compared to those meeting criteria for hypertension (stages 1 and 2) or stage 2 hypertension.

See Figure 1 for the study flow chart. Of the 3,671 participants who took part in the baseline exam, 15 did not have complete psychological resources data and were removed for purposes of data analysis. Of the remaining 3,656 individuals, 1,427 met criteria for hypertension (stages 1 and 2) at baseline and were excluded from the hypertension (stages 1 and 2) analyses. An additional 8 individuals were missing SBP and DBP data at baseline and were excluded. Thus, the total sample of individuals who were included in the analyses for hypertension (stages 1 and 2) was 2,221.

Of the 3,656 who took part in the baseline exam and had complete psychological resources data, 719 met criteria for stage 2 hypertension at baseline, and an additional 10 individuals were missing blood pressure data (i.e., SBP or DBP) at baseline. These 729 were excluded from the stage 2 hypertension analyses. Thus, the total sample of individuals included in the analyses for incident stage 2 hypertension was 2,927. Of note, because more individuals met criteria for hypertension (stages 1 and 2) at baseline, compared to stage 2 hypertension, less individuals were included in the analyses for hypertension (stages 1 and 2).

Participants did not have to be present for all subsequent exams to be included in the current analyses. That is, participants were included in the current study if they had complete psychological resources and blood pressure data at baseline even if they did not have complete blood pressure data at all follow-up exams. This decision was made to minimize the loss of data that would occur by including participants with only complete data at baseline, and at the 5-, 10-, and 15-year follow-ups.

Measures

Psychological resources—Two components of psychological resources theorized to be protective from stress exposure (Taylor & Seeman, 1999) were included in the CARDIA year 15 (i.e., baseline) questionnaire battery. These components included optimism and mastery. Optimism was measured with the Life Orientation Test-Revised (LOTR) (Scheier et al., 1994), a 6-item measure that assesses an optimistic attitude. The internal consistency for the current sample was adequate (α = .78). Mastery was measured using the Pearlin Mastery Scale (Pearlin & Schooler, 1978), a 7-item measure that assesses the extent to which persons believe whether they are able to control or influence outcomes in their life. The internal consistency for the current sample was good (α = .80). Responses from both questionnaires were rated on a 5-point Likert scale, ranging from 1 (*strongly agree*) to 5 (*strongly disagree*). Items on each scale were then averaged to create a total score for each component, with higher scores indicating greater levels of optimism and mastery. Each scale was then standardized to a *z*-score and summed to create a total psychological resources score. A similar approach has been used previously to examine psychological resources (de Baca et al., 2020). The internal consistency for the 13-item psychological resources composite measure was good (α = .85).

Incident Hypertension—Hypertension (stages 1 and 2) and stage 2 hypertension were assessed at baseline and the 5-, 10- and 15-year follow-up. Hypertension (stages 1 and 2) was categorized as SBP ≥ 130 mmHg or DBP ≥ 80 mmHg, or use of hypertensive medication. Stage 2 hypertension was categorized as SBP ≥ 140 mmHg or DBP ≥ 90 mmHg, or use of hypertensive medication. Use of hypertensive medication was included in the criteria, as initiation of antihypertensive drug therapy has been recommended for patients outside of the optimal blood pressure ranges (Chobanian et al., 2003), and use of this medication will reduce blood pressure readings in these participants. Hypertension (stages 1 and 2) status was missing for 258 of individuals at the 5-year follow-up, 286 at the 10-year follow-up, and 379 at the 15-year follow-up. Missing data for the stage 2 hypertension status were as follows: 363, 411, and 535, respectively.

Blood pressure was measured in-person by clinic staff. At each visit, participants first completed a quiet rest for 5-minutes. Then, three 1-minute blood pressure measurements were taken from participants as they were seated in an upright position from the right arm. The second and third blood pressure readings were averaged and used for analyses. Between each measurement, participants were instructed to raise their right arm for five seconds. A recovery period of at least 30 seconds was used between each measurement. At baseline, blood pressure was measured with the Hawksley random zero sphygmomanometer. In all subsequent years, an Omron HEM907XL device was used (Ostchega et al., 2010; Levine

et al., 2011; Liu et al., 2012; Thomas et al., 2018; Pugliese et al., 2019). More information regarding these procedures can be found online (https://www.cardia.dopm.uab.edu/).

Covariates—The covariates included in the current study were collected at baseline and included (1) sociodemographic factors, (2) behavioral factors, and (3) depressive symptoms. The sociodemographic covariates included age (years), sex (male or female), race (Black or White), study center (Birmingham, AL; Chicago, IL; Oakland, CA; Minneapolis, MN), and education (years). Behavioral factors included alcohol consumption, smoking status, physical activity level, fast food frequency, and BMI. Alcohol use was assessed with the CARDIA alcohol use questionnaire and calculated as the volume (mL) of alcohol consumed per week. Smoking status was assessed using the CARDIA tobacco use questionnaire and organized into three categories: current smoker, former smoker, and nonsmoker. Physical activity level was assessed using the CARDIA physical activity history questionnaire (Jacobs et al., 1989). The questionnaire measures the intensity and duration of an individual's participation in different moderate (e.g., walking and hiking) and vigorous (e.g., running or jogging) physical activities over the previous 12-months. A computer algorithm was then used to calculate a total activity score for all activities, which was expressed as a continuous score in exercise units. Fast food frequency was assessed with the CARDIA dietary practices, behaviors, and attitudes questionnaire, and measures how many times per week individuals consumed fast food for breakfast, lunch, or dinner. Fast food frequency was included as an indicator of dietary practices, as fast-food intake has been shown to be positively associated with weight gain and insulin resistance (Pereira et al., 2005) and greater fat, saturated fat and sodium intake (Paeratakul et al., 2003). Weight (in kilograms) and height (in meters) were measured during an in-person study visit using a stadiometer and scale. BMI was then calculated with the measured height and weight (kg/m^2). Finally, depressive symptoms were assessed with the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977), a 20-item scale that assesses an individual's mood during the past week. Items are rated on a 4-point Likert scale ranging from 0 (*rarely or none of the time)* to 4 (*m*ost *or all of the time),* with higher scores indicating greater depressive symptoms.

Statistical Analyses

Means and frequencies of participant characteristics were calculated overall and by tertiles of the psychological resources composite score, represented as low, medium, and high. The median and interquartile range were calculated for alcohol consumption and physical activity exercise units, as these variables were not normally distributed. One-way analysis of variance (ANOVA) and chi-square tests were used to assess differences in participant characteristics across tertiles of psychological resources.

Next, two sets of multivariable logistic regression analyses were conducted for hypertension (stages 1 and 2), followed by stage 2 hypertension. Preliminary analyses included the following model:

$$logit\{E(Y_i)\} = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

where Y_i is a binary outcome equal to 0 if an individual does not have hypertension, and 1 if an individual has hypertension; X_1 is the logit value for each individual included in the analyses (i.e., the logit value for each participant who does not have hypertension at baseline); X_2 is the continuous value of the sum of psychological resources, and X_3 is either equal to 5 to indicate a 5-year follow-up, 10 to indicate a 10-year follow-up, and 15 to indicate a 15-year follow-up. As indicated previously, participants did not need to attend all three follow-up visits to be included in the current analyses because all models were longitudinal with Time added as a variable. This approach allows for the inclusion of participants who had baseline data regardless of the number of follow-up visits, as it does not require that all participants have the same number of visits. Thus, if participants had missing blood pressure data at one of the follow-ups, only that observation was excluded, but the other observations were retained for analysis. A series of sensitivity analyses were also conducted with participants with complete primary outcome data (i.e., blood pressure data) across exam years for both hypertension (stage 1 and 2) and stage 2 hypertension outcomes.

Using multivariable logistic regression, covariates were added to each subsequent step. In line with previous research (Boehm et al., 2020; Kubzansky et al., 2020), sociodemographic, behavioral factors, and depressive symptoms covariates were selected as potential confounders. Step 1 adjusted for sociodemographic variables assessed at baseline (age, sex, race, study site, and years of education). Step 2 additionally adjusted for behavioral factors (alcohol consumption, smoking status, physical activity level, fast food frequency, and BMI). Step 3 was further adjusted for the presence of depressive symptoms. Separate analyses were conducted with hypertension (stages 1 and 2) and stage 2 hypertension as binary outcomes with steps 1, 2, and 3 for the composite *z*-score for psychological resources and each of its *z*-score components (i.e., optimism and mastery) to test the individual impact of each construct. Odds ratios are reported as the exponentiation of the standardized estimate, while confidence intervals (CIs) are reported as log odds. A total of 6 models were run, with three steps per model. All analyses were conducted using SAS, version 9.4 (Cary, NC). Finally, given the balanced sample between White and Black participants, a series of exploratory analyses examined the association between psychological resources and incident hypertension stratified by race.

Results

Participant Characteristics

On average, participants were 40.0 ± 3.6 years old at baseline, 58.0% identified as female and 58.0% identified as White (Table 1). The number of individuals who met criteria for hypertension (stages 1 and 2) across the 15 years were: 262 (13.4%), 515 (26.6%), and 632 (34.3%) at the 5-, 10- and 15-year follow-up exams, respectively. The number of individuals who met criteria for stage 2 hypertension across the 15 years were: 267 (10.4%), 580 (23.1%), and 764 (31.9%) at the 5-, 10-, and 15-year follow-up, respectively. The percentage of individuals who met stage 2 hypertension criteria at each follow-up, by level of psychological resource, is presented in Figure 2. The total sample size for each hypertension outcome across the follow-up periods is provided in Figure 1. When psychological

resources were examined across tertiles (i.e., low, medium, and high), participants differed on several characteristics, including smoking status, education, physical activity, and depressive symptoms. Individuals with low psychological resources were more likely to be a current smoker and reported significantly less years of education and moderate-to-vigorous physical activity compared to medium and high groups. Additionally, individuals with low psychological resources reported significantly greater levels of depressive symptoms compared to those in the medium and high groups.

The Unadjusted Effect of Psychological Resources on Hypertension (Stages 1 and 2) and Stage 2 Hypertension.

Univariate analyses were performed to determine the unadjusted association of psychological resources with incident hypertension at each of the three follow-up exam years. The first model included a binary outcome for hypertension (stages 1 and 2) with psychological resources and time as predictors. Following exponentiation of the standardized estimate, for each 1-unit increase in psychological resources, the odds of developing hypertension (stages 1 and 2) decreased by 0.12 (95% CI: −0.22, −0.04; $p < .01$). Further, each 5-year increase in time across the 15-year follow-up was associated with a 0.11 increase in odds of developing hypertension (stages 1 and 2) (95% CI: 0.10, 0.12; $p < .001$). Similarly, for each 1-unit increase in psychological resources, the odds of developing stage 2 hypertension decreased by 0.14 (95% CI: −0.23, −0.07; $p < .001$), and each 5-year follow-up period corresponded with a 0.13 increase in odds of developing stage 2 hypertension (95% CI: 0.11, 0.13; $p < .001$).

Psychological Resources and Incident Hypertension (Stages 1 and 2).

Details including odds ratios of the standardized estimates, confidence intervals, and indications of significance for each model can be found in Table 2. Greater psychological resources were associated with lower odds of developing hypertension (stages 1 and 2) in step 1 (OR = 0.89, 95% CI: −0.21, −0.03; $p < .01$). In steps two and three, greater psychological resources were no longer associated with lower odds of developing hypertension (stages 1 and 2) (Step 2: OR = 0.92, 95% CI: −0.19, 0.02; $p = .12$; Step 3: OR = 0.90, 95% CI: −0.23, 0.02; $p = .10$).

Regarding these relationships among the individual components of psychological resources, optimism was associated with lower odds of developing hypertension (stages 1 and stage 2) in step 1 (OR = 0.88, 95% CI: −0.22, −0.04; $p = .01$). However, in steps 2 and 3, greater optimism was no longer associated with lower odds of developing hypertension (stages 1 and 2). No associations were observed for mastery regarding hypertension (stages 1 and 2).

Psychological Resources and Stage 2 Incident Hypertension.

Details including odds ratios of the standardized estimates, confidence intervals, and indications of significance for each model can be found in Table 2. After adjusting for sociodemographic factors (step 1), greater psychological resources were associated with lower odds of developing stage 2 hypertension (OR = 0.88, 95% CI: −0.21, −0.04; $p < .01$). In step 2, which further adjusts for various behavioral factors, greater psychological resources were no longer associated with stage 2 hypertension (OR = 0.92, 95% CI:

−0.18, 0.01; $p = .07$). Similarly, following adjustment for depressive symptoms (step 3), the associations between psychological resources and incident stage 2 hypertension remained non-significant (OR = 0.94, 95% CI: −0.17, 0.05; $p = .29$). After examining these relationships using the components of psychological resources as predictors, it was found that higher levels of optimism and mastery were associated with lower odds of developing stage 2 hypertension in step 1 (respectively: OR = 0.90, 95% CI 0.19, −0.02; $p < .01$; OR = 0.90, 95% CI −0.19, −0.03; $p < .01$). In steps 2 and 3, neither optimism nor mastery remained associated with stage 2 hypertension. Tables S1 and S2 contain final model data for hypertension (stage 1 and stage 2) and stage 2 hypertension, respectively.

Regarding sensitivity analyses, a total of 1,650 participants had complete outcome data across the three follow-up periods for hypertension (stages 1 and 2), whereas 2,136 participants had complete outcome data across the three follow-up periods for stage 2 hypertension. Results from these analyses can be found in Table S3 and, in general, followed the same pattern of results.

Exploratory Analyses

Given the balanced sample of White and Black participants in the current sample, models were stratified by race. Findings from these exploratory analyses can be found in the supplemental materials. To summarize, stratified models followed a similar pattern to the main study findings, such that all models were non-significant following adjustment of behavioral factors and depressive symptoms (Table S4).

Discussion

We examined the individual and combined associations of psychological resources (optimism and mastery) with incident hypertension (stages 1 and 2) and stage 2 hypertension over a 15-year period. This study examined this association across middle adulthood, with the average participant being 40 years old at the study baseline. Prior research has shown that men and women with hypertension in middle adulthood have higher lifetime risk for stroke, cardiovascular disease, and coronary heart disease (Allen et al., 2012). Thus, participants in the current study are at a critical age for the development of hypertension and future risk for adverse events. Findings indicated that combined psychological resources were associated with lower odds of developing both hypertension (stages 1 and 2) and stage 2 hypertension after accounting for sociodemographic characteristics; however, these associations were no longer statistically significant following further adjustment for behavioral factors and/or depressive symptoms. Similarly, optimism and mastery were no longer associated with hypertension (stages 1 and 2) and stage 2 hypertension after adjusting for behavioral factors and/or depressive symptoms. Interestingly, psychological resources were not associated with hypertension prior to the inclusion of depression, and when depression was added, it did not meaningful contribute to the models.

These findings vary from recent prospective reports examining psychological resources and incident hypertension. For instance, Kubzansky and colleagues (2020) examined whether optimism was associated with lower risk of developing hypertension in a U.S. active-duty military population over a four-year period. Findings from this investigation indicated

that optimism was associated with reduced risk of hypertension, even after adjusting for sociodemographic factors (e.g., age, sex, race), behavioral factors (e.g., alcohol and tobacco use, BMI), and a depression diagnosis (Kubzansky et al., 2020). However, in the current study, optimism was not associated with lower odds of developing hypertension (stages 1 and 2) and stage 2 hypertension after adjustment for behavioral factors and depressive symptoms. There are several differences between these two studies to consider, including demographics and characteristics of the study samples. Kubzansky et al. (2020) examined a military population while the current study examined a population-based national cohort. Further, the average age at baseline of participants in the current study ($M = 40.0$) was about ten years older than the activeduty military sample ($M = 29.0$), and the age range for participants differed between studies. In Kubzansky et al. (2020), hypertension diagnosis and depression were obtained from electronic health records (i.e., ICD-9 codes), whereas the current study measured blood pressure in-person, and depressive symptoms (not diagnosed depression) were assessed via self-report. Moreover, the previous report examined the associations between optimism and incident hypertension over a four-year period, whereas the current study examined this association over 15-years. To further clarify the impact of optimism on hypertension, future research should seek to replicate these findings, and continue to examine these factors longitudinally. As several studies have now investigated the impact of optimism on the development of hypertension (e.g., the current study, Kubzansky et al., 2020, Trudel-Fitzegerald et al., 2014), meta-examinations could help clarify the strength of this association and identify potential moderators that influence the magnitude of this association, such as age. However, given that investigations examining associations among optimism and hypertension appear to be understudied, more empirical research in this area is needed before such reviews can be conducted.

In the current sample, mastery was only associated with lower risk of developing stage 2 hypertension, independent of sociodemographic factors. Mastery was not associated with hypertension (stages 1 and 2). To our knowledge, this study is the first to specifically examine the association between mastery and hypertension prospectively. Previously, meta-analytic findings have indicated mastery may be associated with better cardiometabolic health (Roepke & Grant, 2011), including blood pressure. However, only a few of the studies included in that review used blood pressure as the metric of cardiovascular health. Future work would benefit from additional prospective investigations examining the association of mastery on incident hypertension over time.

Interestingly, although optimism and mastery are theorized to be two distinctive constructs, the Cronbach's alpha for the overall psychological resource for combined optimism and mastery was greater than the Cronbach's alpha for either optimism or mastery alone. This may suggest that these two constructs are more related than previously thought. Future examinations into these two constructs might be helpful in parsing out whether mastery and optimism are better captured under one distinct latent construct, particularly when using factor analytic methods.

Alternative Explanations

Contrary to hypotheses, independent and combined psychological resources were no longer associated with decreased odds of developing hypertension (stages 1 and 2) and stage 2 hypertension in middle adulthood, following adjustment of behavioral factors. Based on these findings, it appears that psychological resources do not play a protective role in the development of incident hypertension above and beyond behavioral factors such as alcohol use, tobacco use, moderate-to-vigorous physical activity, fast food intake frequency, and BMI. Behavioral factors thus appear to confound the association between psychological resources and incident hypertension. This may suggest that behavioral factors play a more important role in the development of incident hypertension than the role of psychological resources. As smoking status was associated with low psychological resources, this may suggest these participants are using maladaptive coping mechanisms, thus increasing their odds of developing hypertension.

Interestingly, the results of the current study differ from previous studies examining the association between optimism and incident hypertension. For example, in Kubzansky et al., 2020, findings were only partially attenuated by the inclusion of health behaviors. An alternative interpretation of the current findings might suggest that behavioral factors may have a mediating role in the association between psychological resources and incident hypertension. For example, having high expectations for, and feeling in control of future outcomes, may lead individuals to have a stronger sense of control over their health. This strong sense of control may correspond with an internal health-related locus of control, in which individuals believe their own consistent engagement in health behaviors, such as regular physical activity, limiting alcohol and tobacco consumption, and reducing fast food intake, leads to positive health outcomes. In the current study, the psychological resources and behavioral factor variables came from the same data collection year (CARDIA exam year 15). Thus, an exploratory mediation was not formally tested, as mediation analyses require temporal precedence. Future research, within the CARDIA study sample and in other study population, could benefit from such *a priori* investigations.

Strengths and Limitations

The current study has several strengths. The sample size for the current study was relatively large and consisted of a longitudinal investigation over 15-years. Hypertension (stages 1 and 2) and stage 2 hypertension were measured objectively at in-person study visits, and the sample included only individuals without hypertension at baseline. There are also limitations that should be considered. While study retention rates across the 15-years were relatively high for the incident hypertension outcomes, some individuals were missing blood pressure data at the 5-, 10- and 15-year follow-up. It is possible that these individuals who were lost to follow-up went on to develop incident hypertension, thus, the rates of incident hypertension in the current sample may be underestimated. Although a longitudinal model was employed to maximize the use of available data, not all participants in the models had complete primary outcome data for the three follow-up visits. Sensitivity analyses conducted in participants with only complete primary outcome data across all time points followed the same pattern of results; however, the missing data remains a limitation of the current study and should be considered when interpreting the results.

There are also several limitations to the way in which blood pressure was measured and incident hypertension was defined. The current study examined blood pressure in a clinical setting, rather than at-home blood pressure or ambulatory blood pressure monitoring. Clinic blood pressure may not reflect blood pressure in real world settings, making it less ecologically valid than other blood pressure measurements. Relatedly, incident hypertension inclusion criteria included use of antihypertensive medication. Although those on antihypertensive medication are assumed to be in the stage 2 hypertension category (based on treatment guidelines at the time of the exam), it is possible that participants had stage 1 hypertension. The current study did not examine stage 1 hypertension alone, due to sample size constraints of the current study. Future research with larger samples would benefit from examinations of psychological resources prospectively, across stage 1 hypertension, stage 2 hypertension, and hypertension (stages 1 and 2). Similarly, the current study did not examine elevated blood pressure, which could also be further explored in future work.

It is worth noting that the current study did not measure incident hypertension with a formal diagnosis of hypertension. Because incident hypertension relied solely on the blood pressure readings from a clinical setting, it is possible that participants with white-coat effect were flagged as having incident hypertension when in fact they did not have a clinical diagnosis of hypertension (Pickering et al., 2002). It could also be the case that some participants have masked hypertension, with normal blood pressure readings in clinical settings, but elevated blood pressure readings in other settings (Peacock et al., 2014).

While the current study attempted to adjust for behavioral factors such as alcohol consumption, smoking status, and physical activity, these measures were examined by self-reported questionnaire, which are subject to bias. It is also possible that other covariates that may be related to incident hypertension were not included in the current study, such as social support. Participants in the current sample identified as only White or Black; thus, findings cannot generalize to other racial or ethnic groups. The current study also did not include an *a priori* power calculation for the race-stratified exploratory analyses. Depressive symptoms in the current study were measured via self-report questionnaire and not by a structured clinical interview. Finally, psychological resources in the current study were only measured at one study time point. Thus, investigations into whether these factors changed or were stable across time were not possible. Results of the current study should be interpreted with these limitations in mind.

Conclusions

Hypertension is a major public health concern that is associated with reduced health-related quality of life, functional impairment, psychological distress, and death. As such, examining factors that may protect against the development of hypertension is critical. Optimism and mastery are two psychological resources that may help individuals protect themselves from stress exposure over time. The current study sought to examine the individual and combined associations of these resources with incident hypertension (hypertension (stages 1 and 2) and stage 2 hypertension) over a 15-year period (across middle adulthood) in a large sample of White and Black individuals. Contrary to expectations, findings indicate that individual and

combined psychological resources do not protect against the development of hypertension (stages 1 and 2) after adjustment of behavioral factors and depressive symptoms. As these results differ from previous reports (e.g., Kubzansky et al., 2020), future research should continue to investigate the associations between different types of psychological resources and incident hypertension.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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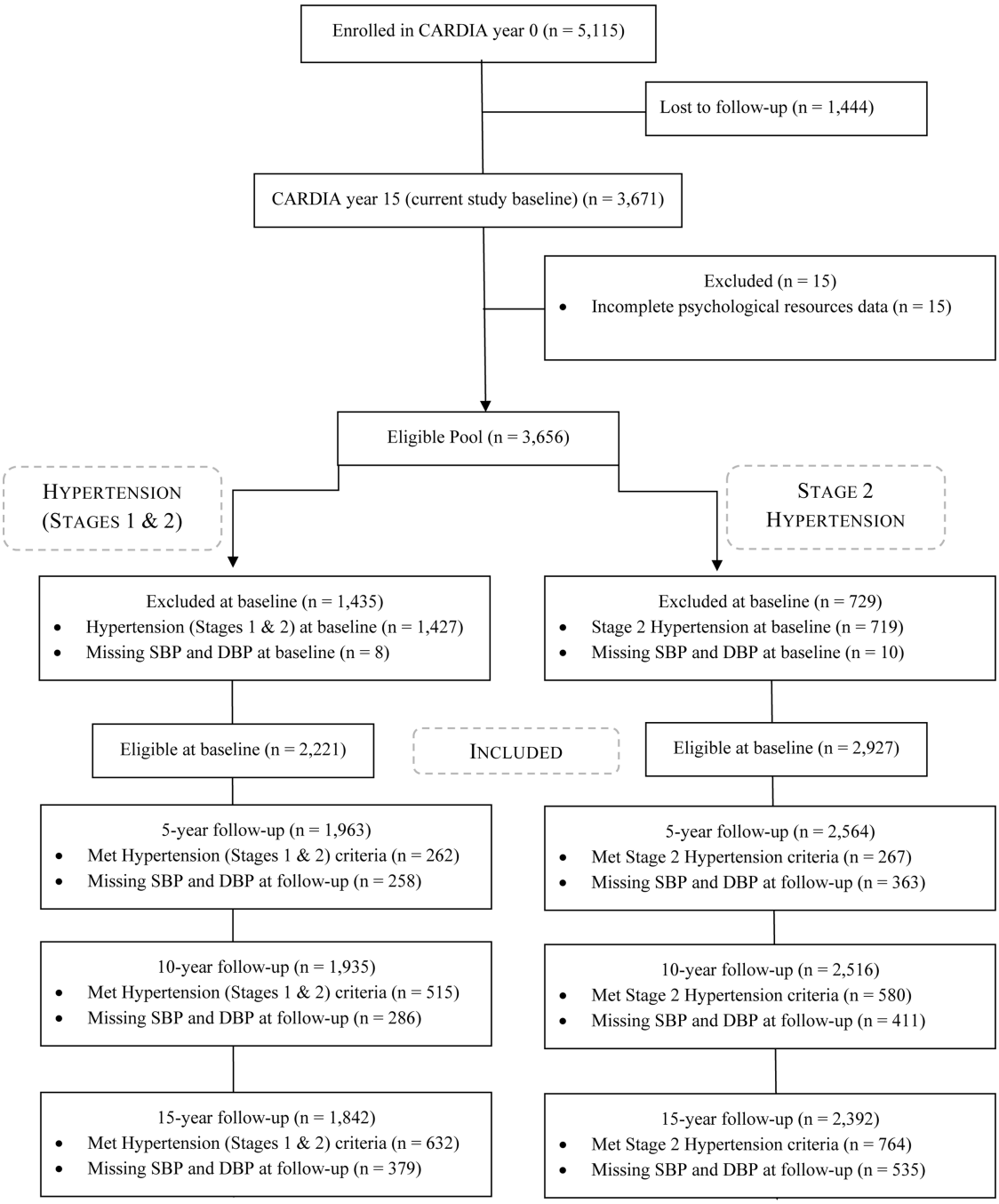

Figure 1.
Study population flow chart.

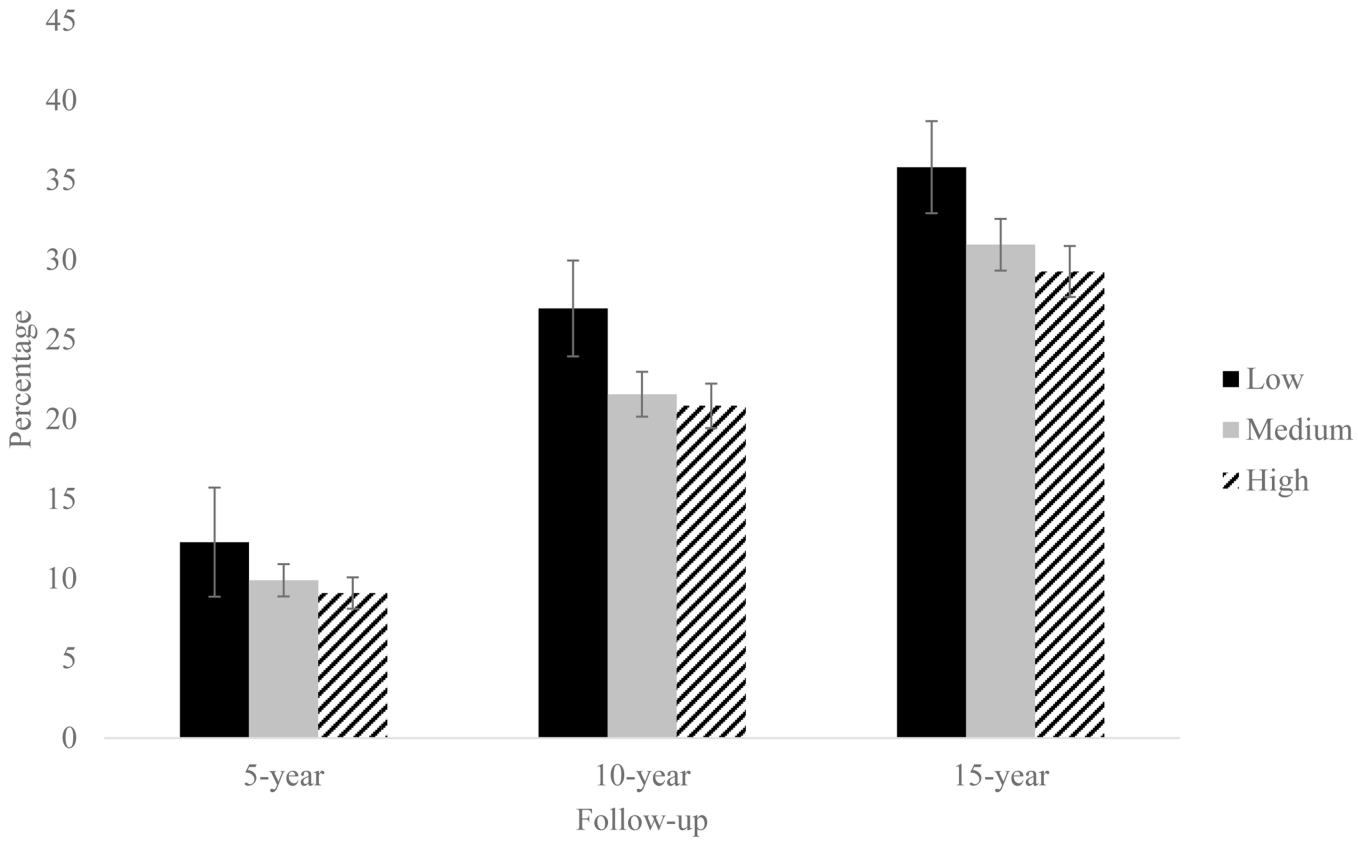

Figure 2.
Percent of individuals who met stage 2 hypertension criteria at each follow-up, by level of psychological resources. CARDIA, 2000–2016

Table 1.

Baseline (2000–01) participant characteristics overall and by level of psychological resources, for those without stage 2 hypertension at study year 15: CARDIA, 2000–2016

Baseline Characteristics	Total (N=2,927)	Level of psychological resources			F (df) or χ^2 (df)
		Low (N=983)	Medium (N=972)	High (N=972)	
Age, mean years ± SD	39.99 ± 3.63	40.03 (3.69)	40.01 (3.65)	39.94 (3.54)	0.15 (2, 2924)
Self-reported Sex, N(%)					2.62 (2)
Female	1697 (57.98)	563 (57.27)	555 (57.10)	579 (59.57)	-
Male	1230 (42.02)	420 (42.73)	417 (42.90)	393 (40.43)	-
Self-reported Race, N(%)					1.52 (2)
Black	1230 (42.02)	428 (43.54)	389 (40.02)	413 (42.49)	-
White	1697 (57.98)	555 (56.46)	583 (59.98)	559 (57.51)	-
Education, mean years ± SD	15.08 ± 2.54	14.68 (2.61)^{ab}	15.02 (2.51)^{ac}	15.53 (2.42)^{bc}	28.52 (2, 2920)***
Alcohol consumption, median ml ± IQR	2.43 (0–12.95)	2.39 (0–12.61)	2.43 (0–13.34)	2.43 (0–12.75)	2.08 (2, 2920)
Smoking status, N(%)					50.29 (4)***
Never smoker	1749 (59.82)	548 (55.80)^{b}	567 (58.39)^{c}	634 (65.29)^{bc}	-
Former smoker	552 (18.88)	165 (16.80)^{b}	190 (19.57)^{c}	197 (20.29)^{bc}	-
Current smoker	623 (21.31)	269 (27.39)^{b}	214 (22.04)^{c}	140 (14.42) ^{bc}	-
Moderate-to-vigorous physical activity, median exercise units ± IQR	288 (146–502)	243 (125–450)^{ab}	300 (150–508)^{ac}	319 (168–552)^{bc}	20.04 (2, 2919)***
Fast food frequency, mean times/week ± SD	2.76 (3.37)	2.79 (3.33)	2.74 (3.18)	2.73 (3.61)	0.09 (2, 2635)
BMI, kg/m^2	27.91 (6.21)	28.30 (6.65)	27.78 (6.01)	27.65 (5.93)	2.98 (2, 2899)
Depressive symptoms, mean ± SD	8.83 (7.69)	13.94 (8.71)^{ab}	7.77 (6.07)^{ac}	4.75 (4.56)^{bc}	477.01 (2, 2897)***

Note: Group comparisons were examined using one-way Analysis of Variance for continuous variables and chi-square tests of independence for categorical variables. For post hoc comparisons

^{a}indicates a significant difference between low vs. medium

^{b}indicates a significant difference between low vs. high

^{c}indicates a significant difference between medium and high.

$^{*}p < .05$

$^{**}p < .01$

***
$p < .001$. Low, Medium, High resources refer to tertiles of a z-score based composite score of psychological resources (optimism and mastery) – see methods section

Table 2.

Associations between baseline psychological resources (standardized) and the odds of developing incident hypertension over 15-years[a]: CARDIA, 2000–2016

	Step 1[b]	Step 2[c]	Step 3[d]
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Hypertension (stages 1 and 2)			
Psychological resources	0.89 (−0.21, −0.03) **	0.92 (−0.19, 0.02)	0.90 (−0.23, 0.02)
Optimism	0.88 (−0.22, −0.04) **	0.92 (−0.19, 0.02)	0.90 (−0.22, 0.01)
Mastery and personal control	0.92 (−0.18, 0.01)	0.94 (−0.16, 0.05)	0.94 (−0.18, 0.06)
Stage 2 Hypertension			
Psychological resources	0.88 (−0.21, −0.04) **	0.92 (−0.18, 0.01)	0.94 (−0.17, 0.05)
Optimism	0.90 (−0.19, −0.02) **	0.94 (−0.16, 0.03)	0.96 (−0.14, 0.07)
Mastery and personal control	0.90 (−0.19, −0.03) **	0.92 (−0.17, 0.01)	0.94 (−0.17, 0.05)

Note: Each row represents a different logistic regression model

[a] incident hypertensions is examined as hypertension (stages 1 and 2) and stage 2 hypertension alone

[b] adjusted for age, sex, race, study center, and education

[c] adjusted for age, sex, race, study center, education, alcohol, tobacco, physical activity, fast food frequency and BMI

[d] adjusted for age, sex, race, study center, education, alcohol, tobacco, physical activity, fast food frequency, BMI, and depressive symptoms

** $p \leq 0.01$