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Hypertension and objective and self-reported stressor exposure

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REVIEW

HYPERTENSION AND OBJECTIVE AND SELF-REPORTED STRESSOR EXPOSURE: A REVIEW

IVAN NYKLÍČEK, AD J. J. M. VINGERHOETS and GUUS L. VAN HECK

Abstract—A review of the literature on the relationship between blood pressure and stressor exposure revealed a discrepancy between the results of studies based on objective measures of stressor exposure and studies based on self-reports. Whereas in the studies based on objective measures, a clear predominance of positive associations between blood pressure level and stressor exposure was found, in the studies based on self-reports, the results were highly inconsistent. Several moderator variables have been proposed that could explain the discrepancies found in the literature, such as awareness of hypertension and treatment. In studies in which these moderators were taken into account, inverse associations between blood pressure and self-reported stressor exposure have often been found. It is suggested that this result is brought about by altered appraisal of stressors in hypertensives.

Keywords: Appraisal; Awareness; Hypertension; Objective; Self-report; Stressor exposure.

INTRODUCTION

The potential role of psychosocial factors in the etiology and course of essential hypertension has been studied for a length of time. One major research tradition in this area includes those theories that emphasize the importance of (negative) environmental influences like major life events (e.g., [1]), exposure to chronic stressors (e.g., occupational stressors [2]), and circumstantial positive factors that help attenuate the negative effects of stressor exposure (e.g., social support [2]). Two major approaches have been employed in this research area. In the first approach, the level of stressor exposure has been assessed by means of retrospective self-reports. Frequently blood pressure is used as an independent variable in a design in which hypertensive groups and normotensive groups are compared with respect to the self-reported amount or impact of stressors. It is clear that in this approach the results are dependent on the individual's appraisal of the situation [3, 4]. This has an important limitation: the possibility of retrospective bias (e.g., a "search for meaning"), especially if the hypertensive group consists of patients or, in general, individuals aware of having the disorder. For this reason, some researchers used a different strategy: the primary subjects of study were not individuals with hypertension, but individuals exposed to environmental stressors,

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for instance, subjects living in areas with a high crime rate [5] or persons having experienced traumatic events [6]. It is obvious that in this approach stressor exposure is often established in a more objective way than in the former approach; the subjects have simply been exposed to a real ecological event or situation, instead of giving retrospective ratings concerning the number or intensity of stressors. Here blood pressure is the dependent variable. It is of utmost importance to control for differences between the groups other than stressor exposure level, as such differences may account for any associations found. Because such different methodological aspects may influence results, it is conceivable that these two approaches may produce (mutually) inconsistent results.

In this review, we will examine the literature of both traditions concerning the relationship between hypertension or, more generally, tonic blood pressure level and stressor exposure. Both field studies comparing exposed and nonexposed groups and research based on retrospective self-reported stressor exposure will be summarized, and the results will be discussed. When discrepancies between reported results are found, differences between the studies will be outlined with respect to (a) subject sample characteristics, (b) operationalizations of the independent and dependent variables, (c) ways of controlling for confounding variables, and (d) the design and statistical methods used. Furthermore, the effects of potential moderator variables, such as awareness of having hypertension, will be examined comprehensively.

The literature searches were carried out using electronic databases, such as PsychLit and the Social Sciences Citation Index. Furthermore, existing reviews of the relevant fields (e.g., [7, 8]) were consulted.

First, a review will be provided concerning studies regarding the relationship between blood pressure and *objectively* derived measures of real-life stressor exposure. Second, studies concerning the relationship between blood pressure and *self-reports* of exposure to psychosocial stressors will be discussed in two subsections, one focusing on major life stressors (e.g., life events) and one on occupational stressors. Potential moderator variables will be discussed, and possible explanations for the results will be offered. Finally, conclusions and suggestions for future research will be given.

BLOOD PRESSURE AND OBJECTIVELY ASSESSED STRESSOR EXPOSURE

In this section, studies concerning the relationship between blood pressure and objectively established stressor exposure will be discussed, that is, studies in which stressor exposure has been established by means other than self-reports. Included are studies of individuals exposed to acute traumatic events or to chronic stressors. In all of these studies, blood pressure level was the dependent variable (see Table I).

Ruskin et al. [6] studied subjects who witnessed the 1947 Texas City explosion. Subjects who experienced this disaster showed elevated blood pressure levels for days after the event. Miasnikov [9] reported prolonged elevations of blood pressure in Leningrad residents after heavy bombardments of the city in World War II. However, whether such acute disastrous stressor exposures contribute to the development of hypertension remains controversial. Another traumatic event that has been studied is the Three Mile Island nuclear accident. This event also had chronic aspects, because the threat of radiation remained for a long time. Baum [10] has summarized the Three Mile Island studies and has demonstrated that Three Mile Island residents exhibited, among

Table I.—Blood pressure and objectively established stressor exposure

Studies [Ref]	N*	Stressor	Results†
Ruskin et al., 1948 [6]	180 (m + f)	city explosion	BP ↑
Miasnikov, 1961 [9]	? (m + f)	WW II bombardments	BP ↑
Harburg et al., 1970 [5]	280 (m + f)	stressfulness of residence	BP ↑
Kasl & Cobb, 1970 [20]	44 (m)	job-loss	BP ↑
Cobb & Rose, 1973 [22]	12,760 (m)	stressful job	BP ↑
Cassel, 1974 [11]	review	migration	BP ↑
Page, 1976 [15]	review	acculturation	BP ↑
Jonsson & Hansson, 1977 [21]	118 (m)	industrial noise	BP ↑
Marmot et al., 1980 [13]	11,920 (m)	migration	BP 0
D'Atri et al., 1981 [19]	568 (m)	crowding in prison	SBP ↑
Waldron et al., 1982 [14]	143 (m + f)	money economy	BP ↑
Rofé & Goldberg, 1983 [17]	5,804 (f)	stressfulness of residence	BP ↑
Baum, 1990 [10]	85 (m + f)	nuclear accident	BP ↑
Theorell et al., 1991 [23]	2,900 (m)	stressful job	DBP ↑
Fox et al., 1993 [24]	198 (f)	stressful job	BP ↑
Schaubroeck & Ganster, 1993 [25]	390 (m + f)	stressful job	DBP ↑

*The number of subjects in the study, m = male, f = female, review = review article, based on several studies with unknown number of subjects.

† SBP = systolic blood pressure, DBP = diastolic blood pressure, BP = blood pressure (systolic and diastolic), ↓ = lower, ↑ = higher, 0 = no effect.

other things, higher levels of blood pressure and catecholamines up to 6 years after the accident compared with a control group living near another nuclear power plant.

In studies of chronic psychosocial stressors, several investigators have focused on groups of individuals living in different cultures or persons who have migrated to a society whose sociocultural characteristics are different from those of the country of origin [11–14]. Although often methodologically limited, several studies have provided evidence for the view that, in contrast with the situation in the industrialized world, blood pressure does not rise with age in various nonindustrialized cultures [8]. For instance, Waldron et al. [14] observed lower blood pressures and slower rise of blood pressures with age in cultures that had lower involvement in a money economy and less economic competition, even after controlling for salt consumption. When such societies assimilate aspects of Western culture into their lifestyle, such as economic competition, blood pressure increases with age [15]. It has been argued that this association might be primarily due to psychosocial discrepancies between the different types of cultures [16]. However, migration studies have yielded inconsistent results with respect to sociocultural determinants of hypertension. Cassel [11], for instance, has reported that when individuals migrated to an industrialized country, their blood pressure indeed increased with age. Marmot et al. [13] compared Japanese men living in Japan with those who had migrated to Hawaii or California. The migrants showed substantial increases in rates of coronary heart disease, but not in blood pressure levels. This negative finding may be due to the fact that blood pressure levels of Japanese living in Japan are comparable to those of Caucasian Americans living in the USA, despite the fact that coronary heart disease rates are higher in the USA than in Japan. Thus, the specific sociocultural factors that play a role in the development of hypertension may be similar in Japan and the USA. Other factors may account for the difference in CHD prevalence between the two countries. On the other hand, positive outcomes, such as the findings reported by Cassel, are rather difficult to

interpret. The migrants might constitute a selective group of people with certain characteristics in which they differ from the average individual staying home. Thus, although in cross-cultural studies some support has been found for an association between psychosocial variables and blood pressure level, the methodological limitations do not permit any definite conclusions.

Research on chronic psychosocial stressors has also concentrated on groups of individuals within one culture, living in areas that differ with respect to stressor exposure levels. For instance, Rofé and Goldberg [17] found that pregnant women who lived in a high-stress environment (frequent terrorist attacks) displayed higher blood pressure levels than women living in a low-stress area (no terrorist attacks). Moreover, the beginning of a war increased blood pressure in all women, especially in those living in the high-stress area. Harburg et al. [5] compared blacks living in urban areas with high-stress levels with those living in low-stress areas, as defined by a number of socioeconomic statistics, like crime rate, overcrowding, unemployment rate, etc. They reported that in high-stress areas, black residents showed a significantly greater proportion of essential hypertensives compared with those living in low-stress areas. Similar results have been obtained in a later study [18].

Other evidence of psychosocial effects on blood pressure comes from a study on crowding in prisons [19]. Although blood pressure levels and variabilities of the prisoners did not differ initially, the prisoners who were forced to stay in dormitories instead of single cell accommodation, showed elevations of their blood pressure later on. This change was not observed in the prisoners who could stay in their single cells. It should be noted, however, that the possibility cannot be ruled out that there is some characteristic of hypertension-prone prisoners that has caused their transfer to the dormitory.

Studies with objectively derived measures of occupational stressor exposure have demonstrated a positive association between these measures and blood pressure level. For instance, in a longitudinal study [20], men experiencing job loss showed blood pressure elevations up to 2 years later. Furthermore, Jonsson and Hansson [21] reported that systolic and diastolic blood pressure were significantly higher in male industrial workers with a noise-induced auditory impairment than in their male colleagues of the same age with normal hearing. In a well-known study of air traffic controllers, Cobb and Rose [22] reported higher age-specific prevalence and annual incidence rates of hypertension among air traffic controllers compared with second class airmen (whose work is assumed to be less stressful than the work of the former group). Moreover, controllers working at high traffic density centers, with higher stressor levels, showed higher prevalence rates than controllers working at low traffic density centers. Recently, job strain, assessed by an objective job classification procedure, was found to be significantly positively associated with diastolic blood pressure during work and at night [23]. The association was stronger when occupations classified as physically demanding were excluded from the analysis. Fox, Dwyer, and Ganster [24] studied the number of stressors experienced by nurses in a hospital as rated by the head nurse. They reported a significant positive association between the number of stressors and the nurses' blood pressure levels both at work and at home. Finally, another recent study controlled for a number of confounding variables and found that chronic exposure to occupational stressors — derived from an objective job classification procedure — was associated with higher resting diastolic blood pressure [25].

Although some methodological drawbacks have been present in this approach, the overview certainly suggests a positive association between objectively established stressor exposure and blood pressure level. However, because most studies reviewed here were cross-sectional or had a relatively short period of measurement after the onset of the stressor, one cannot be certain that such blood pressure elevations could eventually lead to essential hypertension.

BLOOD PRESSURE AND SELF-REPORTED STRESSOR EXPOSURE

Potential moderator variables: awareness of and treatment for hypertension

In general, when interpreting results of studies based on self-reports, one should always be aware of the possibility of bias as a result of confounding mechanisms, like search for meaning, desirable responding, denial, etc. Therefore, before presenting an overview of the literature concerning the relationship between blood pressure and self-reported stressor exposure, we will demonstrate that two mutually related factors that are often present in research in this field may facilitate the distortion of self-reports of affect-laden matters like experienced stressors. These two factors are *awareness of having hypertension* and *treatment for the disease*. Many of the studies concerning the relationship between stressor exposure and hypertension are retrospective in nature. The perception of past stressors or reports of earlier behavior may be distorted by psychological phenomena, such as searching for meaning, in individuals who are treated for hypertension or who have just become aware of having the disease.

In general, aware hypertensives have frequently been found to have lower scores on self-reported well-being and higher scores on scales for measuring physical and psychological symptoms than both normotensive and unaware hypertensive control groups [26–31] (see Table II for an overview of relevant studies).

On the other hand, in two screening studies [32, 33], no differences in psychological well-being were found between aware hypertensives and normotensives. These results suggest that not awareness per se, but a selection bias of neurotic, complaining, and help-seeking individuals, who have a larger probability of having a potentially elevated blood pressure discovered, may be responsible for the association between the awareness of hypertension and the poorer sense of well-being found in many studies. However, whether this association results from awareness of hypertension or from selection bias is of secondary importance. The statistical association of awareness of hypertension with self-report scores may confound the results of studies on hypertension and self-reported stress and stressor exposure. Therefore, this association should not be ignored by researchers in this field.

In contrast, when compared with hypertensives already aware of having the disease for a longer time and even in comparison with normotensives [27, 34–37], unaware hypertensives and individuals recently found to have elevated blood pressure have scored favorably on psychological measures. Additionally, Rostrup and Ekeberg [38] reported no difference in psychological distress between unaware hypertensives and “new” hypertensives. These results thus suggest that when an individual is not aware of having elevated blood pressure or does not (yet) regard himself or herself as “being a hypertensive,” elevated blood pressure may be associated with a diminished perception of aversive information. This hypothesis will be discussed in more detail in a later section.

Table II. — Awareness of hypertension and self-reported well-being

Studies	N*	Groups†	Instruments‡	Results§
Monk, 1980 [28]	2,851 (m + f)	aware DHTs vs. unawares	GWB	aware DHTs: lower psychological well-being
Soghikian et al., 1981 [30]	52,948 (m + f)	aware DHTs vs. unawares	a 5-item checklist	aware DHTs: lower psychological well-being
Mann, 1984 [32]	654 (m + f)	aware BHTs vs. NTs	GHQ	no difference in psychological well-being
Zonderman et al., 1986 [31]	970 (m + f)	aware BHTs vs. unawares	CMI, AAQ	aware BHTs: more symptoms, worse self-related health
Irvine et al., 1989 [26]	162 (m + f)	aware BHTs vs. unawares	EPI, SSTPI, SSAQ, CMS	aware BHTs: more neurotic and anxious
Moum et al., 1990 [33]	3,530 (m + f)	aware DHTs vs. NTs	a 6-item checklist	no difference in psychological well-being
Müller et al., 1994 [29]	90 (m + f)	aware DHTs vs. NTs	POMS, a 13-item list, a 17-item list	aware DHTs: more symptoms, worse mood, less life-satisfaction
Kidson, 1973 [27]	150 (m)	aware DHTs vs. NTs	16PF, CMI, EPI	aware DHTs: worse psychological profiles
Davies, 1970 [35]	128 (m)	unaware DHTs vs. NTs	structured interview, EPI	unaware DHTs: fewer physical symptoms
Berglund et al., 1975 [34]	57 (m)	“new” aware DHTs vs. “old” aware DHTs	a 30-item symptoms list	unaware BHTs: fewer symptoms, less depressed
Santonastaso et al., 1984 [36]	324 (m + f)	“new” aware DHTs vs. “old” aware DHTs	SRT	“new” aware DHTs: fewer symptoms
Thomas & Kirkcaldy, 1988 [37]	192 (m + f)	“new” aware BHTs vs. NTs	FPI	“new” aware DHTs: less neurotic, less anxious, less inadequate
Rostrup & Ekeberg, 1992 [38]	32 (m)	“new” aware DHTs vs. unaware DHTs	KSP	“new” aware BHTs: less aggressive, less dominant
				no difference in psychological distress scores

* The number of subjects in the study, m = male, f = female.

† DHTs = definite hypertensives (systolic blood pressure ≥ 160 mmHg and/or diastolic blood pressure ≥ 95 mmHg), BHTs = borderline hypertensives (systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg), NTs = normotensives (systolic blood pressure < 140 mmHg and diastolic blood pressure < 90 mmHg), “new” = individuals who just learned about their elevated blood pressure, “old” = individuals who knew about their blood pressure elevation for a long time.

‡ 16PF = 16 Personality Factor Questionnaire, AAQ = Activities and Attitudes Questionnaire, CMI = Cornell Medical Index, CMS = Cook-Medley Scale, EPI = Eysenck Personality Inventory, FPI = Freiburger Personality Inventory, GHQ = General Health Questionnaire, GWB = General Well-Being questionnaire, KSP = Karolinska Scale of Personality, POMS = Profile of Mood States, SRT = Symptom Rating Test, SSAQ = Spielberger Self-Analysis Questionnaire, SSTPI = Spielberger State-Trait Personality Inventory.

§ Scores of the first group (mentioned under “Groups”) compared to the second group (see † for explanation of the abbreviations).

With respect to treatment, similar results have been found: treated hypertensives score lower on psychological well-being than untreated hypertensives [39, 40], “new” hypertensives [34], and normotensives [28] (Table III).

Only Soghikian et al. [30] found the opposite, that is, higher psychological well-being in treated than in untreated subjects. However, in contrast to the samples used in the other investigations, the treated subjects in this study were successfully treated; their blood pressures had returned to normal levels. The success of the treatment could have accounted for the favorable scores in this particular sample.

To summarize, it can be concluded that, because of their possibly biasing influence, awareness and treatment of hypertension should always be accounted for in research on blood pressure and self-reports of affect-laden matters. In the next sections, the focus will be on the relationship between blood pressure and two categories of self-reported stressor experiences, namely, perceived life stressors and occupational stressors.

Life stressors

Among studies in which self-reported occurrence of life events is the subject of interest, the results seem rather contradictory (see Table IV).

In their classical study, Reiser et al. [41] found that the occurrence of stressful life situations was associated with the onset of hypertension and with medical complications during the course of the disease. In this study, no control group was included, which is a serious limitation, of course (this is also the reason why the study is omitted in Table IV). Myers and Miles [42] found that in a sample of low-income blacks, individuals with borderline hypertension (some of them were treated for the disease) reported more negative life events than normotensive blacks. Similar results were demonstrated in India; treated hypertensives reported more negative life events than matched normotensives [43]. Also, Osti et al. [44] found more negative life events reported by hypertensive patients, compared with a control group of patients with other cardiovascular disorders. In contrast, results from several other studies suggest a negative association between blood pressure and the number of self-reported life events. For instance, Svensson and Theorell [45] found that 18-year-old men with sustained blood pressure elevation reported fewer negative life events than control subjects. Theorell et al. [46] showed that young males with elevated blood pressure reported fewer life events than subjects with normal blood pressure readings. Linden and Feuerstein [47] showed that untreated hypertensives reported fewer interpersonal stressors and were less depressed than medicated hypertensives and normotensives.

Jorgensen and Houston [48] investigated whether a possible bias of hypertensives regarding the reporting of stressful life events could have a genetic component. They compared the self-reported life-stressors of young normotensive subjects who had a family history of hypertension—a risk factor for the development of hypertension later in life [49]—with those of persons with no family history of hypertension. Males showed a positive association between resting systolic blood pressure and reported avoidable life events, whereas for females the reverse pattern was found. There was no difference between the groups with respect to the number of unavoidable life events. Thus, in this specific sample, report rates depended on the sex of the subject and the extent to which the experienced event was avoidable. The authors concluded that among normotensive individuals a family history of hypertension, by itself, is not associated with a bias in reporting life events.

Table III. — Treatment for hypertension and self-reported well-being

Studies	N*	Groups†	Instruments‡	Results§
Tibblin & Lindström, 1972 [40]	622 (m)	treated DHTs vs. untreated DHTs vs. NTs	a 10-item symptoms list	treated DHTs: more symptoms untreated DHTs: fewer symptoms
Berglund et al., 1975 [34]	115 (m)	treated DHTs vs. "new" DHTs	a 30-item symptoms list	treated DHTs: more symptoms
Goldberg et al., 1980 [39]	777 (m + f)	treated DHTs vs. untreated DHTs	Langner MHSQ	treated DHTs: more symptoms
Monk, 1980 [28]	2,851 (m + f)	treated DHTs vs. NTs	GWB	treated DHTs: lower psychological well-being
Soghikian et al., 1981 [30]	52,948 (m + f)	successfully treated Ss vs. untreated Ss	a 5-item well-being checklist	treated Ss: higher psychological well-being

* and † as in Table 2.

‡GWB = General Well-Being questionnaire, Langner MHSQ = Langner Mental Health Status Questionnaire.

§Scores of the first group (mentioned under "Groups") compared to scores of the second group (DHT = definite hypertensives, Ss = subjects).

|| Individuals successfully treated for hypertension versus normotensive individuals not treated for hypertension, but once diagnosed as having hypertension.

Table IV. — Blood pressure and self-reported life stressors

Studies	N*	Groups†	Instruments‡	Results§
Osti et al., 1980 [44]	20 (m + f)	DHT patients vs. NT patients	interview	DHTs: more life stress
Myers & Miles, 1981 [42]	76 (m + f)	Partly treated BHTs vs. NTs	RLCQ	BHTs: more life stress
Lal et al., 1982 [43]	108 (m + f)	DHT patients vs. NTs	a 67-item life event scale	DHTs: more life stress
Linden & Feuerstein, 1983 [47]	38 (m)	Mostly untreated BHTs vs. NTs	an ambulatory event diary	BHTs: less everyday life stress
Svensson & Theorell, 1983 [45]	47 (m)	Mostly unaware BHTs vs. NTs	a 48-item life event scale	BHTs: less life stress
Theorell et al., 1986 [46]	88 (m)	Mostly untreated BHTs vs. NTs	a 37-item life event scale	BHTs: less life stress

* and † as in Table 2.

‡RLCQ = Recent Life Change Questionnaire.

§Scores of the first group (mentioned under "Groups") compared to scores of the second group (DHTs = definite hypertensives, BHTs = borderline hypertensives).

The inconsistencies found in these outcomes may be due partly to differences between the samples of subjects used. For instance, in the study by Jorgensen and Houston [48], a very specific group of subjects participated: young normotensive individuals with a family history of hypertension. As is indicated above, the results were inconsistent and difficult to interpret. The other studies differed with respect to the hypertensive samples used. Studies in which positive associations were found between blood pressure level and reported life events included hypertensive patients, whereas in studies in which the association was negative, the subjects were either unaware of their blood pressure [45] or were primarily untreated hypertensives [46, 47]. This may be a relevant difference between the studies, in view of the well-known caveat of retrospective bias. As has been discussed in more detail in a previous section, treatment and awareness of having the disease may have an influence on reporting behavior that results in a bias of the results due to phenomena such as a “search for meaning” [26, 27]. The data suggest that, when treatment and awareness are absent, an inverse association is more likely to be found between blood pressure level and self-reported stressor exposure. This is in line with the results obtained in two large studies on occupational stressors, which are discussed below [50, 51]. As Theorell [52] has stated, persons at risk for the development of hypertension or persons who are in an early stage of asymptomatic hypertension (and who are mostly unaware of it) may tend to have a “noncomplaining” life attitude and underreport stressors. This would be in agreement with the studies discussed above, in which unaware, just diagnosed, and untreated hypertensives were found to report fewer physical and psychological symptoms than normotensives and hypertensives who had been aware of having the disease for a long time [27, 34–36, 40]. The awareness of the disease and treatment were not the only differences between the samples of subjects studied. The samples also differed with respect to age, race, and sex composition: young white males [45, 46], or blacks and Indians of both sexes and of a broad range of ages [42, 43]. To what extent these variables might contribute to the found differences in reporting behavior is unknown. However, their influence cannot be ruled out at present.

Occupational stressors

Inconsistencies with respect to the relationship between blood pressure level and self-reported exposure to stressors have also been found in occupational research (see Table V).

On several occasions, a positive association has been found between blood pressure level and self-reported job stressors [53–56]. For instance, one study [53] controlled for a number of potentially confounding variables and showed that diastolic blood pressure level correlated positively with various indices of the stressfulness of work conditions, namely, poor contact with co-workers, low decision latitude, and overall job dissatisfaction. Schnall et al. [54] operationalized job strain as the combination of high work load and low decision latitude. After controlling for confounders, they found that high blood pressure in males from a wide range of occupations was associated with high job strain. Van Egeren [56] used the same operationalization of job strain as Schnall et al. in a study of 37 normotensive workers with sedentary jobs (males and females). The results were congruent with those of Schnall and co-workers: subjects with high-strain jobs had higher systolic blood pressure—not only at work,

Table V. — Blood pressure and self-reported occupational stressors

Studies	N*	Indep. variable	Instruments†	Results‡
Jenkins et al., 1985 [50]	416 (m)	job dissatisfaction	JDI(2)	later BP ↓
Matthews et al., 1987 [53]	288 (m)	job stress	JEI, JDI(1)	DBP ↑
Winkleby et al., 1988 [51]	1,428 (m)	job stressors	a 19-item list	BP ↓
Schnall et al., 1990 [54]	215 (m)	job strain	JCQ	BP ↑
Van Egeren, 1992 [56]	37 (m + f)	job strain	JCQ	SBP ↑
Fox et al., 1993 [24]	136 (f)	job strain work load job stressors	JDWH + DGAC JDWH MISE	BP ↑ BP 0 DBP ↓
Theorell et al., 1993 [55]	56 (f)	job strain	JCQ	DBP ↑

* as in Table 2.

† DGAC = Dwyer-Ganster Amount of Control scale, JCQ = Job Content Questionnaire, JDI(1) = Job Descriptive Index, JDI(2) = Job Description Inventory, JDWH = Job Demands and Worker Health, JEI = Job Environment Inventory, MISE = Motowidlo et al.'s Inventory of Stressful Events.

‡ SBP = systolic blood pressure, DBP = diastolic blood pressure, BP = blood pressure (systolic and diastolic), ↓ = lower, ↑ = higher, 0 = no effect.

but also at home. The same operationalization of job strain has also been used in a study conducted with female hospital personnel [55]. After controlling for several confounders, they found significant positive associations between perceived job strain and diastolic blood pressure during working hours and at rest.

In contrast, some other studies reported negative associations that were often contrary to the expectations of the researchers. For example, a study of 416 air traffic controllers compared normotensives who developed borderline or definite hypertension during a 3-year follow-up with those who remained normotensive. Those who had developed borderline or definitive hypertension reported fewer life stressors, less tension and anxiety, less depression, less burnout, and more satisfaction with jobs and co-workers than did their colleagues who stayed normotensive [50]. In an extensive study ($N = 1,428$), San Francisco bus drivers were surveyed as part of an occupational health study [51]. An inverse association was obtained between blood pressure level and subjects' self-reports of work-related problems. This association remained significant after adjustment for 12 potentially confounding variables. When the analysis was done using only the data of the 1,040 normotensive subjects, again an inverse association was found. In contrast to these inverse associations, positive associations between self-reports of occupational problems and other health complaints, such as gastrointestinal, respiratory, and musculoskeletal problems, were reported.

It is difficult to find proper explanations for these inconsistencies. Various sample characteristics, and mutual interactions between them, may have influenced the self-reported rates of stressor exposure. We have not been able to identify systematic differences in sample characteristics, such as age, sex, awareness, or treatment for hypertension, between the studies that showed positive correlations and those with inverse associations. The only clear difference is that, in the studies with negative

associations, the samples consisted of traffic employees. One might, of course, speculate that traffic employees have a hypertensive-prone personality trait or coping style that may incline them to deny problems, but this explanation seems highly improbable. A more plausible explanation may be offered by regarding another source of outcome variance in these studies: the assessment method used to determine the level of stressor exposure. Occupational questionnaires like the Job Content Questionnaire, used in 3 of the 4 studies in which positive associations were found [54–56], have a strong objective component as suggested by a large interoccupation variance [2, 54].

In the previous section, it has been stated that when measures of stressor exposure are derived objectively, positive associations between blood pressure and stressor exposure dominate the results obtained. Therefore, Theorell et al. [23] suggest that, in order to obtain positive associations between these variables, stressor measurement has to be as *objective* as possible. In contrast, as stated by Winkleby et al. [51], when stressors are assessed by means of more *subjective* measures, null or reverse findings are often reported. This explanation is in line with a recent study conducted by Fox et al. [24]. In a sample of 136 nurses, they linked objective and subjective measures of job stressors to blood pressure and cortisol levels. The objective measure of job stressors was the head nurse's ratings of individual nurses' work load. Subjective measures were various self-report questionnaires concerning work load, perceived control, the number of stressful events at work, and overall job satisfaction. The authors found that (a) the objective measure of work load was positively associated with blood pressure level, both at work and at home; (b) job strain (the Karasekian interaction of high work load and low perceived control) was positively associated with blood pressure level (which is in line with the other job strain studies); (c) the subjective measure of work load did not correlate with blood pressure; and (d) the self-reported number of stressful events at work correlated *negatively* with diastolic blood pressure level at home.

Conclusions

The studies using self-reports of stressor exposure show conflicting results. However, when report-biasing factors, in particular, awareness of the disease and treatment, are absent and the questionnaires are subjective rather than objective, results are more in favor of a model that points at an inverse association between blood pressure and stressor exposure. This conclusion is in contrast to the outcome of the review of the literature based on objectively established stressor exposure, in which positive associations predominate. A nice example of the discrepancy between objective and subjective stress measures in relation to blood pressure is the study of Harburg et al. [5], which has been described above. An objectively established index of stressfulness, namely, the area in which the subjects lived, was associated with a higher proportion of hypertension. In contrast, the persons with high blood pressure who were actually living in high stress areas were more satisfied with their neighborhood than their normotensive counterparts in the same tract; consequently, they judged their area as less stressful than the normotensives.

The suggestion that hypertensives have a tendency to label a stimulus as "aversive" less quickly is supported by research on blood pressure and pain perception. In the past 15 years, it has been repeatedly demonstrated that individuals with high blood pressure have a higher pain threshold and pain tolerance than individuals with normal

blood pressure, indicating a tendency for hypertensives to perceive these stimuli as less aversive. This has been found for electrical [57, 58], thermal [59], and finger pressure pain stimulation techniques [60]. Moreover, in normotensive samples as well, a continuous inverse relationship between blood pressure levels and perceived painfulness of physical stressors has been found [60]. This inverse association has been found in both between-subjects [58] and within-subjects designs [61] and in animal [62] as well as in human studies [59].

GENERAL CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This review has discussed studies concerning the relationship between blood pressure and stressor exposure and has offered possible explanations for the discrepancies that were found. The results of studies based on self-reported stressor exposure have often been especially contradictory. The following factors were pointed out: (1) differences in operationalizing the concepts studied; (2) factors like the moderating effect of variables, such as awareness of having hypertension and being treated for the disease; and (3) the relative importance of subjective aspects in the measurements. It has been argued that these factors should be accounted for in future studies concerning the relationship between blood pressure and psychosocial variables.

Furthermore, a discrepancy has been found between the results of studies based on *objectively* established measures of stressor exposure and the results of studies using *subjective* measures. The studies based on objective measures often showed a positive association between stressor exposure and blood pressure. The results of research based on self-reported stressors with a low objectivity level more often yielded negative associations between reported stressors and blood pressure level in subjects who were unaware of their blood pressure elevation. The latter association has also been supported by results from pain research, where substantial evidence has been found for a lower pain appraisal in hypertensives, as compared to normotensives. This discrepancy may partly explain the inability to draw conclusions about the role of stressor exposure in the development of essential hypertension.

It is tempting to speculate that two different sequential mechanisms are responsible for the disagreement between results based on objectively established stressor exposure and results from studies using self-reports. It may be hypothesized that when certain conditions are met, relating to factors such as social support, personality characteristics, coping style, and physiological constitution, frequent intermittent or chronic exposure to stressors may potentiate the development of sustained elevated blood pressure. However, elevated blood pressure may subsequently result in certain conditions that are responsible for the lower rates of self-reported stress and stressor exposure repeatedly found in hypertensives. The role of the following conditions, relevant for the latter relationship, may be hypothesized.

First, once people have elevated blood pressure, they may not feel well enough to participate in social events or they may consciously try to avoid exposure to stressful situations (withdrawal). Second, high blood pressure may have a negative effect on memory function, which would cause the lower report rates. Third, because of frequent or chronic exposure to stressors, hypertensives may have become less sensitive to acute stressors and, consequently, may perceive them as less threatening (the inoculation hypothesis) [63]. Fourth, hypertensives may have a coping or reporting style that

minimizes the aversiveness of events (either unconsciously or consciously: for example, repression, denial, and nondisclosure). Finally, hypertensives may have a physiologically based altered appraisal of aversive stimuli, for instance, brought about by baroreceptor-mediated CNS inhibition [61].

The first explanation, a diminished exposure to stressors as a result of the elevation of blood pressure, is questionable. Nonparticipation in social events on the part of hypertensives due to less physical and psychological well-being seems unlikely, because elevated blood pressure is mostly asymptomatic [28, 33]. Neither does intentional avoidance as a result of awareness of having high blood pressure seem to be a satisfactory explanation. Several studies that revealed an inverse association between blood pressure and stressor report rates were based on unaware hypertensives [45] or even normotensives [51]. For the same reason, we can eliminate explanations based on selection bias of complaining help-seekers, who have a greater chance of having their blood pressure measured, which implicates a greater probability of discovery of hypertension and awareness of and treatment for the disease.

The second explanation, a deteriorated memory function in hypertensives, has not received much support from the literature to date; the results with respect to delayed recall have been inconsistent [64, 65]. More research would have to be performed to examine this hypothesis in more detail. Also the inoculation hypothesis does not seem very plausible, given the fact that hypertensives have frequently been found to be cardiovascular hyperreactors to behavioral stressors, thus being physiologically sensitive to stressors [66–69]. Moreover, Eysenck suggested that inoculation may play a role in cancer rather than in hypertension [63].

For the final two explanations, namely a defensive coping style and a physiologically based altered perception in hypertensives, indirect support has been found in the literature. Elevated tonic blood pressure has been repeatedly reported to be associated with defensive coping, in both aware and unaware samples (e.g., [70–72]). Diminished perception of physical stressors induced by blood pressure elevation has been demonstrated to be mediated by baroreceptor stimulation and to presumably involve CNS inhibition (e.g., [57, 73]). Both explanations suggest an altered appraisal of stressors, which become less aversive. This could be responsible for the inverse associations found between blood pressure and subjective measures of stressor exposure. For a detailed review of these mechanisms, see Nyklíček, Vingerhoets, and Van Heck [74]. The possibility of an altered appraisal of stressors in hypertensives and persons at risk for hypertension should be investigated systematically in future research. Studies should examine possible underlying psychological and physiological mechanisms such as the ones described above.

Although the sequential relationship between the two mechanisms may be an attractive hypothesis, whether these mechanisms precede elevated blood pressure, are the result of hypertension, or are just epiphenomena of other factors, cannot be inferred from the predominantly cross-sectional studies performed in this area. For instance, it may be hypothesized that altered appraisal is a marker of a risk for hypertension, rather than a result of high blood pressure. Therefore, prospective studies should be designed in order to get more insight into the nature of these relationships, including the issue of causality.

The dual nature of the association between blood pressure and the experience of stressors would imply a complication regarding the measurement of stressor exposure:

a higher blood pressure level will tend to be associated with a higher level of objectively assessed chronic stressor exposure, but also with a lower appraisal of the aversiveness of the stressors and perhaps even with a lower probability of labeling an event as a stressor. Environmental stressor exposure assessed by means of self-reports will always contain a mix of both entities, which considerably complicates the interpretation of data based on this kind of measurement. Therefore, in field research, obtaining the simultaneous assessment of both an objective index of stressor exposure and a (subjective) appraisal of the stressors and treating them as separate variables is recommended. Preferably, coping style should also be included in research in this field. Although coping style has generally been regarded as an important moderator in the relation between stressor exposure and health outcome, the interaction with stressor exposure has often been omitted from research designs. Additionally, the inclusion of various defensive coping measures would be helpful in testing whether the underreporting behavior and/or the altered appraisal in individuals with elevated blood pressure could be attributed to a defensive coping style. Ideally, other potentially relevant variables should be included, such as social support and personality characteristics.

Such studies imply the use of multivariate designs and analyses. Moreover, given the multiple-process nature of the relationships between stressor exposure, appraisal of stressor, and coping, a process approach should be encouraged [4]. This could be realized in ambulatory studies, in which multiple assessments during the day—and preferably during episodes of stressor exposure—are obtained from the subjects. Such an approach may be fruitful for an additional reason: exposure to and inadequate coping with daily hassles has been suggested to be potentially more important with respect to (cardiovascular) health than the experience of the usually rare major life changes [75, 76].

Finally, as stated above, prospective studies should also receive much attention in order to obtain more insight into causal associations. In this context, normotensive potential risk groups—for instance, individuals who prefer certain inadequate coping styles and who are about to enter a situation of chronic stress—would be a particularly interesting group to follow.

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