

Original Research Article

Relationship between hair cortisol status and blood pressure among chronic occupational stress-diagnosed healthcare professionals of Rivers State in Nigeria

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ABSTRACT

Background: The relationship between chronic occupational stress (COS)-related hair cortisol concentration (HCC) and arterial blood pressure (ABP) is inconsistent within the relevant preexisting literature. Therefore, this study aimed to assess the impact of COS-related HCC on ABP among healthcare professionals (HPs) with a COS diagnosis.

Methods: The cross-sectional study was conducted among 426 HPs in two healthcare settings in Rivers State, Southern Nigeria. Data were collected, including subjective measures of COS using the Effort-Reward Imbalance questionnaires, as well as objective measures of COS using HCC at >128 pg/mg hair. COS diagnoses were defined using combined subjective and objective measures. Statistical analyses were conducted at a 95% confidence interval and an alpha level of <0.05 .

Results: 273 (70%) had a COS diagnosis with a mean age of 32.44 ± 5.24 years, and 9.2%, 61.2%, and 29.7% were normotensive, pre-hypertensive, and hypertensive, respectively ($p < 0.05$). The pre-hypertensives and hypertensives were older and had higher mean HCC, body mass index (BMI), effort total score, effort-reward ratio, percentage of OC total score, but lower reward total score compared to the normotensives ($p < 0.05$). HCC had a strong positive correlation with systolic blood pressure (crude beta: 0.724 versus adjusted beta: 0.706; $p < 0.001$), but a moderate positive correlation with diastolic blood pressure (crude beta: 0.477 versus adjusted beta: 0.450; $p < 0.001$). HCC, at >128 pg/mg hair, was associated with pre-hypertension (crude OR: 1.809 versus adjusted OR: 1.611; $p < 0.001$) but more robust with hypertension (crude OR: 3.451 versus adjusted OR: 3.370; $p < 0.001$).

Conclusions: Current findings indicate a relationship between COS-associated HCC and the ABP indices, which should be considered during clinical management for COS.

Keywords: Healthcare professionals, Chronic occupational stress, Hair cortisol concentration, Effort-reward imbalance

INTRODUCTION

In recent times, occupational epidemiologic studies have reportedly shown that chronic occupational stress (COS), identified in multiple disciplines, has a sustained negative influence on arterial blood pressure (ABP) and consequently, has the potential for hypertensive disorders with its attendant consequences.^{1,2}

COS influences ABP through sustained exposure to raised levels of cortisol, a hormone released following hypothalamic-pituitary-adrenal axis (HPA) activation in response to stress. While HPA response is transient in acute stress, it remains sustained in COS, with consequent impact of the deleterious effects of cortisol, including its influence on ABP.²⁻⁶

However, the reported relationships between COS and ABP have also demonstrated inconsistent findings, with some studies, but not all studies, showing an association.¹⁻³ Recent findings indicate that a lack of a reliable measure of COS has significantly contributed to this inconsistent relationship between COS and ABP.^{2,3}

Previous investigations into COS-ABP link have relied on subjective measures of COS through questionnaires.² Unfortunately, these subjective questionnaires are highly unreliable because various factors that characterize COS differ among individuals and over time, are influenced by individual interpretation and coping mechanisms.³ Furthermore, most studies also failed to distinguish specific COS factors from the general chronic stress factors originating from other sources. Some previous studies have used biomarkers of COS in different matrices, such as blood, urine, and saliva, including cortisol levels.^{2,3} However, biomarkers from these matrices are greatly influenced by daily physiological fluctuations, such as circadian rhythms, and are highly sensitive to the impact of transient stressors.⁴⁻⁶

Evidence shows that blood-derived cortisol gradually accumulates in scalp hair as it grows and offers a measure of cortisol secretion over several months. Since scalp hair grows about one cm per month, this allows for a timed retrospective assessment of long-term cortisol levels using just one sample.³⁻⁶ Hence, hair cortisol concentration (HCC) reflects systemic cortisol levels over longer periods than cortisol in blood, urine, or saliva, and is less affected by circadian rhythms and brief stress events.²⁻⁶ Furthermore, HCC status are retrospective indicator of the biologically active cortisol levels during the period of hair growth period.³⁻⁶ Consequently, HCC has recently gained research interest and has been proposed as a valid alternative biomarker for COS.²⁻⁶

Although HCC is increasingly recognized as a valid COS biomarker, it has not been previously used to investigate a possible COS-associated ABP relationship among working groups more prone to COS, such as the healthcare professionals (HPs). Hence, the current study aimed to evaluate the COS-associated HCC and ABP relationship among HPs in Rivers State, southern Nigeria.

METHODS

Study description, area, and sites

This was a sub-study of a research project titled “assessment of hair cortisol concentration as a biomarker of occupational stress among HPs in Rivers State, southern Nigeria,” conducted as part of the requirements for a Master of Public Health degree from Rivers State University (RSU) in Southern Nigeria. The study was conducted in two randomly selected tertiary healthcare institutions from a total of four in the State: Rivers State University Teaching Hospital (RSUTH) and University of Port Harcourt Teaching Hospital (UPTH). These hospitals

employ a large number of HPs, providing advanced medical services and various job roles. Together, they employ over 1,500 medical staff members (RSUTH: 731; UPTH: 1,285; total: 2,016).

Study population

The study population included HPs in randomly selected tertiary healthcare institutions in Rivers State, Southern Nigeria.

Eligibility status

Inclusion criteria

The criteria for inclusion include the following: full-time HPs, HPs on regular call duties and/or rotating shift duties for at least 6 months, and HPs who responded specifically to a positive subjective COS status.

Exclusion criteria

The criteria for exclusion include the following: previous/current history of any endocrinopathies/hemoglobinopathies, pregnant females, recent glucocorticoid recent history of any form of hair treatments (e.g., coloring, perms, etc), and patients not having scalp hair of ≥ 3 cm in the posterior vertex at the time of recruitment.

Study design

It was a cross-sectional study design.

Sample size calculation

Though a calculated minimum sample size of 355 study participants was required for this current study, 426 were eventually recruited. This was determined using the Cochran formula for infinite population $\geq 10,000$ with 50% prevalence (data was not accessible within the region) at 5% degree of accuracy and 95% confidence limit, giving 384.⁷ Assuming a 90% response rate, and compensating for the anticipated non-100% response rate, gave a sample size of 430. The finite population correction factor was then applied since the population studied (RSUTH: 731; UPTH: 1,285; total: 2,016) was $< 10,000$ using the formula, where n is the minimum sample size, N is finite population size ($< 10,000$) = 2,016, and n_0 is the sample size with no correctional factor.

$$\begin{aligned} n &= n_0 N / n_0 + (N + 1) \\ n &= 430 \times 2,016 / 430 + (2,016 - 1) = 866,880 / 2,445 \\ &= 354.5 \\ n &= 354.5 \text{ (approx. 355)} \end{aligned}$$

Allocation of study participants by study center and groups of HPs

This was done using the proportionate allocation protocols recently described by Oni and colleagues based on the total

number of HPs in each study facility (RSUTH: 731; UPTH: 1,285; total: 2,016), the proportion of HPs in each of the six broad categories of HPs as defined in the World Health Organization (WHO) 2013 Global Atlas of the Health Workforce, the number of HPs in each of the six WHO categories within the study center and the calculated minimum sample size of the study ($n=355$).^{8,9} These six broad groups of HPs include physicians/dentists, nursing/midwifery staff, pharmacists, laboratory scientists, health management/support workers, and other health workers (dietitians and nutritionists, medical assistants, physiotherapists, medical trainees, interns, respiratory therapists, operators of medical/dental equipment).⁹

Sampling method and technique

The multi-stage sampling technique was adopted and involved: selection of 2 tertiary healthcare facilities from a total of 4 within the state using computer-generated random numbers, selection of groups of HPs based on inclusion criteria by stratification as described, and selection of HPs using computer-generated random numbers from each professional group in each study center from the staff list as a sampling frame.

Data collection

The data collection was done by trained research assistants who are medical doctors. Data collection was done on the same day for each participant to ensure reliability/consistency and spanned from February to May 2025.

Collection of non-clinical data

First, all potential participants were approached to participate in the study. Following informed consent, an adopted basic information questionnaire was administered to obtain individual characteristics (gender, age, marital status, education status), working characteristics (working years, working system [regular day shift or shift work, day shift work, night shift work, rotating shift work]), and lifestyle (smoking, drinking, sleeping time), chronic stress patterns/factors, and to determine eligibility status.¹⁰ If eligible, an adopted short version of the effort-reward imbalance (ERI) questionnaire was administered to evaluate the subjective COS, and thereafter, the participants were finally prepared for clinical data and hair collection.¹¹

Collection of clinical data

ABP, weight, height, waist circumference (WC), hip circumference (HC), calculated body mass index (BMI), and waist-hip ratio (WHR), were obtained using standard protocols. ABP was measured using an oscillometric device (Omron Model HBP-1300, IL, USA) after a five-minute rest period while seated. The device has been validated and surpasses the basic standards set forth by the relevant international validation authorities.¹² ABP was

measured 3 times, five minutes apart, and the average of the 3 measurements was recorded.

Collection of laboratory data

Hair specimens of approximately 3 cm (approximating 3 months of cortisol exposure since the monthly hair growth rate is reportedly 1 cm/month) in one clump from the posterior vertex of the scalp were collected once per participant. The specimen was secured with tape, placed in a labeled envelope, and transported to the laboratory at RSUTH. AHCC (pg/mg hair) was determined using the ELISA method with the cortisol ELISA kit (Monobind, California, USA).¹³ All the analyses were done in duplicate, and the average was recorded for analysis. Three hair specimens with low, middle, and high levels of HCC were tested 20 times, respectively, during a single assay run to ascertain the intra-assay coefficient of variation (CV) with <5% recorded. Another 3 specimens of the same level of HCC were assayed 20 times, respectively, on separate assay runs to ascertain inter-assay CV with <10% recorded.

Operational definitions

General chronic stress status

This was defined as a consistent sense of feeling pressured and overwhelmed over a prolonged period due to any past or current life event, or a state of protracted worry or mental tension caused by past difficult life situations.¹⁴

Specific stress factors

Financial stress unrelated to current job, current job-related stress, major life changes, current underlying health issues, daily life and busyness not related to current job, and other stress factors were defined as previously described.¹⁴

Subjective and objective COS threshold categories

Subjective COS was defined using the effort-reward ratio (ERR) and over-commitment (OC) dimensions of the ERI questionnaire as previously described.¹¹ $ERR \geq 1$ was used to define the ERR-based subjective COS threshold, while the OC scores above 50% of the total OC score (total 24) were used to define the OC-based subjective COS threshold.¹¹

Objective COS was defined using the HCC based on the reference interval in healthy individuals with low levels of stress, which is 40–128 pg/mg hair as described by Gonzalez and colleagues, with $HCC > 128$ pg/mg hair HCC designated as a positive objective COS threshold.¹⁵

COS diagnosis

This was defined as positive self-report of general chronic stress, positive self-report of current job-related COS, positive ERR-based subjective COS threshold, positive

OC-based subjective COS threshold, and positive HCC-based objective COS threshold, as previously described.^{11,14,15}

ABP categories

Participants were considered normotensive if ABP was <120/80 mmHg, pre-hypertensive if systolic BP was 120-139 mmHg and/or diastolic ABP 80-89 mmHg, or hypertensive if systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg.¹⁶

Anthropometrics

BMI (kg/m²) was calculated as body weight in kg divided by height in square meters (m²) and categorized as normal BMI (≤24.9), overweight BMI (25-29.9), and obese BMI (≥30).¹⁷ WHR ratio was calculated as the ratio of WC in cm to HC in cm.

Smoking/drinking

Smoking was defined as cumulative smoking >100 cigarettes in a lifetime/having smoked within the last 28 days preceding recruitment.¹⁸ In females, drinking was defined as having >3 standard drinks on any single day or >7 drinks/week. In males, drinking was defined as having >4 drinks on any single day or >14 drinks/week.¹⁹

Sleeping time per day

Sleeping time was categorized as deficient/short (<6 hours), insufficient (6-7 hours), and sufficient/long (>7 hours) groups as previously described.²⁰

Work systems

Shift work was defined as work during times that exceed the traditional 9 am to 4 pm and was further categorized as day shift work (9 am to 4 pm), night shift work (4 pm to 9 am), and a rotating shift schedule that incorporates both the day and night shift work.²¹

Data analysis

Statistical Package and Service Solution (SPSS, IBM, Chicago, IL, USA) for Windows version 25.0 was used for statistical analysis. Before analysis, all research data were first inspected for missing (visual inspection/summary statistics) or outlier values (using box plots, scatter plots, and statistical methods such as z-scores and the interquartile range).

Continuous data were also initially evaluated for distribution pattern with the Shapiro-Wilk test before analysis, with all p-values >0.05, indicative of a normal distribution pattern. Continuous data were expressed as mean ± two standard deviations, and compared with the Student t-test or analysis of variance for the normally distributed data.

Categorical data were presented as proportions in numbers/percentages and compared with the Chi-square test or Fisher's Exact test, as appropriate. Linear regression and multiple logistic regression models was to establish the relationships and associations between the independent (HCC) and dependent variables (arterial blood pressures).

All analyses were carried out at 95% confidence intervals, and a p-value of <0.05 will be deemed statistically significant.

RESULTS

As shown in Table 1, the mean age, SBP, DBP, BMI, effort total score, reward total score, effort-reward ratio, percentage of OC total score, and HCC of the studied population were 32.55±5.28 years, 129.32±6.31, 80.35±4.71, 27.12±1.41, 10.68±2.49, 13.01±2.19, 1.92±0.55, 71.70±9.95, and 189.68±34.00, respectively (Table 1). Most were predominantly females in a married union, all tertiary-educated, physicians/dentists, followed by the nurses/midwives, junior staff, on annual income of 1-3 million naira, on workings of less than five years, on nil cigarette smoking status, negative response on alcohol consumption, had insufficient daily sleeping time, pre-hypertensive/hypertensive, overweight, had positive affirmation to general chronic stress with predominantly current job stress, financial stress, and daily life changes/busyness (p<0.05) (Table 3). As also shown in Table 1, 381 (89.5%) attained subjective COS threshold based on the ERR criteria, 310 (72.8%) attained subjective COS threshold based on the OC criteria, and 390 (91.50%), attained objective COS threshold based on the HCC criteria (p<0.001) (Table 1). However, 273 (70%) had COS diagnosis based on the combination of the ERR, OC, and HCC COS criteria, including a positive response to general chronic stress status and current job-related stress as defined previously (Table 1). As shown in Table 2, 25 (9.2%), 167 (61.2%), and 81 (29.7%) were found to be normotensive, pre-hypertensive, and hypertensive, respectively (p<0.001). The pre-hypertensives and hypertensives were older and had higher mean HCC, BMI, effort total score, effort-reward ratio, percentage of OC total score, but lower reward total score compared to the normotensives (p<0.05) (Table 2). Most hypertensives were males (n=41; 50.6%), in married union (n=56; 69.1%), junior-ranked staff (n=46; 56.8%), on 1-3 million naira per annum (n=35; 43.2%), within 5-10 years on the job (n=40; 49.4%), with nil alcohol consumption history (n=273; 100%) and on insufficient daily sleeping time (n=41; 50.6%) compared to the normotensives and pre-hypertensives (p<0.05) (Table 2). While most pre-hypertensives were females (n=101; 60.5%), senior staff (n=89; 53.3%), with less than five working years (n=96; 57.5%), overweight (n=147; 88%) and with positive alcohol consumption response (n=10; 6%) compared to the normotensives and hypertensives (p<0.05) (Table 2). As shown in Table 3, HCC has a strong correlation with SBP (Crude beta: 0.724; CI: 0.658 - 0.872; p<0.001; adjusted beta: 0.706; CI: 0.613-0.814; p<0.001), but a moderate

correlation with DBP (crude beta: 0.477; CI: 0.385-0.696; $p < 0.001$; adjusted beta: 0.450; CI: 0.358-0.624; $p < 0.001$) in both crude and adjusted linear regression (Table 3). As depicted in Table 4, HCC at >128 pg/mg hair was associated with pre-hypertension (crude OR: 1.809; CI: 1.264-3.591; $p < 0.001$; adjusted OR: 1.611; CI: 1.114-

3.160; $p < 0.001$) but more pronounced with hypertension (crude OR: 3.451; CI: 2.603-5.672; $p < 0.001$; adjusted OR: 3.370; CI: 2.351-5.402; $p < 0.001$) when compared to the normotensives using the crude and adjusted multiple logistic regression models (Table 4).

Table 1: Baseline socio-demographics of study participants.

Variables	Total, n=426 M±SD/ N (%)	P value	Variables	Total, n=426 M±SD/ N (%)	P value
Panel A			Panel B		
Age, years	32.55±5.28	-	ABP vital signs		
Gender		0.005*	Systolic ABP, mmHg	129.32±6.31	-
Male	184 (43.20)		Diastolic ABP, mmHg	80.35±4.71	-
Female	242 (56.80)		ABP grades		<0.001*
Marital status		<0.001*	Normotensive	80 (18.5)	
Married	303 (71.10)		Pre-hypertensive	240 (56.3)	
Single	123 (28.90)		Hypertensive	109 (24.9)	
Others	0 (0.00)		BMI, kg/m²	27.12±1.41	-
Educational status		-	BMI grades		<0.001*
Tertiary	426 (100.00)		Ideal	45 (10.5)	
Others	0 (0.00)		Overweight	330 (77.5)	
Healthcare professional cadre		<0.001*	Obesity	51 (12.0)	
Physicians/dentists	165 (38.80)		General chronic stress		<0.001
Nurses/midwives	161 (37.80)		Positive	413 (96.90)	
Laboratory scientists	30 (7.00)		Negative	13 (3.1)	
Pharmacists	20 (4.70)		Specific chronic stress		<0.001
Health management staff	20 (4.70)		Financial	274 (64.30)	
Other health workers**	30 (7.00)		Current job-related	426 (100.0)	
Healthcare job rank		0.777	Relationship problems	10 (2.30)	
Junior	216 (50.70)		Major life changes	10 (2.30)	
Senior	210 (49.30)		Current health issues	0 (0.0)	
Income/annum (₦) (million)		<0.001*	Life changes/busyness	339 (79.6)	
≤1	6 (1.40)		Other stress factors	0 (0.0)	
1–3	185 (43.40)		ERI parameters		
3–5	75 (17.60)		Effort	10.68±2.49	-
≥5	160 (37.60)		Reward	13.01±2.19	-
Working years, years		<0.001*	ERR	1.92±0.55	-
≤5	214 (50.20)		% of OC total	71.70±9.95	-
5–10	171 (40.10)		ERR grades		<0.001*
≥11	41 (9.70)		<1	45 (10.50)	
Cigarette consumption		-	≥1 (COS threshold)	381 (89.5)	
Yes	0 (0.00)		% of OC total		<0.001*
No	426 (100.0)		<50%	116 (27.20)	
Alcohol consumption		<0.001*	≥50% (COS threshold)	310 (72.8)	
Yes	25 (5.90)		HCC, pg/mg hair	189.68±34.00	-
No	401 (94.10)		HCC grades		<0.001*
Nil response	0 (0.0)		Low	3 (0.80)	
Sleeping time/day		<0.001*	Normal	33 (7.70)	
≤6 (deficient)	100 (23.40)		High (COS threshold)	390 (91.50)	
6–7 (insufficient)	226 (53.20)		COS diagnosis		<0.001*
≥7 (sufficient)	100 (23.40)		Positive	273 (70.0)	
WHR	0.90±0.09	-	Negative	117 (30.0)	

*Statistically significant; ABP: arterial blood pressure; BMI: body mass index; WHR: waist-hip ratio; ERI: effort-reward imbalance; ERR: reward-reward ratio; HCC: hair cortisol concentration; OC: over-commitment; COS: chronic occupational stress; **dietitians/nutritionists, medical assistants, physiotherapists, medical trainees/interns, respiratory therapists, and medical/dental equipment operators

Table 2: Distribution of parameters by arterial blood pressure categories among those diagnosed with chronic occupational stress.

Variables	Normotensive	Pre-hypertensive	Hypertensive	P value	Total
	M±SD/ N (%)	M±SD/ N (%)	M±SD/ N (%)		
ABP categories, n (%)	25 (9.2)	167 (61.2)	81 (29.7)	<0.001*	273 (100)
Age, years	31.80±2.08	32.28±5.50	33.93±5.10	0.003*	32.44±5.24
Gender				0.020*	
Male	5 (20.0)	66 (39.5)	41 (50.6)		112 (41.0)
Female	20 (80.0)	101 (60.5)	40 (49.4)		161 (59.0)
Marital status				0.002*	
Married	25 (100.0)	110 (65.9)	56 (69.1)		191 (70.0)
Single	0 (0.0)	57 (34.1)	25 (30.9)		82 (30.0)
Job rank				0.209	
Junior	15 (60.0)	78 (46.7)	46 (56.8)		139 (50.9)
Senior	10 (40.0)	89 (53.3)	35 (43.2)		134 (49.1)
Income/annum (₦) (million)				0.099	
≤1	0 (0.0)	2 (1.20)	1 (1.2)		3 (1.1)
1–3	15 (60.0)	61 (36.50)	35 (43.2)		111 (40.7)
3–5	0 (0.0)	44 (26.30)	16 (19.8)		60 (22.0)
≥5	10 (40.0)	60 (36.90)	29 (35.8)		99 (36.3)
Working years, years				<0.001*	
<5	5 (20.0)	96 (57.5)	36 (44.4)		137 (50.2)
5-10	20 (80.0)	51 (30.5)	40 (49.4)		111 (40.7)
≥11	0 (0.0)	20 (12.0)	5 (6.2)		25 (9.2)
Alcohol consumption				0.037*	
Yes	0 (0.0)	10 (6.0)	0 (0.0)		10 (3.7)
No	25 (100.0)	157 (94.0)	81 (100.0)		263 (96.3)
Sleeping time/day				0.030*	
≤6 (deficient)	5 (20.0)	59 (35.4)	15 (18.5)		79 (28.9)
6–7 (insufficient)	15 (60.0)	63 (37.7)	41 (50.6)		119 (43.6)
≥7 (sufficient)	5 (20.0)	45 (26.9)	25 (30.9)		75 (27.5)
WHR	0.87±0.03	0.88±0.05	0.89±0.08	0.093	0.87±0.06
BMI, kg/m²	26.70±1.65	27.46±1.50	28.80±1.58	<0.001*	27.78±1.65
BMI grades				<0.001*	
Ideal	0 (0.0)	16 (9.6)	29 (35.8)		45 (16.4)
Overweight	25 (100.0)	147 (88.0)	52 (64.2)		224 (82.1)
Obesity	0 (0.0)	4 (2.4)	0 (0.0)		4 (1.5)
Specific stress factors, yes					
Financial	15 (60.0)	109 (65.3)	62 (76.5)	0.133	186 (68.1)
Current work-related	55 (100.0)	167 (100.0)	81 (100.0)	NA	276 (100.0)
Relationship problems	0 (0.0)	4 (2.4)	5 (6.2)	0.165	9 (3.3)
Major life changes	0 (0.0)	4 (2.4)	5 (6.2)	0.185	9 (3.3)
Daily life changes/busyness	21 (84.0)	130 (77.8)	69 (85.2)	0.353	220 (80.6)
ERI parameters					
Effort total score	11.24±0.60	11.41±0.87	11.89±0.39	<0.001*	11.54±0.78
Reward total score	13.20±1.80	12.84±0.74	12.20±2.70	0.012*	13.00±1.68
Effort-reward ratio	2.02±0.42	2.17±0.17	2.27±0.73	0.005*	2.10±0.41
% of OC total score	76.77±8.11	82.55±9.70	84.64±10.30	0.033*	83.20±9.56
HCC, pg/mg hair	168.43±10.33	193.85±11.66	205.66±10.65	<0.001*	200.86±12.96

*Statistically significant; ABP: arterial blood pressure; WHR: waist0-hip ratio; BMI: body mass index; HCC: hair cortisol concentration; OC: over-commitment; COS: chronic occupational stress; NA: not applicable

Table 3: Results of linear regression analysis between HCC and ABP.

ABP class	Crude linear logistic regression			Adjusted linear logistic regression**		
	HCC, pg/mg hair			HCC, pg/mg hair		
	Beta	95% CI	P value	Beta	95% CI	P value
SBP, mmHg	0.724	0.658-0.872	<0.001*	0.706	0.613-0.814	<0.001*
DBP, mmHg	0.477	0.385-0.696	<0.001*	0.450	0.358-0.624	<0.001*

*Statistically significant; beta: standardized coefficient; CI: confidence intervals; ABP: arterial blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; HCC: hair cortisol concentration; **adjusted for age, gender, marital status, working years, alcohol consumption, sleeping time/day, BMI, BMI categories, effort total score, reward total score, effort-reward ratio, and OC total score

Table 4: Result of association between HCC at >128 pg/mg hair and ABP categories using multiple logistic regression models.

ABP categories	Crude logistic regression			Adjusted logistic regression**		
	HCC at >128 pg/mg hair			HCC at >128 pg/mg hair		
	OR	95% CI	P value	OR	95% CI	P value
Normotensive (reference)	1.0			1.0		
Pre-hypertensive	1.809	1.264-3.591	<0.001*	1.611	1.114-3.160	<0.001*
Hypertensive	3.451	2.603-5.672	<0.001*	3.370	2.351-5.402	<0.001

*Statistically significant; OR: odd ratio; beta: standardized coefficient; CI: confidence intervals; ABP: arterial blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; HCC: hair cortisol concentration; **adjusted for age, gender, marital status, working years, alcohol consumption, sleeping time/day, BMI, BMI categories, effort total score, reward total score, effort-reward ratio, and OC total score

DISCUSSION

Principal findings

In the current study, most studied HPs (70%) had a high proportion of COS diagnoses. Among those with a COS diagnosis, the majority were pre-hypertensive and hypertensive at the time of recruitment. Those with pre-hypertensive and hypertensive status had higher mean HCC levels compared to the normotensives. HCC had a strong positive correlation with SBP, but a moderate positive correlation with DBP. At >128 pg/mg hair, HCC was significantly associated with pre-hypertension but more robustly with hypertension.

Principal finding relationships with the existing literature

The current study supports similar research on COS-related HCC and indicators of ABP, such as SBP and DBP, among working populations.¹⁻⁶ Bautista and colleagues investigated whether HCC was independently associated with hypertension in 75 study populations in the Survey of the Health of Wisconsin in the United States.³ The authors used approximate Bayesian logistic regression with a prior odds ratio of 1.0–4.0 to assess the multivariate-adjusted association between HCC and hypertension, even though people with HCC median values of 78.1 pg/mg hair were believed to have been exposed to COS. Those exposed to high COS-associated HCC had a 2.2 times higher prevalence of hypertension. Because they measured exposure and outcome blindly, the authors concluded that measurement errors were unlikely to explain their results. Additional sensitivity analyses suggested that the association was most likely not due to unmeasured

confounders, survival bias, or reverse causality bias. Based on these findings, Bautista and colleagues concluded that elevated HCC could be a potential risk factor for hypertension.³

Wang and colleagues measured the baseline blood pressure of 2520 workers in 2015 and used the occupational stress inventory to measure changes in COS in order to investigate the relationship between changing COS levels, HCC, and hypertension among employees at petrochemical companies in Xinjiang, China.⁴ Between January 2016 and December 2017, COS and BP were monitored, and there were 1784 workers in the final study cohort. 423 eligible study population were selected randomly for hair acquisition to determine HCC levels. The study cohort's mean age was 37.77±7.53 years, and 46% of them were males. Following analyses, Wang and associates found that elevated COS was associated with a higher risk of hypertension (RR=4.200). Compared to workers who experienced constant COS, those who experienced elevated COS had a higher HCC. High HCC was linked to higher rates of elevated SBP and DBP, and it also raised the risk of hypertension (RR=5.270). HCC had a 0.51 mediating effect, accounting for 36.8% of the total effect. Given that HCC was found to have acted as a mediator between COS and hypertension, Wang and colleagues deduced from these findings that elevated COS may raise the incidence of hypertension through elevated HCC.⁴ The current study findings are in line with the reports from Bautista and colleagues from the United States and those from Wang and colleagues from China.^{3,4}

Due to inconsistencies in the existing literature, Pageau and colleagues recently conducted a systematic review and meta-analysis of 16 relevant studies to shed light on the

relationship between COS-associated HCC and ABP. They found that there was a positive correlation between HCC and SBP ($r=0.19$, including a positive correlation between HCC and DBP ($r=0.13$). A significant positive correlation was found between HCC and the presence of hypertension ($OR=3.23$).¹ In light of these results, Pageau and associates concluded that there is currently evidence linking higher HCC to elevated blood pressure and a possible risk factor for hypertension.¹

Results from earlier research on the connection between COS and hypertension, however, have been mixed and contradictory. Cross-sectional studies were conducted in the past, and while COS was linked to hypertension in some of those studies, it was not in others.²

One possible explanation for the inconsistent and contradictory reports is the application of COS biomarkers (i.e., levels of cortisol in blood, urine, and saliva) that represent transient adaptive reactions to stress and/or circadian fluctuations.²² It is unlikely that these brief exposures will result in a chronic stress reaction or the development of persistently high blood pressure.²² Self-reported questionnaire measures of COS are also subject to these limitations because they evaluate personal beliefs and feelings for one month or less and may be influenced by retrospection bias, social desirability, and individual differences in affective state awareness.²³ HCC is a better indicator than the previously mentioned biomarkers, even though it only measures COS levels over months.

Mechanistic consideration

ABP may be influenced by COS through a variety of biochemical pathways, which can result in hypertension.^{24,25} These biochemical mechanisms include increased adrenaline content, increased expression of adrenal alpha receptors, and the effect of catecholamine.⁴⁻⁶ Additionally, through the central nervous system, cortisol induces vasoconstriction and promotes sodium and water reabsorption from renal tubules, all of which increase blood volume and blood pressure.⁴⁻⁶ Evidence indicates that prolonged exposure to high levels of COS-associated cortisol causes glucocorticoid receptor resistance, which impairs the immune system's ability to respond to cortisol's anti-inflammatory effects and creates a chronic pro-inflammatory state that ultimately results in the development of hypertension.^{3-6,24} Furthermore, increased systemic cortisol may cause vascular endothelial dysfunction, suppress inducible nitric oxide synthase expression, reduce endothelial nitric oxide availability, and raise regional vascular resistance, all of which may contribute to blood pressure elevation and hypertension.^{3-6,25}

Relevance of findings to clinical practice and future research

Compared to self-reports and cortisol measurements in other matrices, HCC levels provide a more accurate

indicator of COS exposure and lower variability. Even though it may be useful, the clinical utility of HCC as a tool for risk assessment or tracking COS-related effects, like its impact on ABP, is still unclear and definitely needs more thorough investigation before being confirmed by larger prospective cohort studies.

Strength and limitations

The strength of the current study lies in its large sample size, employment of multiple subjective and objective criteria to define COS, and the adjustment of multiple covariates.

However, the study was limited by some factors that may be areas of improvement in future studies. It was a hospital-based study, and hence, its findings may not be generalized and representative of other situations, limiting the broader applicability of the current findings. As is with most observational studies, its findings do not establish causal relationships but mere associations and so, should be interpreted with caution.

CONCLUSION

The current study findings indicate that COS-associated HCC correlated with ABP. At the threshold adjudged to define objective COS, HCC was also associated with pre-hypertension, but more robustly with hypertension. These observations imply that COS-associated HCC is a major influence on ABP and a critical factor in the evolution of pre-hypertension and hypertension among the studied population. Further research is recommended for confirmation of current findings.

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