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Modifiable risk factors including sunlight exposure and fish consumption are associated with risk of hypertension in a large representative population from Macau

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ABSTRACT

Chinese populations are known to be at risk for vitamin D deficiency, with some evidence that this is due to lack of exposure to sunlight. Vitamin D deficiency and/or low sun exposure have been associated with higher incidence of hypertension in Caucasians. Thus, we investigated these associations in a Chinese population with a high rate of hypertension. From a random household survey of 1410 residents aged ≥18 years, height, weight and blood pressure were measured and demographic, exercise and dietary data were collected, as well as estimated hours of sunlight exposure on weekdays and weekends (in winter and summer). Modifiable predictors of hypertension in these data were lack of sunlight exposure and low intake of fish as well as smoking, obesity and lack of exercise. When investigated in a linear model, sunlight exposure was negatively associated with hypertension ($\beta = -0.072$, $p < 0.001$) as was physical activity ($\beta = -0.021$, $p < 0.001$) and fish consumption ($\beta = -0.177$, $p < 0.001$). In contrast body mass index (weight/height^2) was positively associated with hypertension ($\beta = +0.62$, $p < 0.001$), as were pack-years of smoking ($\beta = +0.27$, $p < 0.001$). On multivariate categorical analysis taking into account demographic risk factors in these data (age, gender and occupation) having more than half an hour's sun exposure per day compared to none was associated with less hypertension (OR = 0.6, 95% CI: 0.4–0.8). Similarly, consuming either oily fish or seafood more than four times per week compared to less was also associated with less hypertension (oily fish (OR = 0.4, 95% CI: 0.3–0.5); seafood consumption (OR = 0.8, 95% CI: 0.7–0.9)). Having daily moderate physical activity compared to none was also associated with a lower risk of hypertension (OR = 0.8, 95% CI: 0.7–0.9). In contrast, being obese compared to normal weight and having more than five pack-years of smoking compared to none were associated with a higher risk of hypertension (OR = 4.6, 95% CI: 3.7–5.7; OR = 1.4, 95% CI: 1.0–1.8, respectively). The major new findings of this study are that more sun exposure and high weekly fish consumption (especially oily fish) may be potentially modifiable independent factors for protecting against risk of hypertension in this population.

This article is part of a Special Issue entitled '16th Vitamin D Workshop'.

1. Introduction

Established determinants of vitamin D status are exposure to sunlight and intake of vitamin D, either from foods or vitamin supplements [1,2]. In addition to maintaining bone and muscle health, vitamin D has recently been postulated to protect against hypertension [3,4]. Chinese populations have been found to be vitamin D deficient [5,6]. This deficiency in Chinese populations has been hypothesized to be due to lack of sunlight, especially in females [7,8]. Thus, we investigated vitamin D status and sun exposure variables, along with established modifiable risk factors for hypertension (smoking, obesity, physical activity) in a large representative healthy population living in Macau, China, adjusted for demographic factors (age, gender, occupation).

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2. Material and methods

2.1. Study sample

Participants (n = 1410, males = 638) aged from 19 to 93 were recruited in 2012 by random selection in Macau.

2.2. Data collection

A detailed interview-administered questionnaire documented demographics, smoking habits, sun exposure, and non-validated food frequency per week of key foods high in vitamin D (especially oily fish and seafood). Sun exposure was measured by time spent in the sun (measured as self-reported minutes per day on weekends and weekdays in different seasons). Physical measurements (height and weight) were obtained on individuals in light clothing without shoes. Body mass index (BMI) was calculated as body weight divided by height squared (kg/m^2). Blood pressure was measured with an automatic sphygmomanometer (OMRON, T9P) and with appropriate size of cuff. Two consecutive measurements of blood pressure were taken on the right arm at heart level according to 1999 World Health Organization/International Society of Hypertension guidelines on hypertension [9]; these measurements were taken with the participant in a seated position after 5 min of rest. The mean of the two measures was used for data analysis. Hypertension was defined according to the Chinese Guidelines on Prevention and Control of Hypertension [10]: systolic blood pressure (SBP) ≥140 mm Hg, diastolic blood pressure (DBP) ≥90 mm Hg, and/or self-reported treatment of hypertension with antihypertensive medication in the last two weeks. Twenty percent of the total study population was on hypertension treatment. Among the hypertensive population (34%) 59% were on hypertension treatment. In order to assess the levels of physical activity, the International Physical Activity Questionnaire short version (IPAQ-S) was used which contains objective questions regarding the frequency and duration of physical activity [11]. Normal weight, overweight and obese cut-offs were determined according to the Chinese specific criteria [12] as BMI < 24 kg/m^2, 24 ≤ BMI < 28 kg/m^2 and BMI ≥ 28 kg/m^2, respectively.

2.3. Data analysis

In order to establish the association between potential risk factors and hypertension, an initial descriptive data analysis (based on mean differences or regression) was performed. Subsequently potential risk factors were assessed categorically by multivariate logistic regression analyses, adjusting for age, gender and occupation [13]. The categorical regression was expressed as adjusted odds ratios (OR) with 95% confidence intervals (CI) [14].

3. Results

3.1. Modifiable risk factors and hypertension: univariate analyses

When investigated in a linear model, sunlight exposure was negatively associated with hypertension (overall $\beta = -0.072$, $p < 0.001$; summer −0.062, $p < 0.001$; and winter −0.077, $p < 0.001$) as was physical activity ($\beta = -0.021$, $p < 0.001$) and fish consumption ($\beta = -0.177$, $p < 0.001$). In contrast BMI was positively associated with hypertension ($\beta = +0.62$, $p < 0.001$), as were pack-years of smoking ($\beta = +0.27$, $p < 0.001$). Table 1 presents these variables expressed as mean differences.

Table 1
Distribution and descriptive characteristics of modifiable risk factors associated with Hypertension n = 1410.

Risk factor	%	Mean SBP	Mean DBP	OR (95% CI)[a]	OR (95% CI)[b]	OR (95% CI)[c]
Sun exposure						
<1/2 h/day	22	125 (20)	76 (12)	1.0	1.0	1.0
≥1/2 to 2 h/day	47	125 (18)	74 (10)	0.9 (0.7–1.0)*	0.9 (0.8–1.1)	0.9 (0.8–1.1)
≥2 to 4 h/day	18	122 (18)	74 (11)	0.6 (0.5–0.7)*	0.9 (0.7–1.1)	0.8 (0.7–1.0)*
≥4 h/day	13	122 (18)	75 (11)	0.5 (0.4–0.7)*	0.8(0.6–0.9)*	0.7(0.6–0.9)*
ANOVA/P trend		<0.001	<0.001	<0.001	0.03	0.004
Food intake						
Oily fish						
<4 times/week	85	126 (19)	75 (11)	1.0	1.0	1.0
≥4 times/week	15	119 (17)*	73 (10)*	0.4 (0.3–0.5)*	0.6 (0.5–0.7)*	0.4 (0.3–0.5)*
Seafood						
<4 times/week	67	124 (18)	74 (11)	1.0	1.0	1.0
≥4 times/week	33	126 (20)*	75 (11)*	0.8 (0.7–0.9)*	0.9 (0.8–1.0)*	0.8 (0.7–0.9)*
Lifestyle factors						
Pack-years of smoking						
None	79	123 (18)	74 (11)	1.0	1.0	1.0
<5 pack years	11	128 (19)	76 (11)	1.4 (1.2–1.6)*	1.3 (1.1–1.6)*	1.3 (1.0–1.6)
≥5 pack years	10	132 (20)	79 (12)	1.7 (1.4–2.0)*	1.4 (1.1–1.8)*	1.4 (1.0–1.8)*
ANOVA/P trend		<0.001	<0.001	<0.001	0.03	>0.05
Body mass index[†]						
Normal	61			1.0	1.0	1.0
Overweight	29	130 (18)	77 (10)	2.3 (2.0–2.5)*	2.0 (1.8–2.3)*	2.1 (1.8–2.4)*
Obese	10	134 (16)*	80 (11)*	4.4 (3.7–5.2)*	4.7 (3.8–5.7)*	4.6 (3.7–5.7)*
Physical activity[‡]						
Low	23	125 (18)	75 (11)	1.0	1.0	1.0
Moderate	48	125 (18)	74 (10)	1.0 (0.8–1.1)	0.9 (0.8–1.0)*	0.8 (0.7–0.9)*
High	29	124 (19)	73 (10)	0.9 (0.8–1.0)*	0.8 (0.7–0.9)*	0.8 (0.7–1.0)*
ANOVA/P trend		>0.05	<0.001	>0.05	>0.05	>0.05

* $p < 0.001$.
[a] Crude.
[b] Adjusted for age, gender and occupation.
[c] Mutually adjusted for age, gender and occupation as appropriate.
[†] Normal: BMI < 24 kg/m^2; overweight: 24 ≤ BMI < 28 kg/m^2; obese: BMI ≥ 28 kg/m^2.
[‡] Categorized according to IPAQ Scoring Protocol.

3.2. Modifiable risk factors and hypertension: categorical and multivariate analyses

On multivariate categorical analysis taking into account demographic risk factors in these data (age, gender and occupation) having more than half an hour's sun exposure per day compared to none was associated with less hypertension (OR = 0.6, 95% CI: 0.4–0.8). Similarly, consuming either oily fish or seafood more than four times per week compared to less was also associated with less hypertension (oily fish OR = 0.4, 95% CI: 0.3–0.5; seafood consumption OR = 0.8, 95% CI: 0.7–0.9). Having daily moderate physical activity compared to none was also associated with a lower risk of hypertension (OR = 0.8, 95% CI: 0.7–0.9). In contrast, being obese compared to normal weight and having more than five pack-years of smoking compared to none were associated with a higher risk of hypertension (OR = 4.6, 95% CI: 3.7–5.7; OR = 1.4, 95% CI: 1.0–1.8, respectively).

4. Discussion

4.1. Comparison to other similar populations

Dietary vitamin D intake has consistently been reported as a determinant of vitamin D status in many studies [1,2,6,15]; studies conducted in the United States of America with 238,199 participants and 52,000 incident cases of hypertension (self-reported not measured) have shown associations between higher dietary vitamin D and lower hypertension [16,17]. A recent meta-analysis [4] reported significant associations between lower 25-hydroxyvitamin D (25OHD) and hypertension, although results from randomized control trials have been conflicting [1,18,19]. Several studies conducted in China have investigated the association between 25OHD levels and hypertension with conflicting results. A large study in Shanghai has reported negative associations between 25OHD levels and hypertension [20], but studies from south-west China of 1420 factory workers have reported null associations [21]. To the best of our knowledge, no studies from China have investigated either sun exposure measures or dietary intake of fish, known to be a reasonable source of vitamin D (personal communication H Greenfield) with hypertension rates [5,22].

4.2. Mechanism of action

There is a growing body of evidence from animal [23] and clinical studies [24] that vitamin D-mediated reduction of hypertension involves increased activation of the rennin-angiotensin–aldosterone system (which is the main regulator of electrolyte and volume homeostasis) that contributes to the development of arterial hypertension.

4.3. Strengths and limitations

The strengths of the present investigation are the size and the representativeness (random sample) of the study population and that the measures of blood pressure and body mass index were performed by the study team. It should be noted that our study is limited by having only key dietary items identified, not an overall food frequency questionnaire and there were no blood measurements of 25OHD. It should be noted that although intake of foods high in vitamin D was not validated in this study, the same food frequency questions used in this study were use in a previously published study where the food items were found to be positively correlated with blood 25OHD levels [5]. In addition, there was no direct measure of sun exposure or physical activity or smoking habits; however, we did collect self-reported recall of sun exposure on weekends and weekdays (during both summer and winter).

5. Conclusion

The major finding of this study is that sun exposure and fish consumption may be potentially modifiable independent factors for risk of hypertension in this population. It should be noted that our results may also be the result of either an independent effect of sunlight on hypertension [25] or reverse causality, as those with higher blood pressure may just go outside less and/or eat less healthy diets. Further investigation with 25OHD levels may shed light to these findings.

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