# Investigating the prevalence of hypertensive heart disease in adults age 20+ in the UK and the US between 2004 and 2019

A Report submitted as the examined component of the Project Module SXB390

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(4575 words)

**Abstract**

Hypertension, consistently high blood pressure, causes scarring to the heart when left untreated. Such fibrosis can result in permanently reduced function of the left ventricle and consequently a life-threatening condition – hypertensive heart disease. Many biological factors can contribute to the difference in risk of cardiovascular disease in individuals including renal function, hormonal changes, and reactive oxygen species. This study will investigate the differences between age groups and sexes in hypertensive heart disease prevalence and bridge the gap to understand the interaction of age and sex. A dataset of results from the Global Burden of Disease 2019 study was analysed, comparing the prevalence rate of hypertensive heart disease per 100,000 adults in both the UK and the US. Prevalence was displayed by country, sex, and age group and the interaction of sex and age group on prevalence tested. The data was statistically analysed using the Mann-Whitney U-test and the two-way analysis of variance test. Prevalence rate of hypertensive heart disease was significantly higher in the US; over 4 times the UK prevalence between 2004 and 2019. The rate of hypertensive heart disease prevalence was significantly higher in females than in males, and prevalence increased as age group increased, in both the UK and US. There was a significant interaction between sex and age group on prevalence in both countries. More consistent diagnostic criteria across the world that accounts for biological race differences would allow more timely diagnosis of hypertensive heart disease. This would impact treatment of cardiovascular disease going forward and have implications for reducing avoidable mortality. The findings suggest that there are significant country differences in the prevalence of hypertensive heart disease, however more large-scale research is needed across the world to improve understanding and treatment.

(286 words)

**List of abbreviations**

| | |
|---|---|
| **ANOVA** | Analysis of variance |
| **BMI** | Body mass index |
| **BP** | Blood pressure |
| **CVD** | Cardiovascular disease |
| **HHD** | Hypertensive heart disease |
| **LVH** | Left ventricular hypertrophy |
| **RAAS** | Renin-angiotensin aldosterone system |
| **ROS** | Reactive oxygen species |
| **UK** | The United Kingdom |
| **US** | The United States of America |

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## 1 Introduction

### *1.1 Background*

The prevalence and control of hypertension is a public health challenge across the world. Insufficient diagnosis and treatment can lead to a life-threatening complication – hypertensive heart disease (HHD). HHD was responsible for almost 1.2 million deaths worldwide in 2019 (Global Burden of Disease Collaborative Network, 2022). Hypertension is defined as an abnormally high blood pressure (BP) in the blood vessels and is usually accompanied by few or no symptoms (World Health Organization, 2023). When hypertension is not effectively treated, prolonged high BP reduces diastolic function, disrupting normal neurohormone response such as in the renin-angiotensin aldosterone system (RAAS), and increasing immune cell interactions promotes fibrosis of cardiac cells. Eventually cardiac fibrosis progresses, extending to the sub-epicardium, causing left ventricular hypertrophy (LVH), enlargement of the left atrium, impaired right ventricle function, and disrupted energy production of cardiomyocytes, all of which contribute to resulting heart failure (Huang et al, 2024). Reduced ejection fraction is characteristic of advanced HHD; the fibrosis of the heart, in particular LVH, means it now pumps out less than 40% of the blood with contraction. At this point, ischaemia, arrythmias and asystole are all possible, ultimately causing a high risk of cardiac death (Haydock and Flett, 2022).

Diagnosis criteria for hypertension varies between country, and specifically between the United Kingdom (UK) and the United States of America (US) (Sheppard et al, 2016; Marshall et al, 2016). Later diagnosis results in greater fibrosis of the heart before treatment commences, and thus more progression to HHD and worse outcomes – for every 20 mmHg systolic and 10 mmHg diastolic increase in BP, the risk of cardiac death is doubled (Tackling and Borhade, 2023). Research has shown that when HHD is poorly treated, the 6-month mortality rate is 16%, and so inconsistent diagnoses between countries may result in differences in the prevalence of HHD (Tackling and Borhade, 2023). There is also a level of fibrosis and ventricular dysfunction that occur with aging regardless of heart health, and so it would be expected to see increased prevalence of HHD with age (Lu et al, 2017).

Existing research into cardiovascular disease (CVD) has highlighted the gap in knowledge regarding the interaction of factors such as sex and aging, and their impact on developing heart disease (Pinto, 2007). Interesting trends have been identified between prevalence of HHD and age and sex in China, with increased female prevalence in adults less than 50, and increased male prevalence in adults above 50 (Xu et al, 2022). Global studies on HHD have identified similar increases of prevalence in aging populations and noted the large variations in this between different countries (Lu and Lan, 2022). This investigation will examine location differences in prevalence, and any interactions with

age and sex in more detail. Rodgers et al (2019) has indicated a relationship between gender and age, with females of older age being more at risk of declining cardiovascular health, CVD including hypertension, and hence HHD. However, they do not examine this across more age groups, focusing only on older and elderly adults 60+. Other research has considered hypertension prevalence across a wider age range (20-79 years) between three countries (England, the USA and Canada), and identified a lack of effective treatment (Joffres et al, 2013). As a result, complications such as HHD lead to premature death (Joffres et al, 2013). However, the use of data almost 20 years old and the small sample sizes highlight the importance of further research into this area, to better understand the mechanisms. Potential biological factors that could contribute to country, age and sex differences include hormonal changes (Maas and Franke, 2009), sodium levels due to salt intake and resulting damage to RAAS (Borrelli et al, 2020), structural arterial changes (Loo et al, 2024), and oxidative stress (Cai and Harrison, 2000). A greater understanding of these has the potential to lead to more targeted treatments for individuals, earlier and more consistent diagnosis, and a reduction in premature deaths.

*1.2 Research question, objectives and hypotheses*

This project aims to examine the gaps in the existing literature of CVD, investigating the prevalence of HHD across male and female adults of ages 20+. The research will examine the prevalence of HHD, focusing on differences between sexes and age groups from two countries and how these factors interact, using global data on HHD. The data is of a larger scale than much existing literature, providing a better overview of the population worldwide, across a timespan allowing trends to be identified and compared. The results and potential biological explanations for differences seen will be discussed in the context of previously undertaken studies, and the impact such results may have on treating cardiovascular health going forward. To examine HHD prevalence, the following hypotheses will be tested (Table 1).

**Table 1:** Experimental and null hypotheses to investigate the prevalence of hypertensive heart disease in adults in the UK and the US between 2004 and 2019.

| Experimental hypotheses | Null hypotheses |
|---|---|
| $H_1$: There is significant difference in the prevalence per 100,000 adults age 20+ of hypertensive heart disease in the UK and in the US between 2004 and 2019. | $H_{01}$: There is no significant difference in the prevalence per 100,000 adults age 20+ of hypertensive heart disease in the UK and in the US between 2004 and 2019. |
| $H_2$: There is significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the UK between 2004 and 2019. | $H_{02}$: There is no significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the UK between 2004 and 2019. |
| $H_3$: There is significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the UK between 2004 and 2019. | $H_{03}$: There is no significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the UK between 2004 and 2019. |
| $H_4$: There is a significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the UK between 2004 and 2019. | $H_{04}$: There is no significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the UK between 2004 and 2019. |
| $H_5$: There is significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the US between 2004 and 2019. | $H_{05}$: There is no significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the US between 2004 and 2019. |
| $H_6$: There is significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the US between 2004 and 2019. | $H_{06}$: There is no significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the US between 2004 and 2019. |
| $H_7$: There is a significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the US between 2004 and 2019. | $H_{07}$: There is no significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the US between 2004 and 2019. |

## 2 Methods

### *2.1 Dataset background and variables*

To investigate prevalence of HHD and factors influencing it, an existing dataset was analysed and tested. The chosen dataset was the Healthcare Access and Quality Index 1990-2019, providing worldwide observational epidemiological data from the Global Burden of Disease (GBD) study 2019 (Global Burden of Disease Collaborative Network, 2022). Data was extracted using the GBD results search tool, for the UK and the US separately across a time span of 2004-2019, and then also split by age group and sex for each country. The data was extracted in raw form and formatted with the use

of pivot tables in Microsoft excel, to present prevalence rate by age group, sex and country. Prevalence was defined as the number of cases of HHD per 100,000 people.

Prevalence levels in 204 countries were recorded as part of the GBD study 2019, using various methods and models including clinical healthcare informatics such as mortality rates, incidence and disability records. This dataset was chosen due to the long timespan and reliable data collection methods through healthcare records. The UK and the US were chosen as they are both countries of high income and showed great levels of variation in HHD prevalence between age groups and sex within the country, and variation between countries.

*2.2 Analysis and statistical testing*

To analyse the differences between countries, mean prevalence data for each country from the years 2004 to 2019 was compared and plotted to assess differences in trends across the time period. The data was analysed using the Mann-Whitney U-test to test for significance between the prevalence rate of HHD in the UK and the US. The independent variable for this testing was country and the dependent variable was prevalence of HHD. To analyse differences between age groups and sex, and also the interaction of these two factors, the two-way analysis of variance (ANOVA) test was carried out. Both independent variables, age group and sex, were categorical. Values for sex were male or female, defined as sex assigned at birth; values for age group were broken into 15 categories of 5 years each, beginning with 20-24 up to 90-94, with a final 16$^{th}$ category of 95+, defined as age in years as of January 1$^{st}$ of that year. Statistical testing was carried out using StatsCloud, and tests were chosen following checks for normality and equal variance in StatsCloud. The data was plotted for each country, as the mean $\pm$ standard deviation, demonstrating changes between age groups and between sex for HHD prevalence, for each of the UK and the US separately. Following the ANOVA testing, the appropriate follow up test (Tukey HSD) was also carried out, to identify which of the groups differences were seen between.

In order to place this investigation into context, well regarded databases including Web of Science were searched for existing research papers on HHD. Search terms used included ‘hypertensive heart disease OR HHD’, ‘age OR ag*’, ‘UK OR United Kingdom’, ‘US OR USA OR United States OR United States of America OR America’ and ‘sex’. The PROMPT criteria (The Open University, 2023) was used to check the integrity of sources and narrow down the resulting literature for relevance.

*2.3 Ethical statement*

Confirmation has been provided that the data was collected ethically by the researchers. Ethics statement: ‘The GBD study’s protocol has been approved by the research ethics board at the

University of Washington. The GBD shall be conducted in full compliance with University of Washington policies and procedures, as well as applicable federal, state, and local laws.' (Global Burden of Disease Collaborative Network, 2022).

## 3 Results

### *3.1 UK and US prevalence rate and trends*

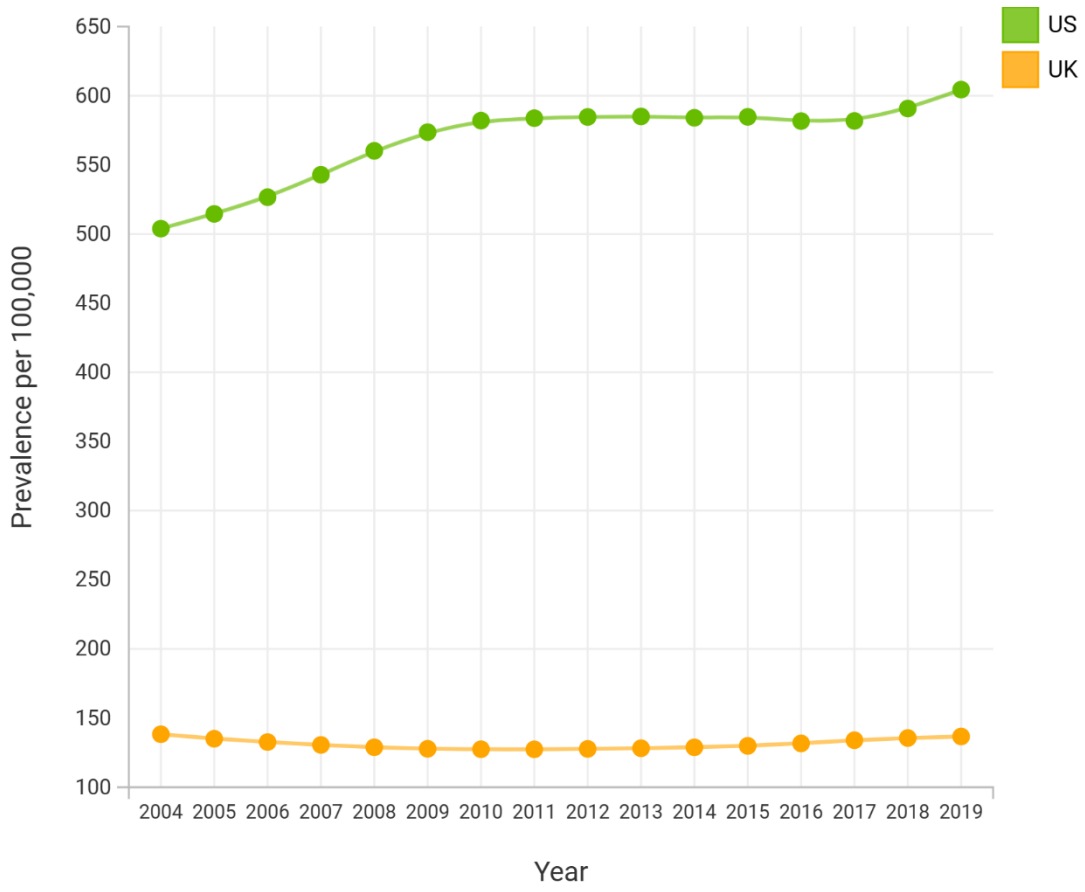
Between the years 2004 and 2019, the US had a much greater prevalence of HHD compared to the UK (Table 2).

**Table 2:** Mean prevalence rate per 100,000 adults 20+ of hypertensive heart disease in the UK and the US between 2004 and 2019. Standard deviation is included in brackets.

| **Country** | **Mean prevalence rate per 100,000 (±s.d.)** |
|---|---|
| **United Kingdom** | 131.3 (±3.53) |
| **United States of America** | 567.8 (±28.69) |

Across the time period, UK prevalence ranged from 127.4 to 136.7 per 100,000. This was compared to the US, which ranged from 503.9 to 604.4 per 100,000. In the US, there was a steady increase in prevalence until 2010, where prevalence plateaued until 2016 where it began to increase again. In the UK, a small dip was seen through the period, but prevalence stayed relatively consistent across the 16 years (Figure 1).

**Figure 1:** Prevalence rate of hypertensive heart disease per 100,000 adults 20+ for each year between 2004 and 2019, for the UK and the US.




Results from the Mann-Whitney U-test show there is a statistically significant difference ($p<0.001$; Table 3) between prevalence of hypertensive heart disease in the UK and in the US, between 2004 and 2019.

**Table 3:** Summary of results from the Mann-Whitney U-test for prevalence per 100,000 of hypertensive heart disease in the UK and the US between 2004 and 2019, with $p<0.001$.

| | **Sample size, n** | **Medians** | **U values** | **Critical value** | **Conclusion** |
|---|---|---|---|---|---|
| **UK vs US** | 16, 16 | 130.3, 581.9 | 256, 0 | 75 | 0 (U) is less than critical value, so null hypothesis is rejected. |

Therefore, the null hypothesis $H_{01}$ (There is no significant difference in the prevalence per 100,000 adults age 20+ of hypertensive heart disease in the UK and in the US between 2004 and 2019) was rejected.

Hence the alternative hypothesis is supported.

*3.2 UK prevalence by age group and sex*

The female group had a greater prevalence of HHD than the male group in the UK, as seen in Table 4 below.

**Table 4:** Mean prevalence rate per 100,000 adults 20+ of hypertensive heart disease in the UK between 2004 and 2019, split by sex. Standard deviation is included in brackets.

| **Sex** | **Mean prevalence rate per 100,000 (±s.d.)** |
|---|---|
| **Female** | 134.06 (±4.45) |
| **Male** | 128.38 (±4.31) |

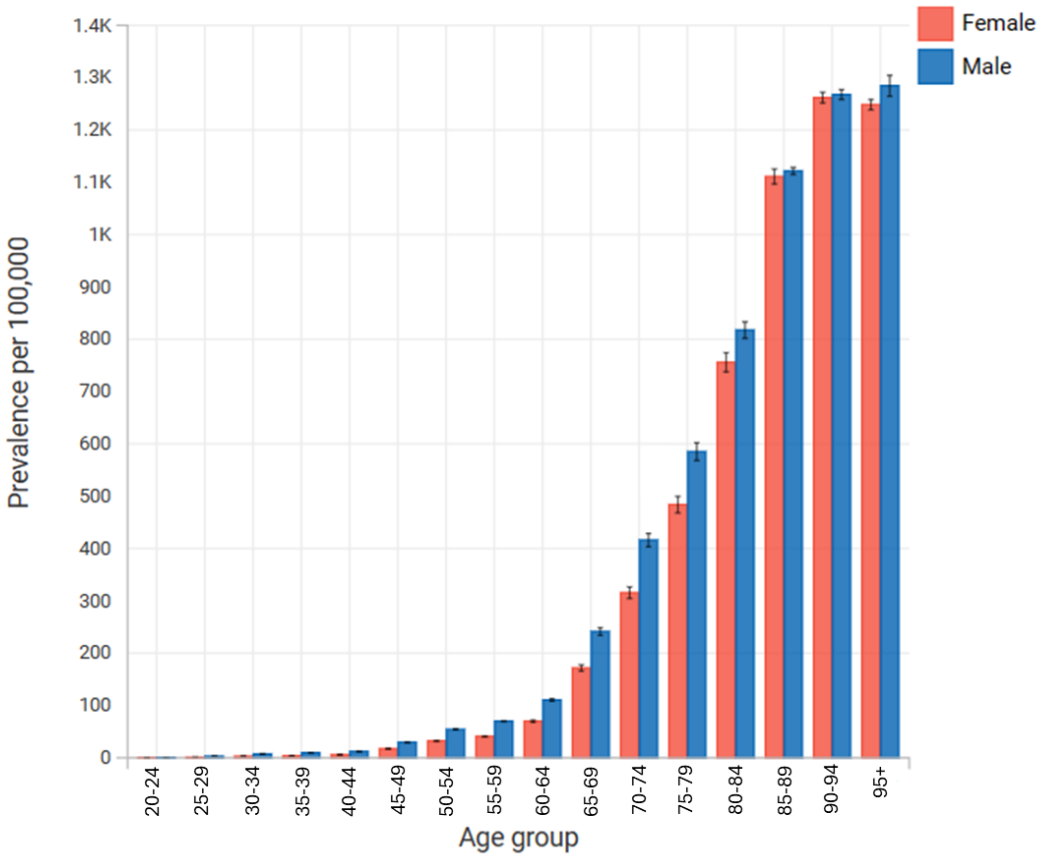
The prevalence of HHD in the UK increased as age group increased (Table 5). At ages 90-94 and 95+, the prevalence was very similar and did not increase further.

**Table 5:** Mean prevalence rate per 100,000 adults of hypertensive heart disease in the UK between 2004 and 2019, split by age group in years. Standard deviation is included in brackets.

| Age group (in years) | Mean prevalence rate per 100,000 (±s.d.) |
|---|---|
| **20-24** | 0.66 (±0.0095) |
| **25-29** | 2.17 (±0.039) |
| **30-34** | 5.09 (±0.41) |
| **35-39** | 6.77 (±0.64) |
| **40-44** | 8.91 (±0.64) |
| **45-49** | 23.37 (±1.03) |
| **50-54** | 43.24 (±1.27) |
| **55-59** | 55.35 (±0.81) |
| **60-64** | 89.90 (±4.32) |
| **65-69** | 205.47 (±12.61) |
| **70-74** | 363.06 (±22.15) |
| **75-79** | 529.36 (±30.51) |
| **80-84** | 781.32 (±32.32) |
| **85-89** | 1115.19 (±21.82) |
| **90-94** | 1264.01 (±15.35) |
| **95+** | 1257.35 (±20.72) |

When shown by age group and sex, prevalence was greater in males than in females up to ages 85-89. At this age group and older, prevalence was very similar in males and females, which can be seen in Figure 2 below. A large jump in prevalence was seen between ages 80-84 and 85-89, in both males and females.

**Figure 2:** Mean prevalence rate per 100,000 adults 20+ (±standard deviation) of hypertensive heart disease in the UK, across the period 2004-2019. Shown by sex and age group in years.




Results from the two-way ANOVA test found that differences between sex (F(1, 480)=[425.56], p<0.001], differences between age groups (F(15, 480)=[24,328.08], p<0.001) and the interaction of sex and age group (F(15, 480)=[30.91], p<0.001) were statistically significant (Table 6).

**Table 6:** Summary of results from the two-way ANOVA test for prevalence per 100,000 of hypertensive heart disease in the UK between 2004 and 2019. *** indicates statistical significance with p<0.001.

| Source of variation | Sum of squares | df | Mean Square | F | P-value |
|---|---|---|---|---|---|
| **Sex** | 129060.50 | 1 | 129060.50 | 425.56 | <0.001*** |
| **Age group** | 110670359.51 | 15 | 7378023.97 | 24328.08 | <0.001*** |
| **Sex x age group** | 140587.50 | 15 | 9372.50 | 30.91 | <0.001*** |

The results show that the following null hypotheses for the UK are rejected (Table 7).

**Table 7:** Null hypotheses for the UK prevalence of hypertensive heart disease, repeated from Table 1.

| | |
|---|---|
| $H_{02}$ | There is no significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the UK between 2004 and 2019. |
| $H_{03}$ | There is no significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the UK between 2004 and 2019. |
| $H_{04}$ | There is no significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the UK between 2004 and 2019. |

Therefore, the alternative hypotheses are supported.

Post hoc testing was carried out using the Tukey (HSD) test (Supplementary Table 3), which found the differences between many different groups. No differences were found between the 20-24, 25-29, 30-34, 35-39 and 40-44 age groups, nor between 40-44 and 45-49, 50-54 and 55-59, and 90-94 and 95+. Comparisons between all other age groups were significant, with all but 2 being significant at $p<0.001$ (30-34 vs 45-49 [$p=0.003$], 35-39 vs 45-49 [$p=0.014$]). Hence this demonstrates the increases in HHD prevalence were statistically significant as age increases, and from 90-94 onwards the prevalence plateaus.

*3.3 US prevalence by age group and sex*

The prevalence of HHD was greater in females than in males in the US (Table 8), the same trend seen in the UK.

**Table 8:** Mean prevalence rate per 100,000 adults 20+ of hypertensive heart disease in the US between 2004 and 2019, split by sex. Standard deviation is included in brackets.

| **Sex** | **Mean prevalence rate per 100,000 (±s.d.)** |
|---|---|
| **Female** | 593.86 (±21.26) |
| **Male** | 540.05 (±38.00) |

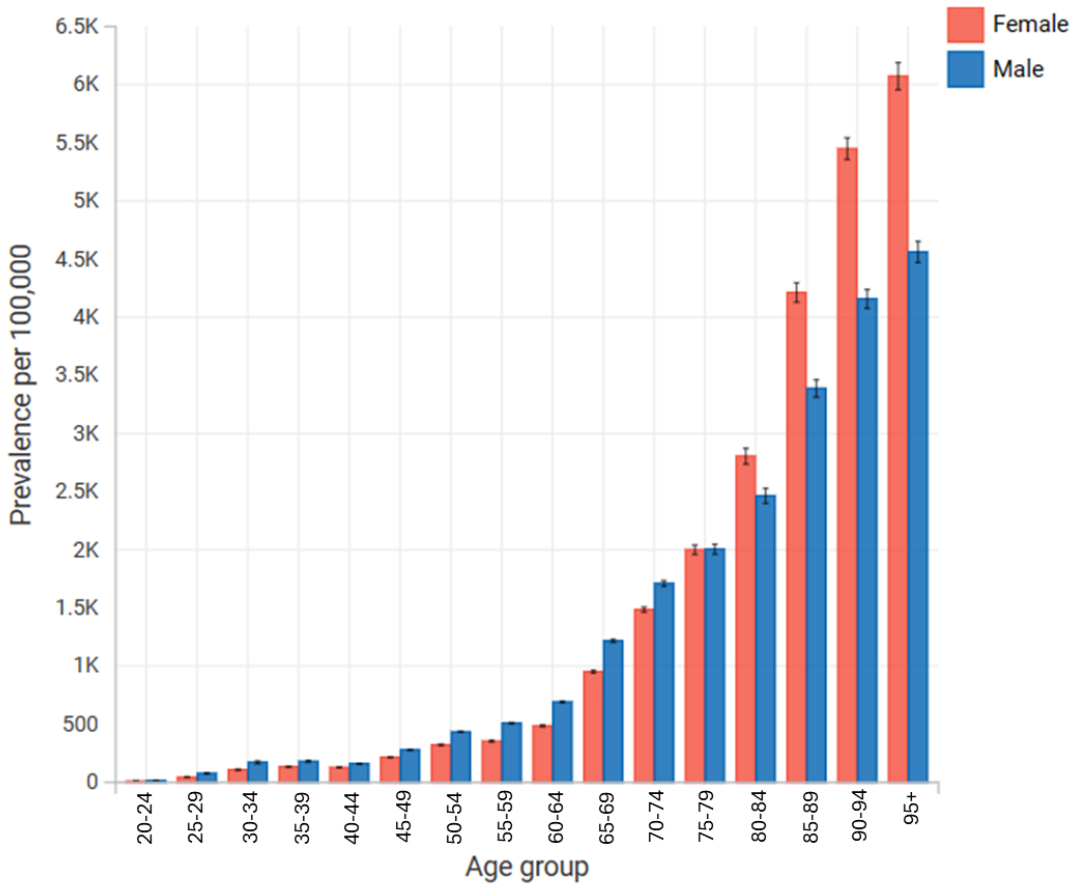
The prevalence of HHD greatly increased as age increased in the US (Table 9). This increase was much more dramatic than the steady increase seen in the UK.

**Table 9:** Mean prevalence rate per 100,000 adults of hypertensive heart disease in the US between 2004 and 2019, split by age group in years. Standard deviation is included in brackets.

| Age group (in years) | Mean prevalence rate per 100,000 (±s.d.) |
|---|---|
| **20-24** | 12.53 (±1.17) |
| **25-29** | 61.14 (±7.13) |
| **30-34** | 140.38 (±17.06) |
| **35-39** | 157.55 (±11.15) |
| **40-44** | 144.38 (±2.94) |
| **45-49** | 247.37 (±5.13) |
| **50-54** | 377.31 (±5.13) |
| **55-59** | 429.71 (±11.07) |
| **60-64** | 584.51 (±11.07) |
| **65-69** | 1077.07 (±22.89) |
| **70-74** | 1589.03 (±42.81) |
| **75-79** | 2002.53 (±79.14) |
| **80-84** | 2667.35 (±126.10) |
| **85-89** | 3916.52 (±147.28) |
| **90-94** | 5049.68 (±162.28) |
| **95+** | 5671.13 (±205.31) |

When shown by sex and age group, prevalence in males was greater than females, up to the 75-79 age group. From age group 80-84 onwards, prevalence was much higher in females than males. The difference between male and female prevalence became larger as the age group increased; the greatest difference was seen at 95+, with female prevalence 6073.34 and male 4561.29 (Figure 3).

**Figure 3:** Mean prevalence rate per 100,000 adults 20+ (±standard deviation) of hypertensive heart disease in the US, across the period 2004-2019. Shown by sex and age group in years.




Results from the two-way ANOVA test found that differences between sex (F(1, 480)=[474], p<0.001], differences between age groups (F(15, 480)=[12,523.48], p<0.001) and the interaction of sex and age group (F(15, 480)=[298.64], p<0.001) were statistically significant (Table 10).

**Table 10:** Summary of results from the two-way ANOVA test for prevalence per 100,000 of hypertensive heart disease in the US between 2004 and 2019. *** indicates statistical significance with p<0.001.

| Source of variation | Sum of squares | df | Mean Square | F | P-value |
|---|---|---|---|---|---|
| **Sex** | 3798616.51 | 1 | 3798616.51 | 474.00 | <0.001*** |
| **Age group** | 1505450304.25 | 15 | 100363353.62 | 12523.48 | <0.001*** |
| **Sex x age group** | 35899756.87 | 15 | 2393317.12 | 298.64 | <0.001*** |

The results show that the following null hypotheses for the US can be rejected (Table 11).

**Table 11:** Null hypotheses for the US prevalence of hypertensive heart disease, repeated from Table 1.

| | |
|---|---|
| $H_{05}$ | There is no significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the US between 2004 and 2019. |
| $H_{06}$ | There is no significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the US between 2004 and 2019. |
| $H_{07}$ | There is no significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the US between 2004 and 2019. |

Therefore, the alternative hypotheses are supported.

Post hoc testing was carried out using the Tukey (HSD) test (Supplementary Table 4), which found the differences between most groups. No differences were found between 20-24 and 25-29, 30-34 and 35-39, 30-34 and 40-44, and 35-39 and 40-44 groups. Comparisons between all other age groups were statistically significant, with all but 3 being significant at $p<0.001$ (25-29 vs 30-34 [p=0.036], 25-29 vs 35-39 [p=0.002], 25-29 vs 40-44 [p=0.019]). This demonstrates that the increases in HHD prevalence were statistically significant as age group increases, and this is consistent across the majority of age groups including the lower ages which were not significant in the UK.

## 4 Discussion

### *4.1 Hypotheses*

The results of this investigation support all of the experimental hypotheses $H_{1-7}$ (Table 1, repeated below).

**Table 1 (repeated):** Experimental and null hypotheses to investigate the prevalence of hypertensive heart disease in adults in the UK and the US between 2004 and 2009.

| Experimental hypotheses | Null hypotheses |
|---|---|
| $H_1$: There is significant difference in the prevalence per 100,000 adults age 20+ of hypertensive heart disease in the UK and in the US between 2004 and 2019. | $H_{01}$: There is no significant difference in the prevalence per 100,000 adults age 20+ of hypertensive heart disease in the UK and in the US between 2004 and 2019. |
| $H_2$: There is significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the UK between 2004 and 2019. | $H_{02}$: There is no significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the UK between 2004 and 2019. |
| $H_3$: There is significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the UK between 2004 and 2019. | $H_{03}$: There is no significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the UK between 2004 and 2019. |
| $H_4$: There is a significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the UK between 2004 and 2019. | $H_{04}$: There is no significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the UK between 2004 and 2019. |
| $H_5$: There is significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the US between 2004 and 2019. | $H_{05}$: There is no significant difference in the prevalence per 100,000 adults 20+ of hypertensive heart disease in male adults and in female adults in the US between 2004 and 2019. |
| $H_6$: There is significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the US between 2004 and 2019. | $H_{06}$: There is no significant difference in the prevalence per 100,000 adults of hypertensive heart disease in different age groups in the US between 2004 and 2019. |
| $H_7$: There is a significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the US between 2004 and 2019. | $H_{07}$: There is no significant interaction between age and sex and the prevalence of hypertensive heart disease per 100,000 adults 20+ in the US between 2004 and 2019. |

That is, country, age group and sex all affect prevalence rate of HHD, and there is a significant interaction between sex and age group and prevalence of HHD. The impact of age group and sex on prevalence was seen in both the UK and the US.

*4.2 Results in context and limitations*

In both the UK and the US, it was seen that as age increases, so does the prevalence of HHD. In both countries, mean female prevalence was significantly higher than mean male prevalence. However, in the US, males up to age 74 had a higher prevalence, and from age 80-84 females had a higher prevalence. This is in comparison to the UK, where higher male prevalence was present until age 80-84, and then the prevalence was equal between male and female for ages 85+. Sex differences

related to age have also been identified in previous research, but in different countries. Xu et al (2022) interestingly saw this trend reversed in China – there was increased prevalence in males 50+ and increased prevalence in females when under 50. However, this study was using data from a much larger time frame, 1990-2019, and could present a better representation of the disease. Given the stark differences seen in trends within age groups and sex in the UK, US and China, this could suggest the differences may be down to country differences themselves, rather than differences due to age or sex. Hence continuing this research across a greater variety of countries would help to identify the cause of the differences.

Recent research has identified not only differences seen between countries, but that some of these differences can be attributed to race. In Asia, structural differences in the cardiovascular system were found compared to Western populations. Biologically, Asians were more sensitive to salt, and this combined with an excessive salt intake due to diet led to increased CVD (Loo et al, 2024). They found that these structural differences also result in a difference in response to BP lowering medications. Hypertension in Asians responds better to calcium channel blockers compared to angiotensin-converting enzyme inhibitors. Furthermore, the impact of hypertension was much greater on related CVDs, such as HHD (Loo et al, 2024). Hence a treatment plan itself may need to be altered depending on race to optimise treatment and allow meaningful comparisons of HHD prevalence. These structural cardiac differences have been seen in other races, such as black African American participants having greater left ventricular size compared to white Western individuals (Chandra et al, 2023). Given the role left ventricle function plays in HHD, this is significant in the risk of HHD and hence its impact on HHD prevalence. As such, it may not be appropriate to consider a country alone as a variable, but also the biological changes in different races. This is especially important in the UK, which has a diverse range of ethnicities with almost 20% of the population declaring their ethnicity as something other than white (Office for National Statistics, 2024).

There are clear differences in average body mass index (BMI) between the UK and the US, that could help explain the difference in prevalence of HHD. In the UK, 63.2% of adults were classed as overweight, comparatively 71.9% of US adults were overweight, where overweight was defined as a BMI of 25+ kg/m$^2$ for both countries (Nortoft et al, 2018). These trends continued across obesity classes – 3.6% of the UK had a BMI of 40-70 kg/m$^2$ compared to 8.1% in the US (Nortoft et al, 2018). A greater BMI is associated with increased risk of cardiovascular events leading to CVD and eventually heart failure (Khan et al, 2018). As the US population has a higher BMI, the results of this investigation with higher prevalence of HHD in the US is consistent with this. In addition, an increase in salt intake (more than 2 g of sodium per day) is associated with increased risk of cardiovascular events, in particular hypertension (Loo et al, 2024). This coupled with the higher BMI in the US

compared to the UK may contribute to the increased rate of HHD in the US. However, research also notes a difference between men and women in regards to BMI – higher BMI overall was seen in females (Nortoft et al, 2018), and so country comparisons should be approached with caution, ensuring all potential factors are considered.

When considering the impact of age group on prevalence of HHD, the normal ageing process must be considered. As we age, the RAAS, responsible for regulating blood volume, becomes less responsive to changes in the body. This causes fluid and electrolyte imbalances and renal damage, further impacting BP (Yoon and Choi, 2014). As a result, individuals are at a greater risk of hypertension, and hence of HHD. Increased reactive oxygen species (ROS) is also known to be a pathogenic mechanism in CVD, particularly in hypertension (Cai and Harrison, 2000; Santos et al, 2018). Disrupted endothelial function due to ROS impairs contraction and relaxation of the ventricles (Cai and Harrison, 2000), causing reduced ejection fraction which is characteristic of HHD (Haydock and Flett, 2022). It is known that ROS increases as humans age, and certain factors such as diet and exercise can impact it (Santos et al, 2018). This explains the increase in prevalence with age group, seen in both the UK and the US. In addition, an excess of salt in diet can also impair the normal RAAS. A consistently increased intake of salt can predispose individuals to high BP and kidney disease, which are risk factors for HHD (Borrelli et al, 2020). Hence the interaction of age group and BMI related factors such as diet and exercise may be of importance to understand HHD prevalence. This investigation did not consider these potential links with BMI as a variable, and hence is a limitation.

In women experiencing menopause, a drop in oestrogen is seen which can increase risk factors for CVDs, in particular hypertension. Women in their 50s and 60s are at a greater risk of developing hypertension, and hence HHD thereafter and later in life (Maas and Franke, 2009). This is consistent with the results of this investigation, where females had a greater prevalence than males age 80+; at this age they will have had many years of reduced oestrogen following menopause. However, due to this, many ‘normal’ menopause symptoms may be symptoms of cardiovascular problems like hypertension but are dismissed as normal due to menopause. This may mean hypertension and hence HHD aren’t picked up very well or treated until late. A recent UK survey found 84% of women felt they were dismissed or not taken seriously when visiting the doctor, in particular for gynaecological or menopause symptoms (DHSC, 2022). In comparison, a similar survey carried out in the US found 29% of women felt their doctor dismissed concerns (KFF, 2022), which is significantly lower than the UK survey. This could lead to an underreported prevalence rate in the UK, as women are not diagnosed promptly, potentially explaining the difference in the UK results compared to US.

Timely diagnosis, and thus treatment, of HHD relies on a pre-existing diagnosis of hypertension. It is clear that the prevalence of HHD is greatly increased in the US compared to the UK, with the US prevalence over 4 times higher. However, a difference in diagnostic criteria for hypertension between the countries may play a part. In the UK BP is not considered hypertensive until a reading of 140/90 mmHg or above, or 150/90 mmHg for 80+ years (NHS, 2023). Comparatively, the US considers readings of 130-139/80-89 mmHg as stage 1 hypertension (American Heart Association, 2024), and, depending on relative risk factors, individuals commence drug treatment straight away. This means individuals are not prescribed medications to control BP until much later in the UK compared to the US. It is possible that hypertension, and thus HHD, are not noticed until later or diagnosed at all, resulting in a falsely lower prevalence rate in the UK, which would explain the lower UK prevalence seen in this investigation. Diagnosis of HHD itself requires a skilled expert using echocardiogram to analyse LVH of the heart (Huang et al, 2024), which is not always available or easily accessible in all countries. In addition, a more consistent diagnostic process of hypertension may allow more meaningful comparisons and identification of risk factors, compared to the current ad-hoc BP readings. It has been suggested that circulating biomarkers NT-pro BNP and sST2 may provide suitable diagnostic criteria of HHD, however more research is needed on this (Ojji et al, 2020). This could have important implications for cardiovascular health across the world, improving prompt diagnosis of hypertension and HHD, hence having the potential to reduce unfavourable outcomes.

An important factor in any disease is the access to healthcare and treatment. This investigation did not consider the impact of socioeconomic differences between countries, age group and sex. Given that the US has privatised healthcare compared to the UK's national health service, it is likely there is a difference in accessing treatment. Those of working age may have access to private healthcare through work, impacting prevalence rate between age groups. Additionally, as less females work compared to males in both the UK and US (World Bank Group, 2023), this could impact sex differences on prevalence of HHD in working individuals.

*4.3 Further studies and recommendations*

As discussed above, there is recent research to suggest that racial differences may play a bigger part than previously thought. The results from Loo et al (2024) highlight the differences in Asians with regards to their circulatory system, sensitivity to salt, and response to drugs for hypertension treatment. As a result, to get a good overview of country differences, it is recommended further research looks at a greater variety of countries, in particular to investigate the disparity in prevalence between continents. It would also be useful to introduce race as an independent variable, to

distinguish between differences due to location and differences due to biological make up. Diagnostic criteria may also need reviewing to account for these race differences (Huang et al, 2024).

Further research on current diagnostic criteria is also recommended. By using a more consistent and accessible process, such as blood samples (Ojji et al, 2020), more accurate HHD prevalence figures can be obtained. This results in more meaningful comparisons and reliable data and allows the true effect of factors such as age and sex to be studied.

**5 Conclusion**

This investigation supported the alternative hypotheses, to demonstrate that the variation of prevalence rate of HHD between sex and age group is significant in both the UK and the US. Significant differences were also present between the UK and the US across the time period 2004-2019. These differences have been identified in previous research, both in these countries and across the world, and hence these results support the existing literature on HHD. This research also supports the role of BMI, salt intake due to diet, and resulting ROS on explaining some of the age and sex differences seen, as well as the interaction of age group and sex.

The trends seen in older women and older men were consistent with hormonal changes seen in menopause, hence explaining higher prevalence in these women. However, this refutes existing research in China, where different trends were seen. The relevance of race in structural arterial differences may be important to understand this, and as such the interaction of country differences with race would be a key area for future research, which this investigation did not consider.

Further areas for future research have been highlighted by this investigation, to fully understand the mechanisms of HHD prevalence. Analysis of prevalence rates should be carried out across a greater range of countries to identify if the same trends are seen across the globe. Due to country differences in diagnostic criteria, for both hypertension and HHD, criteria that is standardised across countries would be beneficial for more valid results. In addition, diagnostics should account for sex and race differences, and use more accessible methods, such as potential blood biomarkers. This could improve global cardiovascular health, allowing earlier diagnosis and treatment of both hypertension and HHD.

**References**

American Heart Association (2024) *High Blood Pressure*. Available at: https://www.heart.org/en/health-topics/high-blood-pressure (Accessed: 11 June 2024).

Borrelli, S., Provenzano, M., Gagliardi, I., Ashour, M., Liberti, M., Nicola, L., Conte, G., Garofalo, C. and Andreucci, M. (2020) 'Sodium Intake and Chronic Kidney Disease', *International Journal of Molecular Sciences*, 21(13), pp. 4744-4745. Available at: https://doi.org/10.3390/ijms21134744 (Accessed: 11 August 2024).

Cai, H. and Harrison, D. (2000) 'Endothelial dysfunction in cardiovascular diseases – The role of oxidant stress', *Circulation Research*, 87(10), pp. 840-844. Available at: https://doi.org/10.1161/01.RES.87.10.840 (Accessed: 28 April 2024).

Chandra, A., Skali, H., Claggett, B., Solomon, S., Rossi, J., Russell, S., Matsushita, K., Kitzman, D., Konety, S., Mosley, T., Chang, P. and Shah, A. (2023) 'Race and Gender-Based Differences in Cardiac Structure and Function and Risk of Heart Failure', *Journal of the American College of Cardiology*, 79(4), pp. 355-368. Available at: https://doi.org/10.1016/j.jacc.2021.11.024 (Accessed: 11 August 2024).

DHSC (Department for Health and Social Care) (2022) *Results of the 'Women's Health – Let's talk about it' survey*. Available at: https://www.gov.uk/government/calls-for-evidence/womens-health-strategy-call-for-evidence/outcome/results-of-the-womens-health-lets-talk-about-it-survey (Accessed: 30 June 2024).

Global Burden of Disease Collaborative Network (2022) *Global Burden of Disease Study 2019 (GBD 2019) Healthcare Access and Quality Index 1990-2019. United States of America: Institute for Health Metrics and Evaluation (IHME)*. Available at: https://doi.org/10.6069/97EM-P280 (Accessed: 29 February 2024).

Haydock, P. and Flett, A. (2022) 'Management of heart failure with reduced ejection fraction', *Heart*, 108, pp.1571-1579. Available at: https://doi.org/10.1136/heartjnl-2020-318811 (Accessed: 17 April 2024).

Huang, X., Hu, L., Long, Z., Wang, X., Wu, J. and Cai, J. (2024) 'Hypertensive Heart Disease: Mechanism, Diagnosis and Treatment', *Reviews in Cardiovascular Medicine*, 25(3), pp. 93-116. Available at: https://doi.org/10.31083/j.rcm2503093 (Accessed: 17 April 2024).

Joffres, M., Falaschetti, E., Gillespie, C., Robitaille, C., Loustalot, F., Poulter, N., McAlister, F., Johansen, H., Baclic, O. and Campbell, N. (2013) 'Hypertension prevalence, awareness, treatment and control in national surveys from England, the USA and Canada, and correlation with stroke and ischaemic heart disease mortality: a cross-sectional study', *BMJ Open*, 3(8), pp. 1-9. Available at: https://doi.org/10.1136/bmjopen-2013-003423 (Accessed: 9 March 2024).

KFF (2022) *Women's Experiences with Provider Communication and Interactions in Health Care Settings: Findings from the 2022 KFF Women's Health Survey.* Available at: https://www.kff.org/womens-health-policy/issue-brief/womens-experiences-with-provider-communication-interactions-health-care-settings-findings-from-2022-kff-womens-health-survey/ (Accessed: 18 August 2024).

Khan, S., Ning, H., Wilkins, J., Allen, N., Carnethon, M., Berry, J., Sweis, R. and Lloyd-Jones, D. (2018) 'Association of Body Mass Index With Lifetime Risk of Cardiovascular Disease and Compression of Morbidity', *JAMA Cardiology*, 3(4), pp. 280-287. Available at: https://doi.org/10.1001/jamacardio.2018.0022 (Accessed: 11 August 2024).

Loo, G., Puar, T., Foo, R., Ong, T., Wang, T., Nguyen, Q., Chin, C. and Chin, C. (2024) 'Unique characteristics of Asians with hypertension: what is known and what can be done?', *Journal of Hypertension*. Available at: https://doi.org/10.1097/HJH.0000000000003706 (Accessed: 23 June 2024).

Lu, L., Guo, J., Hua, Y., Huang, K., Magaye, R., Cornell, J., Kelly, D., Reid, C., Liew, D., Zhou, Y., Chen, A., Xiao, W., Fu, Q. and Wang, B. (2017) 'Cardiac fibrosis in the ageing heart: Contributors and mechanisms', *Clinical and Experimental Pharmacology and Physiology*, 44, pp. 55-63. Available at: https://doi.org/10.1111/1440-1681.12753 (Accessed: 28 April 2024).

Lu, Y. and Lan, T. (2022) 'Global, regional, and national burden of hypertensive heart disease during 1990-2019: an analysis of the global burden of disease study 2019', *BMC Public Health*, 22(841), pp. 1-10. Available at: https://doi.org/10.1186/s12889-022-13271-0 (Accessed: 9 March 2024).

Maas, A. and Franke, H. (2009) 'Women's health in menopause with a focus on hypertension', *Netherlands Heart Journal*, 17(2), pp. 68-72. Available at: https://doi.org/10.1007/BF03086220 (Accessed: 11 June 2024).

Marshall, A., Nazroo, J., Feeney, K., Lee, J., Vanhoutte, B. and Pendleton, N. (2016) 'Comparison of hypertension healthcare outcomes among older people in the USA and England', *Journal of Epidemiology and Community Health*, 70(3), pp. 264-270. Available at: https://doi.org/10.1136/jech-2014-205336 (Accessed: 28 April 2024).

NHS (2023) *High blood pressure (hypertension).* Available at: https://www.nhs.uk/conditions/high-blood-pressure-hypertension/ (Accessed: 11 June 2024).

Nortoft, E., Chubb, B. and Borglykke, A. (2018) 'Obesity and healthcare resource utilization: comparative results from the UK and the USA', *Obesity Science & Practice*, 4(1), pp. 41-45. Available at: https://doi.org/10.1002/osp4.148 (Accessed: 11 August 2024).

Office for National Statistics (2024) *Population of England and Wales*. Available at: https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/national-and-regional-populations/population-of-england-and-wales/latest/ (Accessed: 29 June 2024).

Ojji, D., Libhaber, E., Lamont, K., Thienemann, F. and Sliwa, K. (2020) 'Circulating biomarkers in the early detection of hypertensive heart disease: usefulness in the developing world', *Cardiovascular Diagnosis & Therapy*, 10(2), pp. 296-304. Available at: https://doi.org/10.21037/cdt.2019.09.10 (Accessed: 29 June 2024).

The Open University (2023) 'The PROMPT criteria', *Critically evaluate information, online interactions and online tools*. Available at: https://learn1.open.ac.uk/mod/oucontent/view.php?id=15018&section=3 (Accessed: 13 April 2024).

Pinto, E. (2007) 'Blood pressure and ageing', *Postgraduate Medical Journal*, 83(976), pp. 109-114. Available at: https://doi.org/10.1136/pgmj.2006.048371 (Accessed: 11 March 2024).

Rodgers, J., Jones, J., Bolleddu, S., Vanthenapalli, S., Rodgers, L., Shah, K., Karia, K. and Panguluri, S. (2019) 'Cardiovascular Risks Associated with Gender and Aging', *Journal of Cardiovascular Development and Disease*, 6(2), article number 19. Available at: https://doi.org/10.3390/jcdd6020019 (Accessed: 11 March 2024).

Santos, A., Sinha, S. and Lindner, A. (2018) 'The Good, the Bad, and the Ugly of ROS: New Insights on Aging and Aging-Related Disease from Eukaryotic and Prokaryotic Model Organisms', *Oxidative Medicine and Cellular Longevity*, 2018(1). Available at: https://doi.org/10.1155/2018/1941285 (Accessed: 11 August 2024).

Sheppard, J., Schwartz, C., Tucker, K. and McManus, R. (2016) 'Modern Management and Diagnosis of Hypertension in the United Kingdom: Home Care and Self-care', *Annals of Global Health*, 82(2), pp. 274-287. Available at: https://doi.org/10.1016/j.aogh.2016.02.005 (Accessed: 28 April 2024).

Tackling, G. and Borhade, M. (2023) *Hypertensive Heart Disease*, Treasure Island: StatsPearls Publishing.

World Bank Group (2023) *Labor force, female (% of total labor force)*. Available at: https://data.worldbank.org/indicator/SL.TLF.TOTL.FE.ZS (Accessed: 18 August 2024).

World Health Organization (2023) *Hypertension*. Available at: https://www.who.int/news-room/fact-sheets/detail/hypertension (Accessed: 17 April 2024).

Xu, D., Hu, J., Wang, S. and Chen, L. (2022) 'Trends in the Prevalence of Hypertensive Heart Disease in China From 1990 to 2019: A Jointpoint and Age-Period-Cohort Analysis', *Frontiers in Public Health*, 10, pp. 1-6. Available at: https://doi.org/10.3389/fpubh.2022.833345 (Accessed: 11 March 2024).

Yoon, H. and Choi, B. (2014) 'The renin-angiotensin system and aging in the kidney', *The Korean Journal of Internal Medicine,* 29(3), pp. 291-295. Available at: https://doi.org/10.3904/kjim.2014.29.3.291 (Accessed: 10 June 2024).

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## Appendices

Supplementary information available containing:

**Supplementary Table 1:** Prevalence rate per 100,000 adults of hypertensive heart disease in the UK between 2004 and 2019, split by age group in years and sex

**Supplementary Table 2:** Prevalence rate per 100,000 adults of hypertensive heart disease in the US between 2004 and 2019, split by age group in years and sex

**Supplementary Table 3:** Results of the Post-Hoc Tukey (HSD) test for differences in prevalence of HHD between groups in the UK

**Supplementary Table 4:** Results of the Post-Hoc Tukey (HSD) test for differences in prevalence of HHD between groups in the US