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**Title:** Normal values for finger systolic blood pressure in males and females

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# Normal values for finger systolic blood pressures in males and females

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## Abstract

### Objective

To compare finger systolic blood pressures in males and females and in younger and older persons and provide normal values for all four fingers in younger and older males and females.

### Methods

Eighty healthy subjects participated in the study: 20 males and 20 females aged 20 to 30 years, and 20 males and 20 females aged 55 to 65 years. Finger systolic blood pressures (FSBPs) were measured using strain-gauge plethysmography following local cooling at 30°C and 10°C in accord with International Standard 14835-2. The FSBPs were measured simultaneously in the thumb and the four fingers of the dominant hand and the percentage changes in finger systolic blood pressures (%FSBPs) due to the cold provocation were calculated.

### Results

The median finger systolic blood pressures increased with increasing age in both females and males, with the increase highly significant at 30°C but not at 10°C. The %FSBPs were not significantly affected by the age of males, but were significantly lower in older females than younger females.

The FSBPs were lower in females than in males at 30ºC but there was no significant difference between genders at 10°C. The %FSBPs were higher in younger females than younger males, but only significantly higher in the middle finger and there were no significant differences between the genders in the older age group.

There were only minor differences between the four fingers in the FSBPs at 30 ºC and 10 ºC. The %FSBPs across the four fingers were similar in the younger subjects and in the older females, but varied with finger in the older males.

### Conclusion

Although there are some differences in the %FSBPs associated with age, gender, and finger, the differences may be sufficiently small to use a single value criterion when deciding on abnormalities in FSBP associated with cold provocation for persons aged 20 to 65 years

## Introduction

Vibration-induced white finger (VWF), the vascular component of the hand-arm vibration syndrome (HAVS), is characterised by episodic and clearly demarcated finger blanching. Vascular symptoms typically occur during or following exposure to cold.

The dysfunction causing VWF is associated with greater reductions in finger systolic blood pressures (FSBPs) following cold provocation compared with normal reductions in healthy individuals (Lindsell and Griffin, 1998). Currently, the normal values used to detect arterial dysfunction in the digits are not adjusted for either age or gender.

When suggesting standardised diagnostic methods for assessing components of the hand-arm vibration syndrome, Lindsell and Griffin (1998) mentioned that ageing may influence digital vascular function and affect the criteria used to assess normality. In industrialised nations the mean resting blood pressure increases with increasing age from the early adult years (Light, 1989). However, Bovenzi (1988) found that percentage reductions in finger systolic blood pressures (%FSBPs) in the middle finger with cold provocation at 15°C and 10°C were independent of age in 103 healthy males in four age groups ( 20-29 years, 30-39 years, 40-49 years, 50-60 years). Similarly, Lindsell and Griffin (2002) found that percentage reductions in finger systolic blood pressure produced by cold provocation at 15°C and 10°C on four test fingers relative to a reference finger was not correlated with age in a group of 97 males aged 17-62 years.

Most workers at risk of VWF are male and most studies of finger systolic blood pressures have been conducted with males. However, some women are occupationally exposed to vibration from hand-held vibrating tools and at risk of injury. Myers *et al*. (2001) compared brachial systolic blood pressure in groups of healthy males and females aged 18-30 years and found blood pressure was lower in the females than in the males. O'Brien *et al.* (1991) compared ambulatory blood pressure in males and females aged 17 to 80 years and also found females had lower blood pressures than males at all ages.

There have been few comparisons of finger systolic blood pressures in males and females. Nielsen *et al.* (1980) measured finger systolic blood pressure following local cooling and pressurisation of one digit with body cooling at 10 to 12°C and found no difference in percentage finger systolic blood pressures between healthy males and females, aged 18 to 42 years. Current methods of measuring reductions in finger systolic blood pressure use local cooling and pressurisation of the digit without body cooling and are defined in International Standard 14835-2 (2005). It is not known whether normal values for the reduction of finger systolic blood pressure obtained using the standardised method with pressurisation of a digit and localised cooling are influenced by gender.

The effects of hand-transmitted vibration vary between digits, so some fingers show symptoms and others do not. The diagnosis of VWF is assisted by measurements of finger systolic blood pressure on the digits and International Standard 14835-2 (2005) recommends that "*measurements are made on all possible digits*". Due to the limited availability of multi-channel apparatus for measured FSBP, studies of normal finger systolic blood pressures in healthy subjects have mostly measured FSBP on one test finger and one reference finger (e.g., Bovenzi, 1988; Nielsen *et al*., 1980). Hirai *et al*. (1976) measured FSBP in all five fingers in healthy males and females and found no difference in blood pressure between the five digits. Lindsell and Griffin (2002) measured finger systolic blood pressures simultaneously on four test fingers and one reference finger and found no significant differences in percentage finger systolic blood pressures between the four test fingers for measurements made at 15°C. However, at 10°C the %FSBPs were higher in the little finger.

This study was undertaken to compare finger systolic blood pressures in males and females and in younger and older persons and to provide normal values in all four fingers for both younger and older males and females.

**Method**

*Subjects*

Eighty healthy subjects participated in the study: 20 males and 20 females aged 20 to 30 years, and 20 males and 20 females aged 55 to 65 years (Table 1).

Subjects were students, office workers or retired office workers with no history of regular use of hand-held vibrating tools. None reported cardiovascular or neurological disorders, connective tissue disease, injuries to the upper extremities, a history of cold hands, or were on medication likely to affect finger systolic blood pressures. Each age group included white, Asian and mixed race subjects. The subjects were similar in handedness and distribution of

**Table 1** Median and interquartile range (IQR) of subject characteristics and distributions of handedness, smoking, and alcohol consumption for males and females aged 20 to 30 years and 55 to 65 years.

| Gender | Age range (yrs) | Age (yrs) | Height (cm) | Weight (kg) | Dominant hand | | Smoking | | Alcohol (units per week) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Right | Left | No | Yes | Never | 1 -3 | 4-6 | >6 |
| Female | 20 - 30 | 24 (2.8) | 162 (11.3) | 56 (10.8) | 17 | 3 | 19 | 1 | 11 | 8 | 1 | 0 |
| Male | 20 - 30 | 24 (3.8) | 177 (10.3) | 73 (20.5) | 20 | 0 | 16 | 4 | 6 | 10 | 1 | 3 |
| Female | 55 - 65 | 59 (5.5) | 162 (10.0) | 69 (18.0) | 18 | 2 | 18 | 2 | 6 | 3 | 7 | 4 |
| Male | 55 - 65 | 59 (6.5) | 178 (10.0) | 79 (10.0) | 18 | 2 | 19 | 1 | 3 | 4 | 7 | 6 |

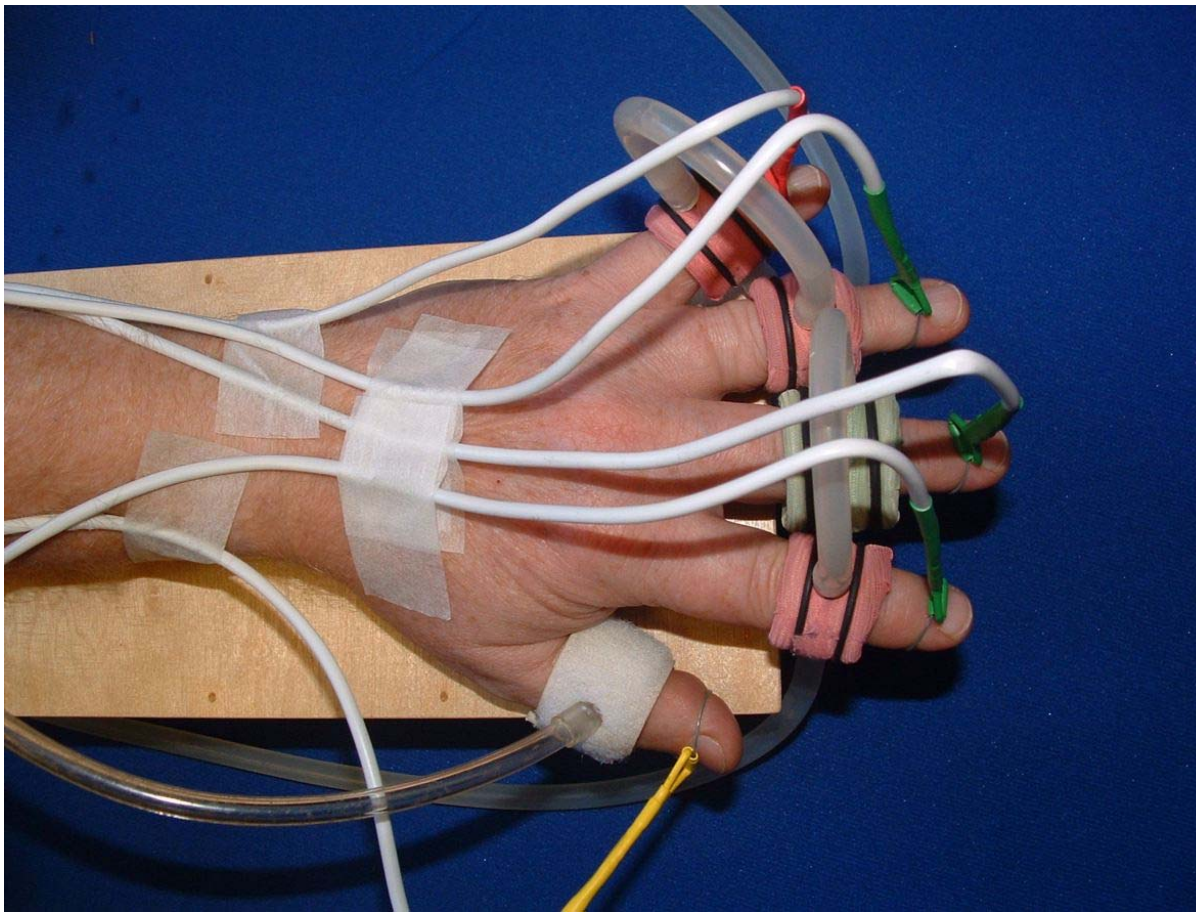

**Figure 1** Occlusion cuffs and strain gauges set up for simultaneous finger systolic blood pressure measurement on four test digits and the reference thumb.

smoking but older subjects reported a greater consumption of alcohol (Table 1).

All the females aged 20 to 30 years, except for one, had a regular menstrual cycle. All the females aged 50 to 60 years were post-menopausal.

*Measures of fingers systolic blood pressure*

Finger systolic blood pressures were measured using strain-gauge plethysmography following local cooling in accord with International Standard 14835-2 (2005).

The FSBPs were measured simultaneously in the thumb and the index, middle, ring, and little fingers of the dominant hand using a multi-channel plethysmograph (*HVLab*, ISVR, University of Southampton). Figure 1 shows the set up of the occlusion cuffs and strain gauges on the four test fingers and the reference thumb.

Mercury-in-silastic strain gauges were placed around the distal phalanges at the base of the nail on all five digits. A cuff for air-inflation was fixed around the proximal phalanx of the thumb. Water-filled cuffs were fixed around the middle phalanges of the other four fingers. The FSBPs were measured at 30°C and 10°C with an initial cuff occlusion pressure of 200 mmHg and an occlusion duration of 5 minutes. Increases in finger volumes following

pressure reduction were detected by means of the strain gauges according to the criteria given by Greenfield *et al.* (1963).

The results of the cold test were expressed as the change of systolic blood pressure in the fingers (test fingers) at 10°C ($FSBP_{t,10°}$) as a percentage of the pressure at 30°C ($FSBP_{t,30°}$), corrected for the change of pressure in the thumb (i.e. the reference finger) during the examination ($FSBP_{ref,30°} - FSBP_{ref,10°}$):

$$FSBP\%_{10°} = (FSBP_{t,10°} \times 100)/[FSBP_{t,30°} - (FSBP_{ref,30°} - FSBP_{ref,10°})]$$

*Experimental procedure*

In accord with ISO 14835-2 (ISO, 2005), measurements were performed in a laboratory with a median temperature of 21.6 °C (range 20.4 to 22.2°C) and smoking, drinking of alcohol, and caffeine consumption were restricted for two hours prior to the experimental session.

Each of the 80 subjects attended the laboratory on one occasion. Measurements were made while the subjects were supine with their dominant hand resting on a support alongside their body at the level of the heart (at the midaxillary line). The non-dominant hand was also alongside the body. After acclimatisation for about 30 minutes, subjects lay supine for 10 minutes during which the fingers were instrumented. Finger systolic blood pressures were then measured at 30°C and then at 10°C. The experimental session lasted about 25 minutes.

The study was approved by the Human Experimentation Safety and Ethics Committee of the Institute of Sound and Vibration Research at the University of Southampton (UK).

*Statistical methods*

Non-parametric tests (Friedman test for *k*-related samples, the Wilcoxon matched-pairs signed ranks test for two-related samples, and the Mann-Whitney U-test for two-independent samples) were employed for statistical analysis. The criterion for statistical significance was $p<0.05$ (two-tailed).

**Results**

Results are given as the median finger systolic blood pressure (FSBP), the percentage finger systolic blood pressure (%FSBP), the inter-quartile range (IQR) in brackets, and as the mean percentage finger systolic blood pressure with one and two standard deviations (SD) in brackets. The median measured FSBPs of the four groups of subjects (females and males aged 20 to 30 years or aged 55 to 65 years) are shown in Table 2. The median %FSBPs for the females and the males aged 20 to 30 years or aged 55 to 65 years are shown in Table 3.

**Table 2** Median finger systolic blood pressure (FSBP) and inter-quartile range (IQR) at 30°C and 10°C in five digits of younger (20 to 30 years old) and older (55 to 65 years old) males and females.

| Age (years) | Gender | Temperature (°C) | Thumb | Index | Middle | Ring | Little |
|---|---|---|---|---|---|---|---|
| | | | FSBP (mmHg) | | | | |
| 20-30 | female | 30 | 114 (16.3) | 98.5 (29.5) | 94.8 (23.3) | 106 (28.5) | 97.9 (32.1) |
| | male | 30 | 115 (14.2) | 103 (21.8) | 116 (11.5) | 111 (24.9) | 111 (30.2) |
| | female | 10 | 121 (17.0) | 93.3 (27.3) | 86.2 (27.4) | 102 (25.3) | 99.2 (25.3) |
| | male | 10 | 124 (14.3) | 97.4 (21.4) | 105 (27.3) | 104 (29.2) | 110 (30.8) |
| 55-65 | female | 30 | 117 (18.3) | 108 (29.8) | 104 (28.7) | 109 (32.6) | 108 (24.2) |
| | male | 30 | 135 (33.0) | 121 (32.7) | 123 (44.2) | 125 (31.4) | 121 (24.2) |
| | male | 10 | 150 (41.8) | 106 (38.0) | 106 (35.5) | 109 (35.7) | 116 (22.3) |
| | female | 10 | 133 (25.7) | 98.1 (33.6) | 98.0 (37.9) | 107 (35.2) | 108 (39.4) |

**Table 3** Median percentage finger systolic blood pressure (FSBP) and inter-quartile range (IQR) at 10°C in four digits of younger (20 to 30 years old) and older (55 to 65 years old) males and females.

| Age (years) | Gender | Index | Middle | Ring | Little |
|---|---|---|---|---|---|
| 20-30 | female | 92.2 (16.7) | 90.5 (18.9) | 91.2 (15.3) | 98.9 (17.9) |
| | male | 88.5 (13.3) | 85.5 (12.8) | 86.9 (12.8) | 92.2 (14.4) |
| 55-65 | female | 84.1 (20.8) | 84.0 (18.3) | 80.7 (12.3) | 88.0 (16.5) |
| | male | 80.6 (13.6) | 87.0 (13.6) | 85.9 (10.9) | 91.0 (14.1) |

*Effect of Gender*

*FSBP*

On all five digits and at both temperatures, the median FSBPs were lower for the group of younger females (aged 20 to 30 years) than for the group of younger males, although in many cases the reduction was not statistically significant (Table 2). On the middle finger the FSBPs were highly significantly lower for younger females than younger males at 30°C, (Mann-Whitney U-test; $p<0.001$) and significantly reduced at 10°C ($p = 0.035$). The reduction was not significant on some other fingers ($p<0.1$).

A similar trend was found in the older subjects. On all five digits and at both temperatures, the median FSBPs were lower for the group of older females (aged 55 to 65 years) than for the group of older males (Table 2). At 30°C, the reduction in FSBPs was significant on four fingers ($p<0.05$) and not significantly different on the index finger ($p=0.091$). At 10°C, the reduction was statistically significant on the thumb ($p=0.017$), but not significant in the four fingers exposed to cold provocation ($p>0.1$).

*%FSBP*

Figure 2 shows the distribution of %FSBPs measured at 10 ºC in each finger for males and females aged 20 to 30 years and 55 to 65 years.

On all four digits exposed to cold, the median %FSBPs were higher in younger females compared to younger males (Table 3). The reduction was statistically significant on the middle finger ($p=0.028$) but not on the other three fingers.

For the older subjects, the median %FSBPs on all four digits were similar for females and males ($p>0.1$).

*Effect of Age*

*FSBP*

On all five digits, at both temperatures, and with both genders, the median FSBPs were higher for the older subjects (aged 55 to 65 years) than the younger subjects (aged 20 to 30 years) (Table 2).

At 30°C, the increase in FSBPs in older males was highly significant ($p<0.01$), except on the middle finger ($p=0.355$) (Table 2). At 30°C the increase in FSBPs in older females was significant on the middle and little fingers ($p<0.05$) and marginally not significantly different in the index finger ($p=0.089$).

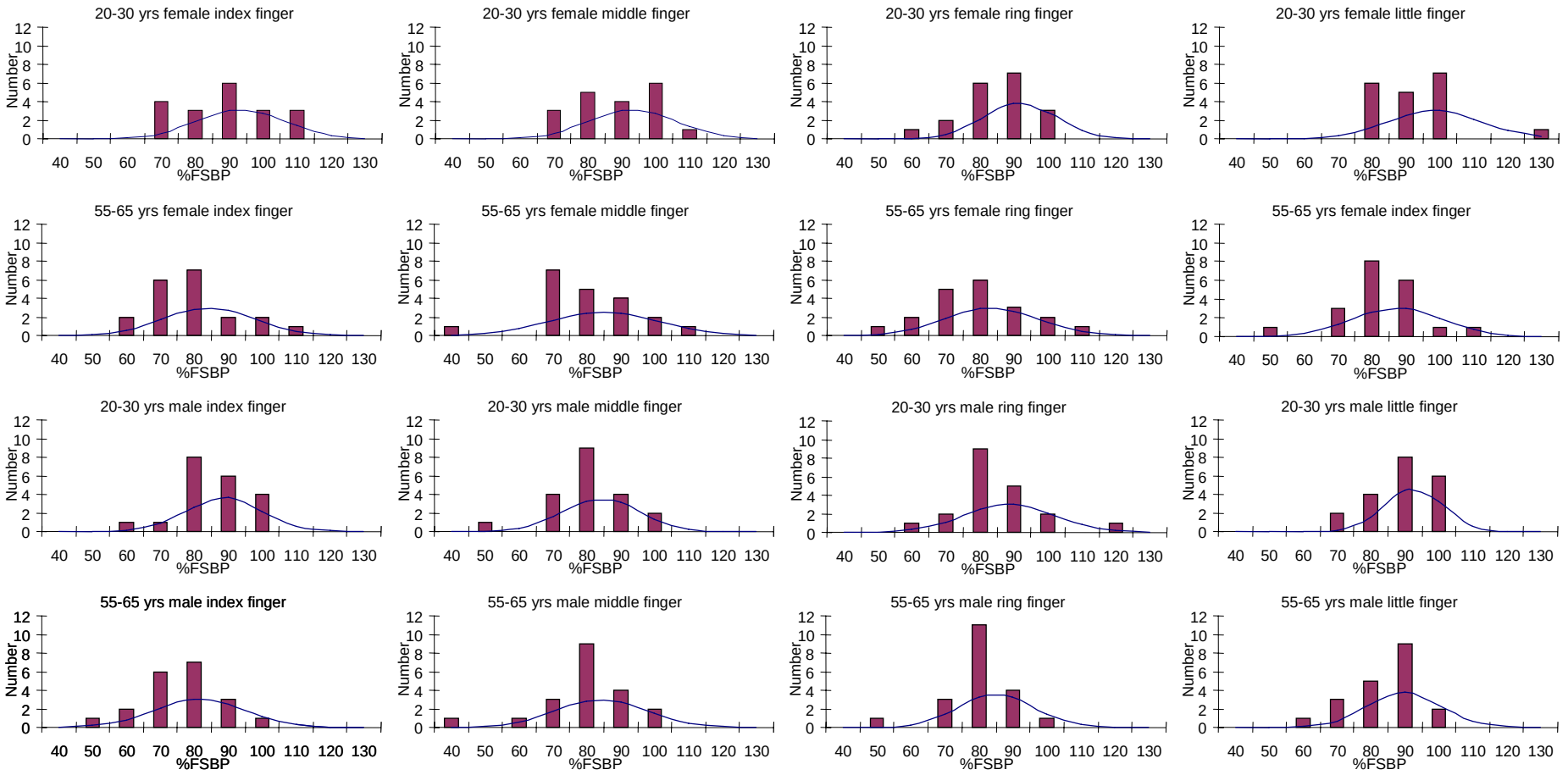


**Figure 2** Distribution of percentage finger systolic blood pressures (%FSBP) at 10 ºC for females and males aged 20 to 30 years and 55 to 65 years (Number of subjects for each group of 20 subjects).

At 10°C, in the four fingers exposed to cold provocation the increase in FSBP was not statistically significant for either the males or the females ($p$>0.1). In the air occluded thumb, the increase in the FSBP in older males was highly significant ($p$=0.001) and the increase in FSBP in the older females was marginally not significantly different ($p$=0.079).

*%FSBP*

On all four digits, the median %FSBPs were lower for the older females than the younger females (Table 3). The reduction in %FSBP in older females was significant in three digits ($p$<0.05), and marginally not significantly different in the middle finger ($p$=0.084).

There were no significant differences in %FSBPs between younger and old males ($p$>0.1) – the median %FSBPs were similar on three digits but lower on the index finger in the older males.

*Effect of digit*

*FSBP*

There was a significant overall difference in measured FSBP between the five digits ($p$<0.01; Friedman) (Table 2). The median FSBP was greater in the thumb than in the other four digits for both genders, both age groups and at both temperatures. The difference was statistically significant for all four fingers ($p$ < 0.05; Wilcoxon), except at 30°C in the younger males for the index and little finger ($p$>0.1) and the younger females for the ring finger ($p$=0.77).

In the younger males at 30°C there was a significant difference in measured FSBP between the four test digits ($p$=0.001) with significantly higher median FSBP in the middle finger than in the ring finger ($p$=0.006) and marginally not significantly higher FSBP than in the little finger ($p$=0.079).

At 10°C there were significant differences between the four test digits in both the younger males and the younger females ($p$<0.05) (Table 2). In the younger males the index finger had significantly lower median FSBP than the other test digits ($p$<0.05). In the younger females the ring finger had significantly higher median FSBP than the middle finger ($p$=0.011).

In the older subjects at 30°C there was a significant difference in measured FSBP between the test digits for the females ($p$=0.001) and a marginally non-significant difference for the males ($p$=0.071) (Table 2). In the older females the FSBP on the ring finger was higher than on the index and middle fingers ($p$<0.05) and marginally non-significantly higher than on the little finger ($p$=0.079). In the older males, the index finger had lower FSBP than the ring finger ($p$=0.003) and a marginally non-significantly lower FSBP than the middle finger ($p$=0.052).

In both the older males and the older females, the FSBP was lower in the index finger than in the ring finger at both temperatures ($p$<0.05) and lower on the index finger than the little finger at 10°C ($p$<0.05).

*%FSBP*

There were no overall significant differences in %FSBP across the four digits for the younger males or the younger and older females (Friedman; $p$>0.1) (Table 3). In the older males the %FSBP differed across digits ($p$ < 0.01; Friedman) and was significantly greater in the little finger than the other three digits ($p$<0.05).

**Discussion**

Lindsell and Griffin (1998) reported a range of %FSBPs from 83 to 100% for the 10°C test for males. Lindsell and Griffin (2002) reported mean %FSBPs in the index, middle, ring and little fingers at 10°C of 93.4, 92.3, 94.3 and 98.3, respectively for a group of males aged 17 to 62 years. Nielsen *et al*., (1980) reported %FSBPs of 83.8% and 81.3% for the 10°C test for females and males respectively. The results from the present study are broadly similar.

Finger systolic blood pressures at 30°C increased with increasing age in both the females and the males, consistent with systemic blood pressure increasing with age. Franklin *et al*. (1997) report a greater systolic blood pressure in older adults than younger adults. With aging, the arteries stiffen and require the heart to work harder to overcome increased arterial resistance (Saladin, 2005). The older subjects in this study were working or retired adults with risk factors associated with increased blood pressure (e.g. increased weight, stressors, and a fairly sedentary life).

In the four cooled fingers, measured finger systolic blood pressures at 10°C were not affected by age for either males or females. However, during cooling of these fingers there was a significantly higher FSBP in the thumb for older subjects than for younger subjects.

Measures of %FSBP were less affected by age than the measured FSBP: there was no significant effect of age in the males but the older females had significantly lower %FSBPs than the younger females. The lower %FSBP in the older females compared to the younger females suggests the higher systemic pressure in the older females affected the %FSBP. The absence of an effect of age on %FSBP in males is consistent with the findings of Bovenzi (1988) and Lindsell and Griffin (2002).

The measured FSBPs were lower in females than in males at 30ºC. In general, pre-menopausal women have lower blood pressures than men and, prior to age 55, there is a lower prevalence of clinical hypertension in women than in men. In 352 healthy subjects aged 20 to 79 Wiinberg *et al*. (1995*)* found that ambulatory blood systolic blood pressures were significantly higher in men than in women but increased only slightly with age. Franklin

*et al*. (1997) reported a gender difference in blood pressure trends with age: blood pressure started lower in women than in men, was similar by the sixth decade, and was frequently higher than males with further increases in age. The measured FSBPs at 10°C were not significantly affected by gender, except for increased FSBP in the middle finger in younger males compared to younger females, and increased FSBP in the thumb in older males compared to older females. The median %FSBPs were higher in the younger females than the younger males (although only significantly higher on the middle finger) and there were no significant differences between the genders in the older age group. So notwithstanding differences between genders in the measured FSBPs at 30°C there was little overall effect of age on the %FSBPs.

This study measured FSBP simultaneously in five digits and found an overall difference in FSBP between digits. At 30°C and 10°C, there were some significant differences in measured FSBP between the four digits but the differences showed no clear pattern in the four groups of subjects. No differences in %FSBPs were found between test digits, except in the older group with higher %FSBP in the little finger than the index finger. This is consistent with Lindsell and Griffin (2002) who found greater %FSBPs on the little finger in older males.

Currently, within the UK, an indication of unusual response to cold is indicated using two criteria: it is assumed that there is a 'possible problem' if the %FSBP is less than 80% and a

**Table 4** Predicted values of percentage finger systolic blood pressure (%FSBP) for 'possible disorder' (mean minus one standard deviation) and 'probable disorder' (mean minus two standard deviations) for the four groups of 20 subjects and the combined group of 80 subjects.

| Criterion | Age (years) | Gender | Predicted values of %FSBP | | | |
|---|---|---|---|---|---|---|
| | | | Index | Middle | Ring | Little |
| 'Possible disorder' (mean – 1 SD) | 20-30 | female | 81 | 81 | 81 | 85 |
| | | male | 78 | 73 | 76 | 84 |
| | 55-65 | female | 69 | 71 | 74 | 79 |
| | | male | 71 | 69 | 70 | 75 |
| | Overall | | 74 | 73 | 75 | 80 |
| 'Probable disorder' (mean – 2 SD) | 20-30 | female | 68 | 68 | 71 | 72 |
| | | male | 67 | 62 | 63 | 76 |
| | 55-65 | female | 55 | 57 | 63 | 69 |
| | | male | 58 | 53 | 57 | 62 |
| | Overall | | 61 | 59 | 63 | 68 |

‘probable problem’ if the %FSBP is less than 60% (Lindsell & Griffin, 2002). These percentages correspond to the mean %FSBP less one and two standard deviations, respectively, from values reported in healthy persons by Lindsell and Griffin (1998). Assuming the values are normally distributed, these values correspond, respectively, to the values below which there are 18% and 2.5% of the %FSBPs in normal healthy persons. Table 4 shows the %FSBPs corresponding to the mean %FSBP less one and two standard deviations from the mean values measured in the present study. It may be seen that the current value for indicating ‘possible dysfunction’ (i.e. less than 80%) is broadly similar to the mean %FSBP less one standard deviation in the younger males and females and fairly similar to values for the older males and females. The current value for indicating ‘probable dysfunction’ (i.e. less than 60%) is also similar to the values corresponding to the mean %FSBP less two standard deviations in the older males and females and fairly similar to values for the younger males and females.

The effect of changing the criterion from 18% to 2.5% is to reduce the chance of a false positive finding, so increasing the specificity of the diagnostic test (i.e. the number of true negative results expressed as a proportion of the total of true negative and false positive results). This has the effect of increasing the chances of a false negative result and thereby decreasing the sensitivity of the test (i.e. the number of true positive results expressed as a proportion of the total of true positive and false negative results). Studies with patients reporting vascular effects of hand-transmitted vibration have investigated the sensitivity and specificity of %FSBP for diagnosing vibration-induced white finger (e.g. Lindsell and Griffin, 2002). Currently, studies of vascular tests are limited by the absence of an independent means of confirming the existence of vascular disorders caused by hand-transmitted vibration and doubts as to the reliability of patient reports of their symptoms, especially when they are claiming compensation.

The normal values presented may be assumed to apply to persons similar to those investigated, but there may be some (e.g. manual outdoor workers, subjects of different ethnic groups), for whom different normal values may be appropriate. Based on the current results, it seems reasonable to assume that when expressed in terms of the percentage reduction in finger systolic blood pressure (%FSBP), the cold reaction of subjects aged 31 to 54 years will be similar to that found in subjects aged 20 to 30 years and those aged 55 to 65 years.

**Conclusions**

Although there are some differences in the %FSBPs associated with age, gender and finger, the differences may be sufficiently small to use a single value criterion when deciding on

abnormalities in FSBP associated with cold provocation in males and females aged 20 to 65 years.

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