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Research Article

Cardiovascular Responses to a Cold Pressor Test in College-Age Young Single Adults

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Abstract

Ninety-nine college-age young single adults were exposed to a cold pressor test. They were asked to submerge their instrumented hand for three to four minutes, with fingers extended, into a container of water chilled to 0-5 ºC with chipped ice. Skin temperature at the base of the thumb decreased about nine degrees during the test. Twenty eight of the ninety-nine volunteers (28 per cent) displayed exaggerated pressor responses to the test. For example, under baseline conditions systolic and diastolic blood pressures averaged about 121 mmHg and 75 mmHg, respectively, in the two groups. During the test systolic and diastolic pressures rose about 5-6 mmHg in the majority of the students (typical responders, 72 per cent). Conversely, systolic pressure rose to 144 mmHg while diastolic rose to 90 mmHg in those displaying an exaggerated response. These changes were 3- to 4-fold greater ($P<0.05$) than corresponding changes in typical responders. Heart rate increased modestly but significantly in both typical and exaggerated responders. Results reveal that a significant fraction of college-age young single adults display atypical hypertensive responses to a cold pressor test. Even though there is no current consensus that such individuals are at increased risk of developing cardiovascular disease later in life more inquiry is needed [1-4].

Introduction

Cardiovascular disease is still the leading cause of death in industrialized nations. Identifying young adults who might be at increased risk of developing cardiovascular disease is a worthy goal. The cold pressor test assesses the response of systemic arterial blood pressure and heart rate to immersion of the hand (or other limb/organ) in chilled water [1-4]. Since the 1930s the cold pressor test has been used:

- as an exploratory technique in normotensive and hypertensive subjects [6-9],
- to elucidate autonomic disorders in nutriregulation of the coronary circulation [10-14],
- as a means of activating sympathetic efferent pathways to the heart, skeletal muscle and skin [15-22].

A cold pressor test causes measurable arteriolar vasoconstriction and subsequent increments in blood pressure and circulating catecholamines [6-14]. Whether expressed as systolic, diastolic or systemic mean arterial pressure, elevations in the typically-responding subject amount to five or six mmHg [11-14]. Corresponding changes in heart rate are less definitive [19]. The cold pressor test has been used to compare responses of healthy young adults with elderly adults stricken by cardiovascular disease [1]. It has been proposed that such a test might be helpful in identifying young people who are at increased risk of developing cardiovascular disease later in life [2-4]. For example, in response to a standard cold pressor test a fraction of the population appears to display an exaggerated pressor response. In such cases the elevation in blood pressure might be significantly greater than five or six mmHg. Based on this [1-4] and related information [8] we hypothesized that a significant fraction of college-age, young

single adults would display an exaggerated pressor response to immersion of their hands in cold water. We further hypothesized that males and females would be equally susceptible and that the response would occur across cultures.

Methods

Cold pressor tests have been used to assess mammalian cardiovascular function for decades. One of the gaps in knowledge in the field is the need for more data in college-age young single adults. For example, we need to know whether or not there are gender, racial and chronobiological components to the response in this age group (Table 1).

gender		ethnicity (race)
f	m	A B H I O W
49	50	21 10 8 11 8 41
f, female; m, male; A, Asian; B, Black; H, Hispanic; I, Indian; O, Other; W, White.		

Table 1: Characteristics of college-age young single adults who underwent a 3-minutes cold pressor test.

To help address these and related concerns we performed experiments in student volunteers who averaged 20±1 years of age. They were all junior and senior undergraduates. Males and females in equal numbers and of multiple cultural backgrounds participated. Once students arrived at the laboratory they were asked to rest comfortably on a cot (supine position). Instrumentation included attaching a temperature-monitoring thermocouple at the base of the thumb of the experimental hand (Physitemp Thermalert, model TH-8; thermocouple skin sensor, model SST-1, Physitemp Instruments, Inc., Cliffton, NJ) and placing an inflatable blood pressure cuff around the contralateral upper arm. Students were then allowed about fifteen minutes for heart rate and blood pressure to achieve the physiological steady state (no changes after duplicate readings taken five minutes apart). Monitored variables included skin temperature (T_s, ^oC), systemic arterial blood pressure, both systolic (P_s, mmHg) and diastolic pressure (P_d, mmHg), and Heart Rate (HR, cycles/minute). Heart rate was determined by palpating the radial pulse in the contralateral wrist.

Following instrumentation and achievement of the physiological steady state, baseline data were recorded (T_s, HR, P_s, P_d). Then, responding to an audible cue from a research assistant (i.e. "3, 2, 1, go") the volunteer immersed the experimental hand up to the wrist in a hard-rubber pail (~3.5L) of water prechilled to 0-5^{o}C with crushed ice. Subjects were not allowed to form a fist in the experimental hand, i.e. fingers were fully extended. The hand was kept immersed for three minutes (3 min) and there was no conversation between the experimental subject and research assistants. The experimental subject was also instructed to lie still with minimal movements during the test. After about three minutes of immersion experimental data were collected and again on audible cue the volunteer withdrew his/her hand from the chilled water. A research assistant blotted the hand dry with a towel and the volunteer was asked to remain still for another fifteen minutes. Monitored variables were measured once more after the 15-minute period.

Statistics: Statistical variability was identified between typical and exaggerated responders using Analysis of Variance for Repeated Measures (ANOVA, one-way analysis, completely-random design). Comparisons between two means were achieved using Student's t-test for unpaired data. When more than two means were compared a priori tests such as Tukey's w-procedure and Least Significant Difference were used. Statistically significant differences were accepted at the standard $P<0.05$ level, and all data are reported as means plus or minus one standard error of the mean (s.e.m.).

Results

Typical Responses

Skin Temperature: Skin temperature in the instrumented hand dropped from an average of 33±2 to 24±2^{o}C ($P<0.05$) three minutes after immersion. Skin temperature had not fully returned to baseline values fifteen minutes after removal of the hand from the chilled water. There were no statistically significant differences in temperatures in volunteers displaying typical vs exaggerated responses.

Heart Rate: Heart rate increased from 71±1 cpm to 79±2 cpm ($P<0.05$) after three minutes of immersion in chilled water. Heart rate returned to baseline values fifteen minutes after removing the hand from the chilled water. During immersion there were no statistically significant differences in heart rate between typical and exaggerated responders.

Systolic Arterial Blood Pressure: On the average P_s increased modestly but significantly ($P<0.05$) from 121±1 mmHg under baseline conditions to 126±1 mmHg during the cold pressor test (Figure 1).

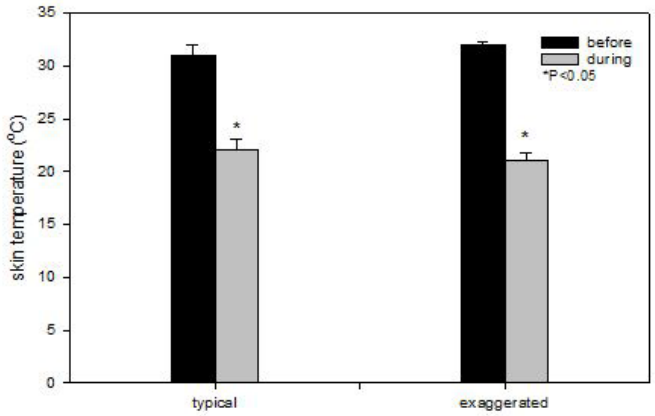

Figure 1: Skin temperature in young single adults exposed to a cold pressor test. Data in this and other figures were collected immediately before and approximately three minutes after a hand was immersed in chilled water. Note the absence of differences between the two groups.

Of seventy-one volunteers in whom these data were generated two and eleven, respectively, had P_s that did not change or decreased modestly during the cold pressor test. Diastolic arterial blood pressure: On the average P_d increased modestly but significantly (P<0.05) from 74±1 mmHg under baseline conditions to 80±1 mmHg during hand immersion (Figure 2).

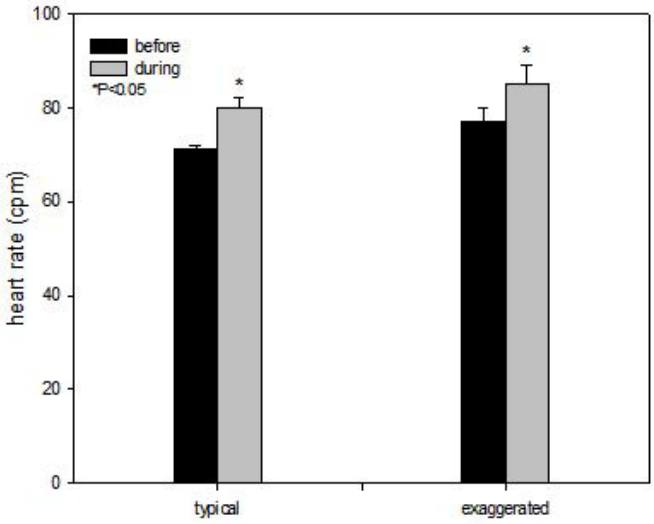

Figure 2: Heart rate responses in young single adults exposed to a cold pressor test. Note that heart rate increased modestly but significantly (P<0.05) in both typical and exaggerated responders.

Of the seventy-one volunteers studied to generate these data four and eleven, respectively, had Pd that did not change or decreased modestly during immersion.

Exaggerated Responses

Skin Temperature: Skin temperature in the instrumented hand dropped from an average of 32±1 to 23±2oC (P<0.05) three minutes after immersion. Skin temperature had not fully returned to baseline values fifteen minutes after removal of the hand from the chilled water. There were no significant differences in temperatures in volunteers displaying typical vs exaggerated responses.

Heart Rate: Heart rate increased from 77±3 to 85±4 (P<0.05) after three minutes of immersion in chilled water. Heart rate returned to baseline values fifteen minutes after removing the hand from the chilled water. During immersion there were no statistically significant differences in heart rates between typical and exaggerated responders. However, under baseline conditions heart rate was modestly, but significantly elevated in exaggerated responders (Figure 3).

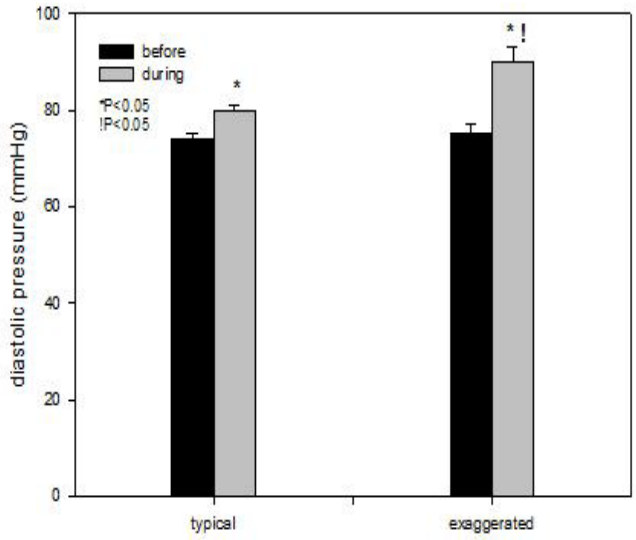

Figure 3: Diastolic blood pressure responses in young single adults exposed to a cold pressor test. Note the significantly greater elevation of pressure in the exaggerated responders (! P<0.05).

Systolic Arterial Blood Pressure: On the average Ps increased significantly (P<0.05) from 121±2 mmHg under baseline conditions to 144±3 mmHg during the cold pressor test (Figure 4).

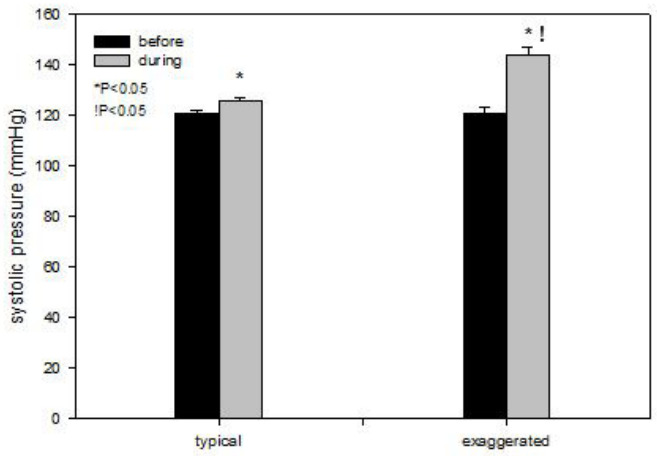

Figure 4: Systolic blood pressure responses in young single adults exposed to a cold pressor test. Note the significantly greater elevation of pressure in the exaggerated responders (! P<0.05).

Of twenty-eight volunteers in whom these data were generated none had P_s that did not change or decreased modestly during the cold pressor test.

Diastolic Arterial Blood Pressure: On the average P_d increased significantly (P<0.05) from 75±2 mmHg under baseline conditions to 90±3 mmHg during hand immersion of the twenty-eight volunteers studied to generate these data only one had P_d that did not increase during immersion.

Discussion

Cold pressor tests have been used to evaluate autonomic control of the human cardiovascular system [13-29] and to describe influences of increased sympathetic nerve activity on the vasculature of both skin and skeletal muscle [15-24]. The test has also been used to discriminate cardiovascular effects of painful stimuli [16] and results are known to be influenced by disease [25-26]. For example, the test is reported to produce exaggerated pressor responses in hypertension-prone humans [2-9] and augmented coronary vasoconstriction in patients with ischemic heart disease [10-12].

Conversely, responses are diminished in patients with orthostatic hypotension caused by impaired efferent sympathetic function. In normotensive young adult patients Benetos and Safar [27] observed an inverse relationship between age and changes in diastolic blood pressure during a CPT, but a similar relation was not observed in hypertensive patients. Also, plasma renin was about sixty per cent higher in hypertensive patients who responded to a CPT than those who did not respond. There was no relationship between the response of blood pressure and a family history of hypertension [27].

More than seven decades ago Thacker [8] used the test in college-age young adults to compare responses in hypo-, normo- and hypertensive students. Comparing hypertensives to normotensives he found that the pressor responses were greater and took longer to achieve in the hypertensive students. He also reported that exaggerated responders were more than five times as likely to have a history of cardiovascular disease in their families. Only male students were used in Thacker's study [8] and because of the era (1935-1939) it is likely that the majority were White. More recently [5] reported a difference in normotensive vs hypertensive young Blacks to a cold pressor test lasting four minutes [2-4] were among the first to suggest that the test might be a useful way of detecting young adults at risk of developing cardiovascular disease later in life. In the current study we collected data from both males and females and found no differences. We also tried to recruit from a range of cultural/ethnic backgrounds from (Table 2).

Typical	White (n=31)>Asian (n=16) > Indian (n=8) > Other (n=7) > Black (n=6) = Hispanic (n=6)
Exaggerated	White (n=11) > Asian (n=5) > Black (n=4) > Indian (n=3) >Hispanic (n=2) > Other (n=1)

Table 2: Cultural demographics and frequency of responses of college-age young single adults exposed to a 3-minutes cold pressor test.

One can see that exaggerated responders were more than twice as likely to be White. However, given the small samples sizes we also found relatively high frequencies of Asians, Indians, Blacks and Hispanics who displayed exaggerated responses.

- **Among typical responders the frequency of distribution was:** Whites>Asians>Indians>Others> Blacks>Hispanics.
- **The order was different for those displaying an exaggerated response:** Whites>Asians>Blacks>Indians>Hispanics>Other s.

Despite the small sample sizes, and among the exaggerated responders, representation by Blacks was more like that for Whites and Asians. Earlier Calhoun et al. [28] compared sympathetic nerve activity, heart rate and systemic arterial blood pressure to a cold pressor test in Black (24±2 years) and White (28±2 years) normotensive male and female subjects. The subjects were predominantly students with similar educations (like those in the current study only a bit older). Under supine resting conditions mean arterial pressure and sympathetic nerve activity were not different in the two groups. During a 2-minute cold pressor test, mean arterial pressure, heart rate, and sympathetic nerve activity in skeletal muscle increased in both groups. The increments were significantly greater in Blacks than Whites. [28] concluded that young Blacks might be predisposed to the development of hypertension later in life.

In addition to a racial component to the CPT there might also be a temporal element. Our volunteers took the test between 9-10 a.m. 2-3 p.m. and 7-8 p.m. In teaching the physiology of blood

pressure to young adults we have observed a significant elevation in diastolic pressure in males, but not females, in the p.m. vs a.m. hours (unpublished observations). When considering the effects of diurnal and ultradian rhythms on human physiology, blood pressure and blood chemistry, it seems plausible that the time of day a CPT is administered could influence the outcome. On the other hand, body position seems to be unimportant. Thacker found no differences in the magnitude of pressor responses in the same students tested while lying down (supine position) vs sitting up [8]. By our definition (i.e. during CPT a change in diastolic, systolic or both pressures must be at least 2x that of a typical responder to qualify as an exaggerated response) nearly one in every three students displayed an exaggerated response to a CPT. In those who responded typically both diastolic and systolic pressures rose about 5-6 mmHg during the 3-minute test [11-14].

Conversely, exaggerated responders experienced elevations of diastolic and systolic pressures of nearly 3-4 times the above numbers. Of seventy-one volunteers responding typically there was a small handful whose blood pressure either decreased modestly or did not change during the test. Among twenty-eight exaggerated responders none had P_s that did not change or decreased during the test. Only one of the twenty-eight had P_d that did not increase during immersion of the hand. Moreover, all young adults who took the test displayed a modest but statistically significant tachycardia during the three minutes. There were no differences between typical and exaggerated responders nor between males and females in the elevated heart rate responses. Conversely, the relative but modest tachycardia under baseline conditions in exaggerated responders might be indicative of an over-stimulated sympathetic nervous system, i.e. a genetically-predisposed anticipatory sympathetic response to an imminent challenge such as a CPT. If this is true then baseline, resting heart rate might also be a predictor of an exaggerated response to a CPT.

Summary

In my lab a large proportion of college-age young adults taking a cold pressor test showed an exaggerated blood pressure response. Males and females were equally affected, but Whites, Asians and Blacks seemed more prone to the exaggerated responses than did Indians, Hispanics and Others. A racial component to the response in young adults has been previously reported between Blacks and Whites [28]. Whether or not there is a chronobiological component to the exaggerated response, especially in males, should be investigated. We conclude that a significant fraction of college-age young single adults displays an exaggerated blood pressure response to a cold pressor test. According to others such young people might be at increased risk of developing cardiovascular disease later in life.

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