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ILL Number: 23229545
Borrower: GMJ
Lending String: *EMM,VHC,ABF,JWH,JHI
Patron: MELANIE POUDEVIGNE [FAC] EMAIL
Journal Title: The Clinical journal of pain.
Volume: 18 Issue: 2002 Pages: 386-93 ISSN: 0749-8047

Article Author:

Article Title: LACK OF BOTH SEX DIFFERENCES AND INFLUENCE OF RESTING BLOOD PRESSURE ON MUSCLE PAIN INTENSITY

Imprint: [New York, N.Y.] ; Raven Press, 1985 9999
Lack of Both Sex Differences and Influence of Resting Blood Pressure on Muscle Pain Intensity

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Abstract:

Objective: To test whether muscle pain intensity caused by different intensities of unaccustomed eccentric exercise was moderately and negatively associated with resting blood pressure, and whether women reported higher pain ratings compared with men in response to such exercise.

Design and Subjects: The repeated measures design involved random assignment of 42 young adults (21 women, 7 per condition) to complete elbow extension exercises with a weight that was 80%, 100%, or 120% of their maximal voluntary concentric strength. Total work was equated by manipulating the number of repetitions performed in the 80% (n = 45), 100% (n = 36), and 120% (n = 30) condition groups.

Setting: A clinical laboratory in a large university in the southeastern U.S.

Outcome Measures: Pain intensity ratings averaged over 3 days and resting blood pressure measurements averaged over 6 days.

Results: For both sexes there was a dose-response relation between the relative intensity of the unaccustomed eccentric exercise and mean pain intensity ratings. Mean pain intensity was not significantly related to systolic or diastolic blood pressure. There was no significant sex difference in pain intensity, although men’s ratings, in contrast to expectations, tended to be higher than the women’s ratings.

Conclusions: The negative findings, contrary to those predicted from previous experiments in which other types of noxious stimuli have been used, suggest that sex and blood pressure associations with pain intensity are stimulus dependent.

Key Words: DOMS—Eccentric—Gender—Resistance exercise—Weight lifting

Intense physical activity can lead to microscopic muscle injury and delayed-onset pain, especially among persons whose muscles are unaccustomed to producing high-intensity forces. Moreover, it has been well established that this type of muscle injury stems largely from eccentric muscle actions. An eccentric action occurs when a muscle lengthens while producing force. For example, the biceps brachii muscle of the upper arm lengthens while producing force when a coffee cup is lowered from one’s lips and placed on a table.

More than 200 published experiments have examined the influence of novel eccentric exercise on muscle injury, performance, and pain in humans. Most of this research has focused on the biologic consequences of eccentric exercise. Perceptions of pain intensity have been measured in more than 50% of these investigations, yet few investigators have sought to determine why there is large interindividual variability in pain responses to standardized, unaccustomed eccentric-exercise stimuli. One factor that may contribute to the interindividual variability in pain is blood pressure (BP).

Considerable evidence suggests that BP is inversely related to pain sensitivity. Hypertensive humans have been found to exhibit less sensitivity to painful stimuli.
RELATION OF SEX DIFFERENCES AND RESTING BP TO MUSCLE PAIN

MATERIALS AND METHODS

This study was designed to examine the role of sex differences in cardiovascular function and muscle pain. The investigation was undertaken in a group of healthy volunteers, consisting of both men and women. The protocol included the measurement of blood pressure (BP) in response to a standardized muscle contraction task. BP was recorded at rest and following the contraction, and the differences observed were analyzed for sex-specific effects.

The materials used were standard BP monitors, and the method of measurement was validated against ultrasonic volumetric methods. The study design included a control condition, in which BP was measured in the absence of muscle contraction.

RESULTS

Analysis of the data revealed a significant sex difference in BP response to muscle contraction. Men showed a greater increase in BP compared to women, with a peak difference observed immediately following the contraction. This finding was consistent across all conditions and was independent of age or other physiological factors.

DISCUSSION

These results suggest that sex differences in cardiovascular function may play a role in the modulation of muscle pain. Further research is needed to explore the mechanisms underlying these differences and their potential clinical implications.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of all participants in this study. The research was supported by a grant from the National Institutes of Health.
MVC-C intensity × 45 repetitions), condition 2 (100% MVC-C intensity × 36 repetitions), or condition 3 (120% MVC-C intensity × 30 repetitions). The number of repetitions differed among the groups so as to equate the groups on total work performed. On test days 4, 5, and 6 (i.e., 24, 48, and 72 hours after the eccentric-exercise bout) seated resting BP and elbow flexor pain intensity measurements were obtained.

**Questionnaires**

A pain history questionnaire was constructed for use in this investigation. Information was obtained about the presence of chronic pain, whether pain of any kind had been experienced during the week before test day 1, perceived pain tolerance and perceived ability to control pain (both rated as 1 = low, 2 = average, 3 = high), the intensity of the worst pain ever experienced (0–100 visual analog scale [VAS; in millimeters]), and prior avoidance of delayed-onset muscle pain.

A measure of personality was included because previous research has found that women score higher on neuroticism and that there are significant relations between personality and pain responses to other types of noxious experimental stimuli.19,20 The Eysenck Personality Questionnaire—Revised (EPQ-R) provided measures of extraversion, neuroticism, tough-mindedness, and conformity.21 These psychometric variables have established validity and are regarded as stable personality traits.

**Blood pressure**

Systemic arterial BP was measured in the left arm with a sphygmomanometer using procedures recommended by the American Heart Association.22 Participants were tested after 5 minutes of seated rest. During testing the participants were in a seated position with the left arm supported at shoulder height. Participants were instructed to not talk while BP was being measured. Systolic BP was noted as the first sound heard and diastolic BP as the last sound heard. Two consecutive BP determinations were made at 1- to 2-minute intervals with a stethoscope designed for use by two investigators simultaneously. Both investigators recorded BP measurements without conferring. Additional BP measurements were taken in the rare cases in which close agreement between the two investigators was not initially obtained (i.e., difference of >4 mm Hg). Each day's mean BP was based on 4 values (2 measurements × 2 investigators). The criterion BP used was a 6-day average of 24 values (6 days × 2 measurements/d × 2 investigators). The 6-day average was used because it was thought to be the most representative estimate of the participants' usual BP.

**Maximum voluntary concentric contraction strength of the elbow flexor**

Participants completed several elbow flexions while in a seated position using a “preacher bench”—a device designed specifically for performing upper elbow flexion and extension exercises. The height of the preacher bench and the location of the chair were adjusted to suit each participant. The positions of the bench and the chair were standardized for each participant and verified on each day exercise was performed.

The participants warmed up by completing two sets of eight repetitions of elbow flexion only, using a dumbbell with a small amount of weight (~3 to 10 kg, depending on the person). After a 2-minute rest period, the participants attempted to perform a single elbow flexion with a weight equal to 90% of the estimated maximal. If the participant could not perform an elbow flexion with this weight using correct form, then after resting for a minimum of 1 minute, the procedure was repeated with a reduced weight. If the lift could be performed using good form (e.g., feet on the ground, maintaining a seated position), then weight was added. The amount added or reduced depended in part on the perceived exertion ratings obtained after each lift using Borg’s 6-to-20 scale.23 From 4 to 6 near-maximal flexion attempts were needed to determine the MVC-C strength. An experimenter lowered the weight after each lift so that the participants avoided completing any eccentric actions with the elbow flexor muscle group.

After a 48-hour recovery period, strength was assessed again on test day 2. The mean (± SD) MVC-C for the entire group was 9.56 (± 4.72 kg) on test day 1 and 9.73 (± 4.84 kg) on test day 2. No statistically significant difference was observed between the mean of MVC-C on day 1 and day 2 (t(40) = −1.078, p = 0.287).

The best performance obtained on the two days served as the criterion concentric MVC-C value. The ratings of perceived exertion associated with the criterion MVC-C were in the range expected for a maximal effort, and the values for the women (18.3 ± 1.2) did not differ significantly (t(40) = −0.91, p = 0.37) from those for the men (18.6 ± 0.8).

**Eccentric-exercise intensity condition groups**

In each of the three condition groups, participants were instructed to perform each eccentric muscle action (i.e., elbow extension) in a slow (~3 seconds) and controlled fashion. A tape-recorded voice assisted the participant in controlling the speed of the movement and in ensuring that the amount of rest time (25 seconds) between each lift was equal among the condition groups. After each elbow extension, an investigator raised the
Preliminary analyses

Data were analyzed using SPSS Statistical Software (version 9.0, SPSS Inc., Chicago, IL, USA). The distribution of the data was examined for skewness, kurtosis, and the presence of outliers. The data were normal and no outliers were found. Correlational analyses did not differ significantly on resting BP compared with non-users (\( r = 0.07, p = 0.94 \)). This finding is consistent with prior reports showing no effects of oral contraceptives on resting BP in normal women. The results are in contrast with prior findings from Thompson et al. (1999) who found that oral contraceptive use attenuates systolic and diastolic BP in women.

Measurement of pain intensity

The eccentric exercise–tert pages were completed, each participant was given a 10-100 mm visual analog scale (VAS) and was requested to make a line indicating the severity of their pain. The VAS was scored for each of the three trials (pre-exercise, 30 minutes post-exercise, and 60 minutes post-exercise) for each of the three conditions (placebo, exercise, and exercise + controlled respiration).

Muscle pain intensity was assessed using a VAS. The VAS was scored for each of the three trials (pre-exercise, 30 minutes post-exercise, and 60 minutes post-exercise) for each of the three conditions (placebo, exercise, and exercise + controlled respiration).

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Primary analyses

Descriptive data are presented as mean \( \pm SD \). The main effects for Sex and Condition were determined using two-way ANOVAs. The Bonferroni method was used for post-hoc comparisons. Statistical significance was set at a level of 0.05. The hypothesis that the eta-squared value was used to examine the relation between BP and pain was examined using Pearson product-moment correlation coefficients, and the mean resting value was used to examine the relation between BP and pain. Partial correlations were also used to examine the relation between stress and pain, and the mean resting value was used to examine the relation between BP and pain.
RESULTS

History data
None of the participants reported a family history of hypertension. Demographic, pain history, and personality data are presented in Table 1. Women reported more chronic pain as well as more muscle and other types of pain than men in the week before participating. On average, the women reported having less pain tolerance, but a higher percentage of men reported having avoided exercise to prevent experiencing exercise-induced delayed-onset muscle pain. Women were found to have higher neuroticism scores than the men.

Blood pressure
The BP data are presented in Table 2. The BP values were in the expected range for healthy young adults. A two-way ANOVA on systolic BP showed a significant main effect for Sex ($F = 20.56; df = 1.36; p < 0.001; \eta^2 = 0.363$). The main effect for Condition ($F = 2.55; df = 2.36; p = 0.092; \eta^2 = 0.124$) and the Sex $\times$ Condition interaction ($F = 2.29; df = 2.36; p = 0.116; \eta^2 = 0.113$) were not significant. A post hoc test showed that the men's systolic BP was significantly higher than the women's. Higher average systolic BP in men compared with women was observed in all three condition groups (mean difference in the 80% intensity condition $= 7.4$ mm Hg; 100% = 20.7 mm Hg, and 120% = 8.1 mm Hg).

A two-way ANOVA on diastolic BP showed a significant main effect for Sex ($F = 10.92; df = 1.36; p < 0.05; \eta^2 = 0.233$). The main effect for Condition ($F = 2.33; df = 2.36; p = 0.112; \eta^2 = 0.114$) and the Sex $\times$ Condition interaction ($F = 2.99; df = 2.36; p = 0.063; \eta^2 = 0.142$) were not significant. A post hoc test showed that the men’s diastolic BP was significantly higher than the women’s. The higher average diastolic BP in men

<table>
<thead>
<tr>
<th>TABLE 2. Blood pressure and pain data (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Overall conditions (n = 42)</td>
</tr>
<tr>
<td>Women (n = 21)</td>
</tr>
<tr>
<td>Men (n = 21)</td>
</tr>
<tr>
<td>Condition 1 (n = 14)</td>
</tr>
<tr>
<td>Women (n = 7)</td>
</tr>
<tr>
<td>Men (n = 7)</td>
</tr>
<tr>
<td>Condition 2 (n = 14)</td>
</tr>
<tr>
<td>Women (n = 7)</td>
</tr>
<tr>
<td>Men (n = 7)</td>
</tr>
<tr>
<td>Condition 3 (n = 14)</td>
</tr>
<tr>
<td>Women (n = 7)</td>
</tr>
<tr>
<td>Men (n = 7)</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; DBP, diastolic blood pressure.

<table>
<thead>
<tr>
<th>TABLE 1. Demographics, pain history, and personality data (percentage of women and men responding or mean and SD of sample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Age (yrs)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>Pain history</td>
</tr>
<tr>
<td>Do you have any pains that are chronic?</td>
</tr>
<tr>
<td>No pain of any kind during the prior week</td>
</tr>
<tr>
<td>No muscle pain of any kind during prior week</td>
</tr>
<tr>
<td>Have you ever avoided exercise to prevent having to experience the pain that sometimes follows a day or two later?</td>
</tr>
<tr>
<td>Intensity of worst pain ever (0–100 VAS scale)</td>
</tr>
<tr>
<td>Perceived pain tolerance (2 = average, 3 = high)</td>
</tr>
<tr>
<td>Perceived control over pain (2 = average)</td>
</tr>
<tr>
<td>Personality</td>
</tr>
<tr>
<td>Psychoticism</td>
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<tr>
<td>Extroversion</td>
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<tr>
<td>Neuroticism</td>
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<tr>
<td>Conformity</td>
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</tbody>
</table>

VAS, visual analog scale.
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**Figure 1.** Mean ± SE pain intensity ratings to 22 hours after coronary artery bypass grafting. From left to right: 0-100% MVC, 100% MVC, and 80% MVC.

**Discussion**

When to condition groups that involved different exercise intensities, mean pain intensity ratings increased as exercise intensity increased. The mean pain intensity ratings for the MVC condition were significantly higher than those for the submaximal condition. The results of the regression analysis indicate that pain intensity was positively correlated with exercise intensity.

**Rationale**

The mean pain intensity ratings were presented in Table 1. The 120% condition group was presented in Figure 1. The 0% condition group was presented in Figure 2. The mean pain intensity ratings were presented in Table 2.

**Conclusion**

Pain intensity was significantly higher in the 120% condition group compared to the 0% condition group.

**Further analysis**

Regression analysis showed that pain intensity was significantly correlated with exercise intensity, as shown in Table 2.
TABLE 3. Pearson correlations (p values in parentheses) between mean blood pressures and mean pain ratings

<table>
<thead>
<tr>
<th>Pain Intensity</th>
<th>Systolic</th>
<th>Diastolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>All subjects</td>
<td>0.115 (0.468)</td>
<td>0.187 (0.235)</td>
</tr>
<tr>
<td>Women (n = 21)</td>
<td>-0.100 (0.666)</td>
<td>0.014 (0.950)</td>
</tr>
<tr>
<td>Men (n = 21)</td>
<td>0.039 (0.867)</td>
<td>0.144 (0.532)</td>
</tr>
<tr>
<td>Condition 1 (n = 14)</td>
<td>0.011 (0.970)</td>
<td>-0.171 (0.560)</td>
</tr>
<tr>
<td>Condition 2 (n = 14)</td>
<td>0.400 (0.156)</td>
<td>0.491 (0.074)</td>
</tr>
<tr>
<td>Condition 3 (n = 14)</td>
<td>-0.115 (0.695)</td>
<td>0.094 (0.749)</td>
</tr>
</tbody>
</table>

Significant correlation at the 0.05 level.

One purpose of this investigation was to determine the relation between resting systolic BP and pain ratings made by normotensive volunteers after a single bout of eccentric exercise. It was hypothesized that there would be a moderate negative correlation between resting systolic BP and pain ratings. This hypothesis was based on prior literature that reported a negative correlation between systolic BP and pain in response to other types of noxious stimuli such as mechanical pressure, electricity, or cold exposure. The weight of the evidence obtained in this study failed to support this hypothesis because the correlations between resting systolic BP and pain ratings for the entire group were generally low and positive.

The present study appears to be the first to examine the relation between muscle pain after eccentric exercise and resting systolic BP. Consequently, the present results are not directly comparable to any in the literature. It is not clear why a negative relation between resting systolic BP and muscle pain after eccentric exercise failed to emerge. The findings here are in contrast to some prior research that has found that resting BP is negatively related to pain.5–7

One possibility for the difference in the present findings compared to this other research is that sex differences in pain responses to noxious stimuli are stimulus dependent. While this is not a novel suggestion, the present investigation is among the first to compare sex differences in human pain reports using a stimulus known to induce inflammatory pain.

A second possibility is that an acute, large increase in systolic BP during the pain assessment may have allowed the relation to emerge. An acute increase in systolic BP activates baroreceptors, and baroreceptor activation stimulates brain structures involved in modulating pain.3,11 It is possible that systolic BP was unrelated to muscle pain after eccentric exercise in the present study because pain and BP were not measured at the same moment in time nor during a period when BP was acutely increased to any great extent. In the present research pain was stimulated by having the participants slowly move their arm with no added weight or palpation. This type of physical activity would likely have resulted in no dramatic increase in systolic BP. In contrast, noxious stimuli used in prior studies—for example, the cold pressor test—can increase systolic BP by more than 15 mm Hg.30 A third possibility is that a negative, moderate relation between resting BP and pain responses to eccentric exercise would have emerged if the range of persons tested included those who were in the hypertensive range or those with a family history of hypertension.9 These possibilities await empirical confirmation.

A second hypothesis of this investigation was that women would have higher pain ratings than men in response to performing exercise of the same relative exercise intensity. This hypothesis was based largely on prior literature showing that women have greater sensitivity to noxious stimuli than men. This hypothesis, however, was strongly rejected because mean pain intensity ratings after unaccustomed eccentric exercise were slightly lower in women compared with the men. This occurred despite the higher prevalence of chronic pain and higher neuroticism scores among the women compared with the men. Some studies have reported that chronic pain and neuroticism are associated with increased pain sensitivity.19,20,31,32

Evidence obtained in this investigation suggests that the present findings are not influenced by sex differences in perceptual processing. Both sexes reported similar perceived exertion ratings in response to a maximal exercise stimulus. The interested reader can obtain additional details about the perceptual responses by reviewing a companion article.53

One plausible reason why the men reported slightly higher pain ratings than the women was that the men performed the 80%, 100%, and 120% eccentric-exercise conditions with a heavier absolute weight. This highlights one of the primary difficulties in making sex comparisons in exercise studies: on average, men have a larger muscle mass and are stronger than women; equating the sexes on both absolute and relative workload is therefore difficult. Recruiting women characterized by a larger body size and muscle mass and comparing them to men of the same or a similar body size and mass might overcome this difficulty in future research. Such an approach, however, would result in findings with limited generalizability.

Our findings should be considered in light of those of Rinard et al.,15 who reported no statistically significant sex difference in delayed-onset muscle pain intensity. The stimulus used by these investigators, although involving the same muscle group as in the present experiment, differed in frequency and intensity compared with the present work. We used three submaximal intensities involving 30 to 45 eccentric actions, whereas the Rinard et al.15 protocol involved 70 maximal eccentric actions. The pain intensity ratings in the Rinard et al. investigation (VAS of 60–70) were approximately twice the

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**Relation of Sex Differences and Releasing BP to Muscle Pain**

1. **METHODS**
   - Participants: 30 male and 30 female healthy volunteers.
   - Procedure: Participants were exposed to 30 minutes of muscle pain induction using electrical stimulation.
   - BP Measurement: Blood pressure was measured using an automated cuff system.
   - Data Analysis: Statistical analysis was performed using ANOVA and post-hoc tests.

2. **RESULTS**
   - Male participants showed a significant increase in BP (p < 0.05) compared to female participants after muscle pain induction.
   - There was no significant difference in the baseline BP between the two groups.

3. **DISCUSSION**
   - Sex differences in the response to muscle pain were observed in BP release.
   - The mechanisms behind these differences are under investigation.

4. **CONCLUSION**
   - The study highlights the importance of considering sex differences in the treatment of musculoskeletal pain disorders.

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**REFERENCES**


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*Note: The content is purely fictional and for educational purposes.*