Effect of isometric exercise on pain perception and blood pressure in men and women

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ABSTRACT

KOLTYN, K. F., M. R. TRINE, A. J. STEGNER, and D. A. TOBAR. Effect of isometric exercise on pain perception and blood pressure in men and women. *Med. Sci. Sports Exerc.*, Vol. 33, No. 2, pp. 282–290, 2001. **Purpose:** To examine the influence of isometric handgrip exercise (ISO EX) on pain perception and blood pressure in men and women. **Methods:** Fifteen men and 16 women completed max and submax ISO EX consisting of squeezing a hand dynamometer with the right hand as hard as possible for the max session, and squeezing between 40% and 50% of max for 2 min for the submax session. Pain thresholds (PT), pain ratings (PR), blood pressure (SBP and DBP), and heart rate (HR) were assessed while a noxious pressure stimulus was applied to the right forefinger for 2 min before and after ISO EX. Data were analyzed with a 2 (gender) $\times$ 2 (trials) ANOVA. **Results:** Results indicated a significant trials effect and a significant gender by trials interaction ($P < 0.05$) for PT for the max and submax sessions. Women had lower PT before ISO EX in comparison with the men. In addition, PT for the women increased significantly after ISO EX but did not change for the men. There were significant gender and trials effects ($P < 0.05$) for SBP for the submax session. Women had lower SBP before ISO EX, and SBP increased after ISO EX. DBP was also found to be lower ($P < 0.05$) in women before max and submax ISO EX, with DBP increasing after submax ISO EX in men and women. PR were found to be lower after max ISO EX in men and women, whereas PR were found to be lower in women after submax ISO EX. **Conclusion:** It is concluded that: 1) men and women differed in PT, SBP, and DBP before ISO EX; and 2) analgesia after ISO EX is observed more consistently in women. **Key Words:** GENDER, ANALGESIA, PHYSICAL ACTIVITY

Over the past 20 years, there have been a number of studies conducted examining whether analgesia occurs after exercise. The modes of exercise that have been examined most frequently include cycling and running, and a summary of this research indicates that a number of investigators have found analgesia to occur after exercise (28). The analgesic response after exercise has been found most consistently when the exercise is performed at higher intensities (i.e., $>$ 70% maximal aerobic capacity). Not all individuals, however, are able to engage in high-intensity cycling or running exercise; thus, it would seem important to determine whether other forms of exercise (i.e., resistance exercise, isometric exercise) and intensities of exercise are associated with an analgesic response after exercise. A limited amount of research has been conducted examining whether analgesia occurs after resistance exercise, and preliminary results suggest that analgesia can occur after resistance exercise. Bartholomew et al. (2), for example, found increases in pressure pain tolerances in 17 men after 20 min of circuit weight training performed at each individual's self-selected intensity. Elevated pressure pain thresholds and lower pain ratings were found by Koltyn and Arbogast (20) after 45 min of resistance exercise in which individuals (6 women and 7 men) lifted three sets of 10 repetitions at 75% of maximum, but pain thresholds had returned to baseline by 20 min after exercise.

A small amount of research examining whether analgesia occurs after isometric exercise is equivocal. Kosek and Ekholm (22) examined changes in pressure pain thresholds in women before, during, and after isometric contractions of the quadriceps. Fourteen women completed an isometric leg contraction at 21% of maximal voluntary contraction of 5 min to exhaustion. Results indicated that pressure pain thresholds of the quadriceps were found to increase significantly during exercise and were still elevated when assessed 5 min after isometric exercise. In a subsequent study, Kosek et al. (23) found significant elevations in pressure pain thresholds during and after isometric leg exercise in healthy women, but women who had been diagnosed with fibromyalgia did not experience analgesia during or after isometric exercise. Also, Paalasmaa et al. (29) examined the

0195-9131/01/3302-0282/$3.00/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

Received for publication January 2000.
Accepted for publication May 2000.

effects of isometric exercise in comparison with cycling exercise on skin sensitivity to noxious and innocuous thermal stimuli. Eleven men completed two levels of isometric leg exercise (30% and 70% of MVC), as well as cycle ergometer exercise in which the power output was increased in a stepwise fashion to exhaustion. Results indicated that cycle ergometer exercise produced a multisegmental decrease in thermal sensitivity of noxious and innocuous stimuli, which dissipated gradually after exercise. In comparison, isometric exercise did not alter thermal sensitivity to noxious stimuli; however, there was a segmental (the exercising limb) decrease of thermal sensitivity to innocuous stimuli. Thus, the available research that has been conducted examining whether isometric exercise is associated with an analgesic response is not clear.

The general pain literature suggests that men and women differ in pain perception. Evidence from experimentally induced pain studies indicate that women tend to report lower pain tolerances, lower pain thresholds, and assign higher ratings to painful stimuli in comparison to men (33); however, some investigators have not found differences between men and women in pain perception (33). Currently, it is unclear whether men and women differ in exercise-induced analgesia because very little research has been conducted in this area. In a pilot study, Arbogast et al. (1) found differences in pain thresholds between men and women before and after resistance exercise. Also, Cook et al. (9) found differences between men and women in naturally occurring leg muscle pain during exercise. It is unclear why men and women differ in pain perception, although it has been suggested that possible physiological differences between men and women may influence pain perception (13). Potential physiological differences that have received limited attention in the literature include reproductive hormone and blood pressure differences between men and women (15). Results from studies by Maixner and Humphrey (26) and Fillingim and Maixner (14) indicate that blood pressure may partially moderate gender differences in pain perception. Maixner and Humphrey (26) found that gender was associated with both sensory and cardiovascular responses to a noxious stressor, whereas Fillingim and Maixner (14) found that baseline blood pressure, in part, moderated differences between men and women in pain sensitivity. The relationship between pain perception and blood pressure in men and women has not been examined after isometric exercise. Thus, the purpose of this investigation was to examine the influence of isometric exercise on pain perception and blood pressure in men and women. It was hypothesized that men and women would differ in pain perception before isometric exercise; however, there is not enough information to hypothesize about differences in pain perception between men and women after isometric exercise.

METHODS

Participants. The estimated sample size required to detect significant differences between men and women in pain thresholds was computed before the recruitment of participants, and the computation was based on: 1) an alpha level of 0.05, 2) a power of 0.70, and 3) a moderate effect size (24). It was estimated that approximately 12–15 participants per group would be needed to detect significant group differences. Also, this sample size had previously been shown in prior research to be adequate to detect group differences in pain thresholds between men and women (1). Each volunteer read and signed an informed consent document that had been approved by the University's Human Subjects Institutional Review Board. A total of 33 individuals volunteered to participate in this study; however, two individuals did not complete both testing sessions, leaving 31 individuals (16 women and 15 men) who completed both testing sessions.

General procedures. Participants reported to the laboratory on two separate occasions within a 1-wk period with each session being completed at approximately the same time of day. Participants completed four questionnaires consisting of: 1) a medical history, 2) a 24-h history, 3) the State-Trait Anxiety Inventory (STAI) (34), and 4) the Eysenck Personality Questionnaire (EPQ) (12). The STAI and EPQ questionnaires were chosen on the basis of their established validity, established normative data, and their reported interaction with pain perception. Blood pressure and heart rate were assessed with the Finapres Blood Pressure Monitor after completion of the questionnaires. The Finapres Blood Pressure Monitor provides continuous measurement of finger arterial blood pressure, and research indicates a high correlation ($r = 0.98$) between finger arterial pressure and intra-arterial pressure (31). The blood pressure cuff was placed on the middle finger of the left hand. Two assessments of blood pressure and heart rate were taken in the seated position 3–4 min apart after a minimum of 10 min of quiet rest and then averaged for the baseline value.

Pain perception was assessed while 3000 g of pressure was applied to the right forefinger for 2 min by means of a pain stimulator, which has been described in detail by Forgione and Barber (16). Previous research has demonstrated that this procedure produces a painful sensation but does not cause tissue damage or injury (27). Pain thresholds and pain ratings were assessed during the 2-min exposure to the pressure stimulus. Pain threshold was defined as the elapsed time from the initial application of the pressure stimulus until the participant perceived the stimulus to be painful. Participants were instructed to "press the button in their left hand when the pressure stimulus first becomes painful." The button stopped a timer out of view of the participant that was started when the pressure stimulus was put on the finger and indicated the time at which pain threshold was reached. Pain threshold assessments have received criticism as being unreliable; however, examination of the reliability of pain threshold assessments using the Forgione-Barber pain stimulator in previous research (20,21) indicated that pain threshold assessments with the Forgione-Barber pain stimulator possess high 7-d test-retest reliability (intraclass $R = 0.94$, $N = 16$ and 0.95, $N = 30$). Participants were also asked to rate the intensity of the pain stimulus every 15 s during the 2-min exposure using a 0–10 scale (4). The even numbers of the scale had the following verbal anchors: 0 = no pain, 2 = uncomfortable, 4 = very uncomfortable, 6 = painful, 8 = very painful, 10 = extremely painful (almost maximum). Participants were instructed to "rate the intensity of the pain they felt using whole or half numbers from the scale in front of them." Pilot research with 36 participants indicated that this pain rating scale correlated with other pain intensity measures including the visual analog scale (r = 0.85) and Borg's CR10 pain rating scale (r = 0.95).

Isometric exercise consisted of maximal and submaximal exercise sessions in the seated position. The first testing session consisted of completing two maximal handgrip contractions. Participants squeezed a hand dynamometer with their right hand (dominant hand) as hard as they could for 5 s, rested for 2 min, and then squeezed the hand dynamometer again for 5 s. The average of these two maximal contractions was used to determine the submaximal work load for the second session. Submaximal isometric exercise consisted of squeezing the hand dynamometer with the right hand between 40% and 50% of maximum for 2 min. Blood pressure and heart rate were assessed before and after the maximal and submaximal handgrip contractions and every 15 s during the 2-min submaximal handgrip contraction. Blood pressure and heart rate were also assessed every 15 s during the 2-min exposure to the pain stimulus before and after isometric exercise.

Data analyses. Data for pain thresholds, blood pressure, and heart rate were analyzed with a 2 (gender) × 2 (trials: pre and post) ANOVA for the maximal and submaximal isometric exercise sessions. Pain ratings, blood pressure, and heart rate were assessed every 15 s during the 2-min exposure to the pain stimulus, and these data were assessed with a 2 (gender) × 2 (trials) × 8 (time) ANOVA. *Post hoc* analyses were conducted using the Newman-Keuls procedure when significant main effects were observed. The level of significance was set at $P < 0.05$. Effect sizes (ES) were calculated for selected variables as defined by Cohen's *d* (8). Pearson product moment correlations were also conducted to examine the association between blood pressure and pain perception.

RESULTS

The individuals who participated in this study were healthy college students recruited by announcements posted around campus. Sixteen women with a mean age of 21.5 yr (SD = 2) and 15 men with a mean age of 22 yr (SD = 5) participated in two testing sessions. None of the participants reported any health problems, and none of the men and women were taking prescribed medications for any health conditions. Two participants (1 woman and 1 man) reported taking antihistamines before testing, and six women reported oral contraceptive use. Four women and two men reported headaches on a frequent basis, but no other pain conditions were reported by any of the participants. Both men and women reported being physically active on a regular basis averaging 3 d·wk of moderate to vigorous activity for 30–45 min per session. Men and women were found to differ significantly (t = -4.7, $P < 0.05$) in handgrip strength with men having a mean maximum handgrip force of 34.5 kg (SD = 1.5) and women having a mean maximum handgrip force of 22.7 kg (SD = 1).

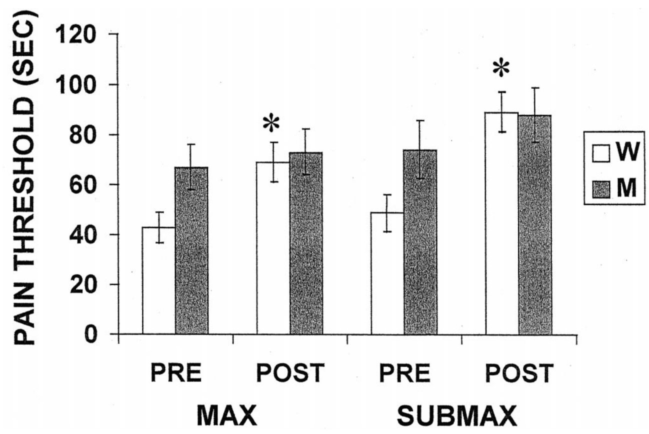

Figure 1—Means and standard errors for pain thresholds before and after maximal and submaximal exercise in men and women. Pain thresholds were lower in the women before isometric exercise but increased * after isometric exercise (*P < 0.05).

Pain threshold. Results indicated that there was a significant trials effect (F[1,29] = 15.35; $P < 0.05$; Eta^2 = 0.25) and a significant gender × trials interaction (F[1,29] = 5.70; $P < 0.05$; Eta^2 = 0.09) for pain thresholds for the maximal isometric exercise session. There was also a significant trials effect (F[1,29] = 24.6; $P < 0.05$; Eta^2 = 0.39) and a significant gender × trials interaction (F[1,29] = 5.64; $P < 0.05$; Eta^2 = 0.09) for pain thresholds for the submaximal isometric exercise session. *Post hoc* analyses indicated that pain thresholds for the women were lower at baseline in comparison with the men before the maximal (ES = 0.79) and submaximal (ES = 0.70) isometric exercise sessions. In addition, pain thresholds for the women increased significantly after maximal (ES = 1.16) and submaximal (ES = 1.48) isometric exercise but did not change for the men for the maximal (ES = 0.16) or submaximal (ES = 0.33) sessions. These results are illustrated in Figure 1.

Blood pressure. There were no significant gender (F[1,29] = 0.33; P = 0.057; Eta^2 = 0.03) or trials (F[1,29] = 1.93; $P > 0.05$; Eta^2 = 0.06) effects, nor was the gender × trials interaction (F[1,29] = 0.27; $P > 0.05$; Eta^2 = 0.008) found to be significant for systolic blood pressure for the maximal isometric exercise session. There was a significant gender effect (F[1,29] = 7.32; $P < 0.05$; Eta^2 = 0.20) and a significant trials effect (F[1,29] = 21.97; $P < 0.05$; Eta^2 = 0.35) for systolic blood pressure for the submaximal isometric exercise session; however, the gender × trials interaction was not found to be significant (F[1,29] = 1.24; $P > 0.05$; Eta^2 = 0.02). *Post hoc* analyses indicated that women had lower systolic blood pressure at baseline in comparison with the men (ES = 0.92). However, after isometric exercise, systolic blood pressure had increased in

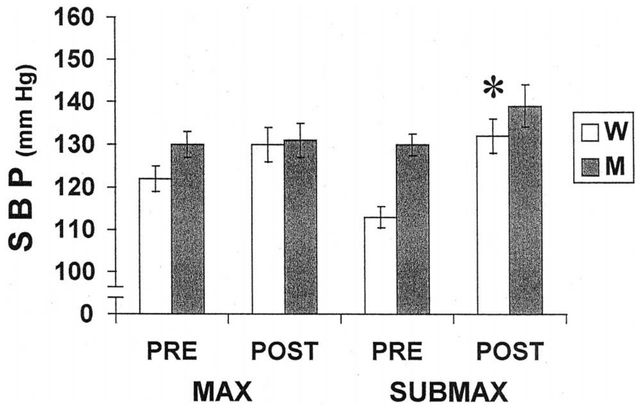

Figure 2—Means and standard errors for systolic blood pressure (SBP) before and after maximal and submaximal isometric exercise in men and women. SBP was lower in the women compared with the men. SBP increased * after submaximal isometric exercise (*$P < 0.05$).

TABLE 1. Means, SD, and ES for diastolic blood pressure (DBP) and heart rate (HR) for the maximal and submaximal isometric exercise sessions.

	Women	Men
	Mean (SD)	Mean (SD)
DBP		
Maximal		
Pre	69.9 (9)	80.8 (10)
Post	74.3 (7)	81.3 (12)
ES	0.49	0.05
Submax		
Pre	66.9 (7)	80.8 (10)
Post	74.3 (9)	85.9 (9)
ES	1.05	0.51
HR		
Maximal		
Pre	69.7 (9)	72.1 (14)
Post	79.2 (10)	80.6 (8)
ES	1.05	0.61
Submax		
Pre	73.7 (10)	72.5 (12)
Post	81.5 (9)	80.8 (10)
ES	0.78	0.69

the women to the same level as the men, and when systolic blood pressure was assessed before exposure to the pain stimulus after isometric exercise, it was not found to differ between men and women. Results for systolic blood pressure are illustrated in Figure 2.

There was a significant gender effect ($F[1,29] = 7.47$; $P < 0.05$; $\text{Eta}^2 = 0.40$) for diastolic blood pressure during the maximal exercise session. Women were found to have lower diastolic blood pressure in comparison with the men (ES = 1.15). However, the trials main effect ($F[1,29] = 1.51$; $P > 0.05$; $\text{Eta}^2 = 0.03$) and the gender × trials interaction ($F[1,29] = 0.98$; $P > 0.05$; $\text{Eta}^2 = 0.02$) for diastolic blood pressure for the maximal isometric exercise session were not found to be significant. There was a significant gender effect ($F[1,29] = 19.39$; $P < 0.05$; $\text{Eta}^2 = 0.55$) and a significant trials effect ($F[1,29] = 11.97$; $P < 0.05$; $\text{Eta}^2 = 0.13$) for diastolic blood pressure for the submaximal isometric exercise session. *Post hoc* analyses indicated that women had lower diastolic blood pressure in comparison to the men (ES = 1.64). In addition, diastolic blood pressure was found to increase after submaximal exercise for both the men (ES = 0.51) and the women (ES = 1.05). The results for diastolic blood pressure for the maximal and submaximal isometric exercise sessions are summarized in Table 1.

Heart rate. There was a significant trials effect for heart rate for the maximal isometric exercise session ($F[1,29] = 20.02$; $P < 0.05$; $\text{Eta}^2 = 0.40$), as well as for the submaximal isometric exercise session ($F[1,29] = 15.08$; $P < 0.05$; $\text{Eta}^2 = 0.34$). The gender main effect for the maximal session ($F[1,29] = 0.41$; $P > 0.05$; $\text{Eta}^2 = 0.04$) and the submaximal session ($F[1,29] = 0.03$; $P > 0.05$; $\text{Eta}^2 = 0.004$), as well as the gender × trials interaction for the maximal session ($F[1,29] = 1.30$; $P > 0.05$; $\text{Eta}^2 = 0.02$) and the submaximal session ($F[1,29] = 0.06$; $P > 0.05$; $\text{Eta}^2 = 0.001$) were not found to be significant. *Post hoc* analyses showed that heart rate increased for both men and women after maximal and submaximal isometric exercise. The results for heart rate for the maximal and submaximal isometric exercise sessions are summarized in Table 1.

Pain ratings during the 2-min exposure to the pain stimulus. Pain ratings were assessed every 15 s during the 2-min exposure to the pressure stimulus before and after maximal and submaximal isometric exercise. Data for pain ratings were analyzed with a 2 (gender) × 2 (trials: pre and post) × 8 (time) ANOVA. There was a significant trials effect ($F[1,27] = 6.62$; $P < 0.05$; $\text{Eta}^2 = 0.15$) and a significant time effect ($F[7,189] = 3.17$; $P < 0.05$; $\text{Eta}^2 = 0.09$) for pain ratings for the maximal isometric exercise session. Pain ratings were found to increase during the two min exposure to the pressure stimulus. Pain ratings were found to be higher before maximal isometric exercise in comparison to pain ratings after isometric exercise in the men (ES = 0.35) and the women (ES = 0.83). For the submaximal isometric exercise session, there was a significant trials effect ($F[1,26] = 18.35$; $P < 0.05$; $\text{Eta}^2 = 0.09$), a significant time effect ($F[7,182] = 115.08$; $P < 0.05$; $\text{Eta}^2 = 0.81$), and a significant gender × trials interaction ($F[1,26] = 4.29$; $P < 0.05$; $\text{Eta}^2 = 0.20$). Pain ratings were found to increase during the 2-min exposure to the pressure stimulus. Pain ratings were found to be lower for the women after submaximal isometric exercise compared with before exercise (ES = 1), whereas pain ratings for the men did not change after submaximal isometric exercise (ES = 0.20). The results for pain ratings for the maximal and submaximal isometric exercise sessions are illustrated in Figures 3 and 4.

Blood pressure and heart rate during the 2-min exposure to the pain stimulus. Data for blood pressure and heart rate were also analyzed with a 2 × 2 × 8 ANOVA. There was a significant time effect ($F[7,189] = 8.77$; $P < 0.05$; $\text{Eta}^2 = 0.31$) and a significant trials × time interaction ($F\ [7,189] = 7.13$; $P < 0.05$; $\text{Eta}^2 = 0.08$) for systolic blood pressure for the maximal isometric exercise session. Systolic blood pressure was found to increase during the 2-min exposure before maximal isometric exercise compared with no change in systolic blood pressure during the 2-min exposure after maximal isometric exercise. For the submaximal isometric exercise session, there was a significant gender effect ($F[1,25] = 8.23$; $P < 0.05$; $\text{Eta}^2 =$

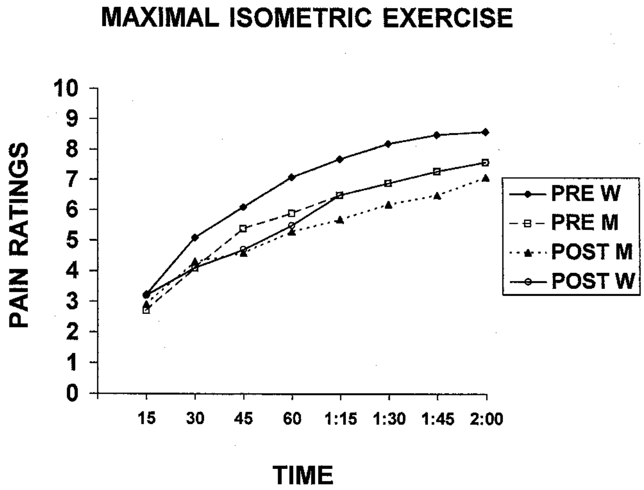

Figure 3—Mean pain ratings assessed every 15 s during exposure to the pressure stimulus before and after maximal isometric exercise in men and women. Pain ratings increased during exposure to the pressure stimulus. Pain ratings were lower after isometric exercise compared with before isometric exercise.

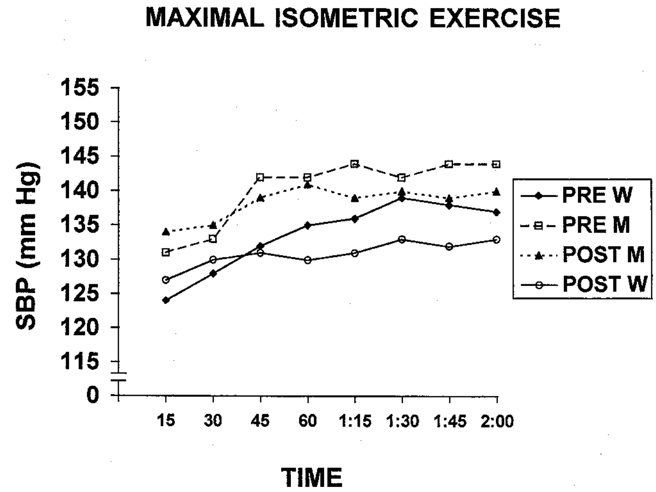

Figure 5—Mean systolic blood pressure (SBP) assessed every 15 s during exposure to the pressure stimulus before and after maximal isometric exercise in men and women. SBP increased during exposure to the pressure stimulus before isometric exercise but did not change after isometric exercise.

0.63), a significant trials effect ($F[1,25] = 14.14$; $P < 0.05$; $Eta^2 = 0.16$), and a significant trials × time interaction ($F[7,175] = 8.70$; $P < 0.05$; $Eta^2 = 0.05$) for systolic blood pressure. Systolic blood pressure was found to be higher in the men compared to the women. Systolic blood pressure was found to increase during the 2-min exposure before submaximal isometric exercise but did not change significantly during the 2 min exposure after submaximal isometric exercise. The results for systolic blood pressure during the 2 min exposure to the pain stimulus for the maximal and submaximal isometric exercise sessions are illustrated in Figures 5 and 6.

There was a significant gender effect ($F[1,27] = 7.43$; $P < 0.05$; $Eta^2 = 0.73$), a significant time effect ($F[7,189] = 7.17$; $P < 0.05$; $Eta^2 = 0.10$), and a significant trials × time interaction ($F[7,189] = 6.79$; $P < 0.05$; $Eta^2 = 0.10$) for diastolic blood pressure for the maximal isometric exercise session. Men were found to have higher diastolic blood pressure compared with the women. Diastolic blood pressure increased during the 2-min exposure before maximal isometric exercise but did not change during the 2-min exposure after maximal isometric exercise. For the submaximal isometric exercise session, there was a significant gender effect ($F[1,25] = 13.10$; $P < 0.05$; $Eta^2 = 0.80$), a significant trials effect ($F[1,25] = 5.33$; $P < 0.05$; $Eta^2 = 0.04$), a significant time effect ($F[7,175] = 5.38$; $P < 0.05$; $Eta^2 = 0.02$), and a significant trials × time interaction ($F[7,175] = 7.11$; $P < 0.05$; $Eta^2 = 0.10$) for diastolic blood pressure. Diastolic blood pressure was found to be higher in the men compared with the women. Diastolic blood pressure increased during the 2-min exposure before submaximal isometric exercise but did not change during the 2-min

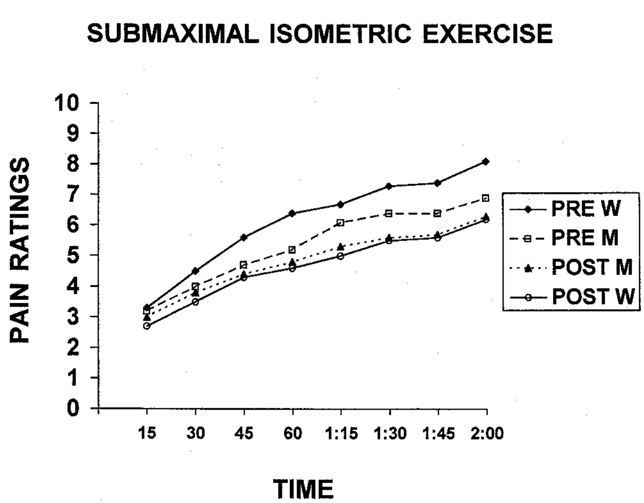

Figure 4—Mean pain ratings assessed every 15 s during exposure to the pressure stimulus before and after submaximal isometric exercise in men and women. Pain ratings increased during exposure to the pressure stimulus. Pain ratings were higher for the women before isometric exercise but were reduced after isometric exercise.

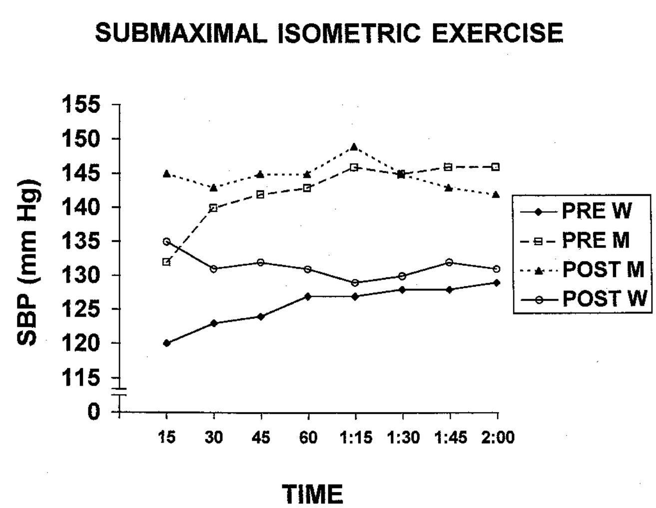

Figure 6—Mean systolic blood pressure (SBP) assessed every 15 s during exposure to the pressure stimulus before and after submaximal isometric exercise. SBP increased during exposure to the pressure stimulus before isometric exercise but did not change after isometric exercise.

TABLE 2. Means and SD for diastolic blood pressure (DBP) and heart rate (HR) during the 2-min pain exposure before and after maximal isometric exercise.

	Women		Men	
	Before	After	Before	After
DBP				
0:15	73 (9)	75 (8)	82 (14)	84 (13)
0:30	74 (10)	75 (7)	83 (13)	85 (13)
0:45	77 (10)	76 (7)	88 (10)	87 (8)
1:00	78 (10)	76 (8)	89 (9)	88 (7)
1:15	79 (11)	77 (8)	89 (10)	87 (8)
1:30	82 (11)	79 (8)	89 (12)	87 (9)
1:45	81 (11)	77 (8)	89 (10)	86 (9)
2:00	80 (12)	77 (9)	89 (10)	87 (9)
HR				
0:15	80 (14)	77 (13)	79 (16)	76 (14)
0:30	80 (14)	76 (10)	79 (15)	69 (22)
0:45	79 (13)	75 (10)	76 (13)	73 (11)
1:00	77 (12)	73 (8)	76 (12)	72 (11)
1:15	75 (12)	71 (8)	74 (12)	72 (10)
1:30	74 (11)	71 (9)	73 (10)	69 (10)
1:45	74 (10)	71 (9)	73 (10)	72 (12)
2:00	73 (10)	69 (9)	70 (12)	69 (10)

exposure after submaximal isometric exercise. Results for diastolic blood pressure during the 2-min exposure for the maximal and submaximal isometric exercise sessions are summarized in Tables 2 and 3.

There was a significant trials effect ($F[1,27] = 14.24$; $P < 0.05$; $\text{Eta}^2 = 0.10$) and a significant time effect ($F[7,189] = 10.85$; $P < 0.05$; $\text{Eta}^2 = 0.30$) for heart rate for the maximal isometric exercise session. Heart rate was found to be higher during the 2-min exposure before maximal isometric exercise compared with after maximal isometric exercise. Heart rate was found to decrease during the 2-min exposure before and after maximal isometric exercise. There was a significant trials effect ($F[1,26] = 17.46$; $P < 0.05$; $\text{Eta}^2 = 0.40$), a significant time effect ($F[7,182] = 8.84$; $P < 0.05$; $\text{Eta}^2 = 0.16$), and a significant trials $\times$ gender interaction ($F[1,26] = 4.35$; $P < 0.05$; $\text{Eta}^2 = 0.10$) for heart rate for the submaximal isometric exercise session. Heart rate was found to decrease during the 2-min exposure to the pain stimulus. Men were found to have higher heart rates during the 2-min exposure before submaximal exercise, whereas men had lower heart rates than women after submaximal isometric exercise. Results for heart rate during the 2-min exposure for the maximal and submaximal isometric exercise sessions are summarized in Tables 2 and 3.

TABLE 3. Means and SD for diastolic blood pressure (DBP) and heart rate (HR) during the 2-min pain exposure before and after submaximal isometric exercise.

	Women		Men	
	Before	After	Before	After
DBP				
0:15	70 (7)	76 (9)	83 (12)	87 (11)
0:30	72 (8)	76 (9)	87 (13)	88 (10)
0:45	74 (10)	77 (9)	90 (16)	90 (11)
1:00	75 (9)	76 (8)	91 (17)	90 (12)
1:15	75 (10)	76 (9)	93 (20)	90 (11)
1:30	76 (10)	76 (9)	93 (23)	90 (11)
1:45	76 (10)	77 (9)	93 (23)	88 (10)
2:00	76 (10)	76 (9)	93 (23)	88 (09)
HR				
0:15	75 (14)	74 (11)	78 (12)	73 (13)
0:30	75 (13)	73 (9)	80 (13)	70 (14)
0:45	73 (12)	71 (11)	80 (14)	70 (12)
1:00	74 (12)	71 (9)	76 (12)	69 (12)
1:15	73 (13)	70 (11)	77 (12)	67 (13)
1:30	73 (11)	70 (9)	74 (14)	68 (13)
1:45	73 (12)	71 (10)	74 (15)	69 (14)
2:00	72 (12)	70 (10)	74 (15)	68 (13)

TABLE 4. Means and SD for systolic blood pressure (SBP) and diastolic blood pressure (DBP) for the men and women during 2 min of submaximal isometric exercise.

	Women	Men
	Mean (SD)	Mean (SD)
SBP		
0:00	122 (15)	135 (13)
0:15	130 (12)	139 (12)
0:30	131 (13)	140 (13)
0:45	135 (16)	143 (13)
1:00	137 (16)	148 (17)
1:15	142 (19)	149 (19)
1:30	145 (18)	152 (22)
1:45	151 (19)	155 (24)
2:00	152 (17)	159 (24)
DBP		
0:00	72 (9)	83 (9)
0:15	76 (8)	83 (13)
0:30	78 (9)	87 (8)
0:45	82 (10)	89 (9)
1:00	84 (10)	94 (11)
1:15	89 (13)	94 (12)
1:30	92 (13)	97 (11)
1:45	95 (13)	98 (14)
2:00	98 (13)	102 (13)

Blood pressure response during submaximal isometric exercise. Blood pressure was also assessed before and every 15 s during the submaximal isometric exercise session. The data were analyzed with a 2 (gender) $\times$ 9 (time) ANOVA. There was a significant time effect ($F[8,224] = 47.02$; $P < 0.05$; $\text{Eta}^2 = 0.53$), but the gender main effect ($F[1,28] = 2.30$; $P > 0.05$; $\text{Eta}^2 = 0.01$) and the gender $\times$ time interaction ($F[8,224] = 0.86$; $P > 0.05$; $\text{Eta}^2 = 0.009$) for systolic blood pressure were not found to be significant. *Post hoc* analyses showed that systolic blood pressure increased during the 2-min isometric exercise session in both men (ES = 1.8) and women (ES = 2). There was also a significant time effect ($F[8,224] = 57.7$; $P < 0.05$; $\text{Eta}^2 = 0.59$) for diastolic blood pressure, but the gender main effect (F 1, 28 = 3.13; $P > 0.05$; $\text{Eta}^2 = 0.05$) and the gender $\times$ time interaction ($F[8,224] = 1.65$; $P > 0.05$; $\text{Eta}^2 = 0.02$) were not found to be significant. *Post hoc* analyses indicated that diastolic blood pressure increased during the 2-min submaximal isometric exercise session for both the men (ES = 1.8) and the women (ES = 2.9). The results for systolic and diastolic blood pressure for the men and women are summarized in Table 4.

Correlations between blood pressure and pain perception. Pearson correlations between blood pressure and pain perception were calculated for the men and women. Resting systolic blood pressure (mean of two assessments) was not significantly correlated ($P > 0.05$) with pain thresholds for the maximal isometric exercise session for the men (r = 0.30) or the women (r = 0.04). Also, resting systolic blood pressure was not found to correlate significantly with pain thresholds for the submaximal session for the men (r = 0.04) or the women (r = 0.25). Resting diastolic blood pressure was found to correlate significantly ($P < 0.05$) with pain thresholds for the submaximal

TABLE 5. Means and SD for the psychological variables for the men and women.

	Women	Men
	Mean (SD)	Mean (SD)
Psychological traits		
Extroversion	14.4 (5)	15.3 (4)
Neuroticism	9.4 (5)	7.5 (4)
Trait Anxiety	35.3 (12)	32.2 (7)
Mood states		
State Anxiety		
Max		
Pre	34.3 (9)	34.2 (10)
Post	32.7 (8)	30.1 (8)
Submax		
Pre	31.4 (8)	33.5 (12)
Post	32.9 (9)	33.8 (11)

isometric exercise session for the men (r = 0.53) but not for the women (r = 0.18). However, resting diastolic blood pressure was not significantly correlated with pain thresholds for the maximal isometric exercise session for the men (r = 0.03) or the women (r = 0.08). The association between pain ratings and blood pressure during the 2-min exposure to the pain stimulus was also examined, and correlations were calculated separately for each sampling time (15, 30, 45, 60, 75, 90, 105, 120 s). Correlations between pain ratings and systolic blood pressure were not found to correlate significantly during the first min of the 2-min exposure to the pain stimulus after maximal isometric exercise for the men (r = −0.01 to 0.29) or the women (r = −0.24 to 0.09), but there were significant correlations between pain ratings and systolic blood pressure for the men during the 2nd min of the 2-min exposure (r = −0.56 to −0.37). Pain ratings and systolic blood pressure, however, were weakly correlated and not consistently negative for the women (r = −0.22 to 0.32) during the 2nd min of the 2-min exposure after maximal isometric exercise. In addition, pain ratings and blood pressure were not found to correlate during the 2-min exposure after submaximal isometric exercise for the men (r = −0.24 to −0.07) or for the women (r = 0.09–0.28).

Psychological variables. Results for the psychological variables are summarized in Table 5. State anxiety was assessed before and after maximal and submaximal isometric exercise, and the data were analyzed with a 2 (gender) × 2 (trials) ANOVA for the maximal and submaximal sessions. Results indicated that there was a significant trials effect ($F[1,29] = 6.02$; $P < 0.05$; $\text{Eta}^2 = 0.20$) for state anxiety for the maximal isometric exercise session. *Post hoc* analyses indicated that state anxiety was lower at the end of the testing session compared with the beginning of the testing session. The gender main effect ($F[1,29] = 0.19$; $P > 0.05$; $\text{Eta}^2 = 0.03$) and the gender × trials interaction ($F[1,29] = 1.23$; $P > 0.05$; $\text{Eta}^2 = 0.03$) for state anxiety in the maximal isometric exercise session were not found to be significant. There were no significant gender ($F[1,29] = 0.17$; $P > 0.05$; $\text{Eta}^2 = 0.01$) or trials ($F[1,29] = 1.15$; $P > 0.05$; $\text{Eta}^2 = 0.03$) main effects, nor was the gender × trials interaction ($F[1,29] = 0.54$; $P > 0.05$; $\text{Eta}^2 = 0.02$) found to be significant for state anxiety in the submaximal isometric exercise session. The psychological traits that were assessed at the beginning of this study and have been shown to interact with pain perception include extroversion, neuroticism, and trait anxiety. These data were analyzed with independent *t*-tests, and results indicated that there were no significant differences ($P > 0.05$) between the men and the women for extroversion ($t = -0.63$; men = 15, SD = 4 and women = 14, SD = 5), neuroticism ($t = 1.0$; men = 7.5, SD = 4 and women = 9, SD = 5), or trait anxiety ($t = 0.86$; men = 32, SD = 7 and women = 35, SD = 10).

DISCUSSION

The primary purpose of this investigation was to examine the influence of isometric exercise on pain perception and blood pressure in men and women. Results from this study indicated that maximal and submaximal isometric exercise were associated with increased pain thresholds in the women. Pain ratings were found to be lower after maximal isometric exercise in men and women. In addition, pain ratings after submaximal isometric exercise were lower in the women compared with before isometric exercise. These results indicate that isometric exercise is associated with an analgesic response; however, the response appears to be more consistent in women. There were increases in pain thresholds and lower pain ratings after maximal and submaximal isometric exercise in the women. In contrast, the men only experienced lower pain ratings after maximal isometric exercise. It is unclear why men and women differ in pain responses to isometric exercise; however, these results are in agreement with results found by Kosek and Ekholm (22) and Paalasmaa et al. (29). Pain thresholds were found to increase significantly in women after isometric leg exercise in the study by Kosek and Ekholm (22). However, in a separate study by Paalasmaa et al.(29), isometric leg exercise was not associated with changes in pain perception in men. The difference in results between the Kosek and Ekholm (22) and the Paalasmaa et al. (29) studies could possibly be explained by different methodologies used in the two studies. In the present investigation, however, the same procedures and methodology were used for both the men and women, but differences still emerged between men and women in their pain perception responses to isometric exercise.

It is unclear why men and women differ in pain perception; however, Fillingim and Maixner (14) suggest that blood pressure may partially moderate differences between men and women in pain sensitivity. Several lines of evidence suggest an interaction between pain regulatory mechanisms and control of blood pressure (32). The same brain stem nuclei, for example, are associated with pain regulation and blood pressure control (6), and drugs that affect blood pressure (e.g., clonidine) have been found to alter pain perception (30). In addition, common neurotransmitters (e.g., monoamines) and neuropeptides (e.g., opioids) are involved with both functions (25). Also, there is evidence suggesting that blood pressure is inversely related to pain sensitivity (32). It has been reported that hypertensive individuals, or individuals at risk for hypertension, have higher pain thresholds compared with age-matched normotensives in response to noxious stimulation (17). Moreover, research has indicated that the relationship between blood pressure and pain perception extends into the normotensive range as well, and in normotensive men it has been found that pain sensitivity is inversely related to resting blood pressure (5). Men have consistently been found to have higher systolic and diastolic blood pressure compared with women (10), but only a few investigators have examined differences between men and women in the relationship between blood pressure and pain responses. Maixner and Humphrey (26) examined differences between men and women in pain and cardiovascular responses to forearm ischemia and found that gender was associated with both the sensory and cardiovascular responses to a noxious stressor. Blood pressure was found to be significantly and negatively correlated with ischemic pain perception in men but not in women. Also, Fillingim and Maixner (14) examined pain responses in men and women as a function of resting blood pressure and found that baseline blood pressure moderated, in part, differences between men and women in pain sensitivity. Resting systolic and diastolic blood pressure were found to correlate with thermal and ischemic pain thresholds in the men but not in the women. In the present study, men were found to have higher blood pressure at baseline in comparison with women, and this was in conjunction with higher pain thresholds at baseline as well. Resting systolic blood pressure, however, was not found to correlate with pain thresholds in men or women, but there was a significant correlation between resting diastolic blood pressure and pain thresholds in the men but not in the women. Systolic blood pressure was found to correlate with pain ratings during the 2nd min of the 2-min pain exposure after maximal isometric exercise in the men but not in the women. There was, however, no significant correlation between systolic blood pressure and pain ratings during the 2-min pain exposure after submaximal isometric exercise in the men or women. It appears that the relationship between blood pressure and pain perception in men and women is complex. When blood pressure was increased in the women to comparable levels with the men after isometric exercise, the differences in pain thresholds between the men and women were no longer evident. The mechanisms by which blood pressure influences pain perception are not entirely clear; however, it has been proposed that baroreceptor activation produced by elevations in blood pressure may alter pain perception. Increases in blood pressure or the stimulation of arterial baroreceptors have been shown to inhibit pain (11, 32). Further research is needed examining the influence of baroreceptor stimulation on pain perception in men and women.

Pain is a complex perceptual experience that can be quantified only indirectly (7). In general, there is no single best method for assessing pain (19); thus, in the present study, two aspects of pain, pain threshold and pain ratings, were assessed. However, one limitation of the present study involves the use of a 0–10 category scale to measure pain intensity. There are limitations in using category scales to measure pain intensity, and the primary problem is that category scales lack true ratio properties. There is a need in future research to measure pain intensity using instruments with true ratio properties. Visual analog scales have been shown to approximate ratio scale qualities better than 0–10 scales (18). In addition, two category-ratio scales have recently been developed and used to examine muscle pain during exercise (3,9). Further research is needed to confirm these findings using pain rating scales with ratio properties in an attempt to most accurately document the relationship between pain intensity ratings and isometric exercise.

Another potential limitation of the current investigation is that the results are restricted to the exercised hand. The right hand was used to complete maximal and submaximal isometric exercise, and the pain stimuli also were applied to the right forefinger. It is unclear whether analgesia occurred in other areas of the body (e.g., left finger) because only the right finger was assessed. Results from previous studies indicate that the effects of isometric exercise appear to be segmental because the effects are restricted to the exercise limb and areas immediately adjacent to it (22, 29). Paalasmaa et al.(29), for example, found that isometric exercise produced a segmental attenuation of thermal sensitivity to innocuous stimuli, whereas cycling exercise produced a multisegmental attenuation of thermal sensitivity to noxious and innocuous stimuli. Further research is needed to determine whether alterations in pain perception after maximal or submaximal isometric exercise are strictly segmental responses or whether isometric exercise can produce a multisegmental response depending upon the intensity and duration of the isometric exercise performed.

In summary, the results of this investigation indicate that pain thresholds were higher and pain ratings were lower after maximal and submaximal isometric exercise in the women. In comparison, men only experienced lower pain ratings after maximal isometric exercise. It is unclear why men and women differed in their pain perception responses to isometric exercise. However, differences in pain perception between men and women were also evident at baseline. Women had lower pain thresholds at baseline in comparison to the men, and this was in conjunction with lower blood pressures. When blood pressure was increased in the women to comparable levels with the men after isometric exercise, pain thresholds were not found to differ between men and women. Additional research is recommended to further examine the relationship between blood pressure and pain perception in men and women.

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