AGE-RELATED DIFFERENCES IN PAIN PERCEPTION AND REPORT

Stephen J. Gibson, PhD, MAPsS,
and Robert D. Helme, MBBS, PhD, FRACP

The older person faces many threats to quality of life, including a marked increase in the incidence of disease, higher levels of functional disability, loss of lifetime partner or friends and family support networks, reductions in economic resources, and the foreboding prospect of institutional placement with an associated loss of independence. Even within this context, however, the presence of severe, unremitting pain is often regarded as one of the most common and devastating threats to health-related quality of life.[94, 164] Recent epidemiologic studies indicate that more than 50% of older persons suffer from some form of persistent, bothersome pain complaint (see Helme and Gibson this volume for review). To provide adequate assessment and treatment for this ubiquitous problem, we need to clearly understand the extent and nature of any age-related change in pain perception and report. Unfortunately, attempts to address this issue have been somewhat sporadic, the results are often conflicting, and there remains a relative paucity of high-quality empirical investigations.

The present article seeks to provide a broad overview of existing knowledge on age differences in pain perception using evidence from clinical studies of pain as a symptom of disease presentation and laboratory-based investigations of experimental pain. Both methods allow for an age-based comparison of the response to acute painful stimulation and provide specific information about age-related differences in the perceived intensity of painful sensation. Despite major methodologic weaknesses in many studies, a critical review of the literature tentatively suggests that pain sensitivity may differ in adults of advanced age. More systematic and directed research will be required to substantiate this view and to help identify the exact reasons for an age-related change in pain perception and report.

From the Department of Medicine, University of Melbourne, Melbourne (SJG); and the National Ageing Research Institute, Parkville, Victoria, Australia (SJG, RDH)

STUDIES OF CLINICAL PAIN PERCEPTION

Atypical presentation of disease or injury is one of the defining features of geriatric medicine, and pain symptoms are probably less common in older adults even in the presence of apparently severe pathology.[87, 126] In fact, it has been argued that pathologic conditions that are known to produce clear and ongoing expressions of pain in young adults may only result in confusion, restlessness, aggression, or fatigue in the older person, thereby leading to misdiagnosis and delays in seeking treatment.[1, 16] It has also been suggested that minor surgical procedures or dental extractions can be undertaken with little or no discomfort to the older person.[34] This general view, which is based mainly on anecdotal clinical experience, may not be entirely accurate, although more recent systematic research efforts do identify some consistent age-related changes in the presentation of clinical pain.

POSTOPERATIVE PAIN

Although adults over 65 years of age have the highest rates of surgical procedures,[44, 130] possible age differences in postoperative pain have received only scant attention until recently. Several studies suggest that older adults report a lower intensity of postoperative or procedural pain when compared with younger adults,[5, 44, 109, 125, 150] although such findings are not universal[116] and may depend on the age range of the sample[38] and the type of scale used to measure pain.[43, 117]

The type of surgery does not appear to be important in finding age differences because diminished pain report has been noted for major intra-abdominal and thoracic surgery, prostectomy, common orthopedic procedures such as knee or hip replacement, and less invasive techniques such as insertion of an intra-arterial line and phlebotomy. The approximate magnitude of change is on the order of a 10% to 20% reduction in intensity per decade of advancing age over 60 years old.[109, 150]

ABDOMINAL PAIN

One major area of investigation involves atypical pain presentation of abdominal complaints, such as peritonitis, intestinal obstruction, diverticulitis, and peptic and duodenal ulcer. Peritonitis and abdominal complaints are more occult in older persons, particularly for pain symptoms.[8, 62, 123] Wroblewski and Mikulowski[166] undertook a retrospective review of 212 cases of peritonitis in adults aged from 60 to 99 years and found that pain occurred in only 55% of patients. Although pain was still considered an important diagnostic symptom, the collection of symptoms with the best overall sensitivity and specificity for peritonitis (i.e., nausea, fever, tachycardia) did not include self-reported pain. Albano et al[1] found that only 22% of elderly with appendicitis presented with the classic sequence of periumbilical pain, nausea and vomiting, and lower right quadrant pain, whereas this symptom pattern was almost universal in children and young adults. Although epigastric pain is the most common symptom of peptic ulcer, this symptom appears less frequently in adults of advanced age. Between 29% and 30% of elderly adults present without pain compared with 8% to 19% of young adults,[26, 28, 138] and a retrospective analysis indicates that pain was the only symptom to differ between age groups in a sample of 168 ulcer patients. Scapa et al[138] reported a highly significant association between old age and mild pain intensity, whereas young adult age was associated with moderate or severe pain in 333 duodenal ulcer patients and 86 patients with myocardial infarction.

MALIGNANT PAIN

Recently, the influence of age on pain symptoms associated with various types of malignancy has been examined using both retrospective and prospective study designs. A retrospective review of more than 1500 cases of lung, gastrointestinal, breast, and bone cancer revealed a marked difference in the incidence of pain between younger (55%), middle-aged (35%), and older adults (26%).[24] Similar results have been reported for rectal cancer, with pain being four times more likely to be a presenting symptom in younger adults when compared with elderly adults.[35] Apart from one exception,[160] most studies have also documented an age-related decline in the intensity of cancer pain symptoms.[14, 15, 17, 24, 107, 149] For instance, a recent multicenter trial of more than 1000 patients with metastatic cancer revealed that younger adults were 1.5 times more likely to report severe pain of greater than 7 on a visual analogue scale (VAS).[17] These age differences were shown to remain even after controlling for age variations in the type of pain pathophysiology, levels of physical function, and the organ system affected by malignancy. It appears, therefore, that age may act as an independent predictor of cancer pain intensity, with older patients experiencing less frequent and diminished pain symptoms.

MYOCARDIAL PAIN

Another major area of study has focused on age-related differences in chest pain complaints. The classic presentation of myocardial infarction usually involves severe precordial pain with radiation to one or both arms and sometimes to the jaw. Variations in this classic sequence are known to occur much more frequently in the elderly,[129, 135, 151] particularly the incidence of silent or painless myocardial infarction. Since the development of universal criteria for the diagnosis of myocardial infarction, most studies have reported an incidence of between 35% and 42% painless myocardial infarction in adults older than 65 years of age.[95, 104, 105, 152] Moreover, atypical presentation (i.e., dyspnea or syncope as a major symptom and a lack of pain radiation to other body sites) has also been noted in those who do report at least some chest pain.[3, 105, 147, 152] This trend may occur more frequently in adults of very advanced age,[119] with a 50% atypical presentation in 75- to 85-year-old adults and a rate of 75% in patients aged 85 and older.[119] As expected, the age-related change in pain report has been shown to cause delays in diagnosis and in treatment.[156]

Recently, there have been several attempts to provide a more controlled and quantitative investigation of age differences in myocardial pain. Strenuous physical exercise can induce myocardial ischaemia, as defined by a 1-mm depression in the ST segment of the electrocardiogram in patients with pre-existing coronary artery disease. It has been suggested that by comparing the latency to onset of pain after exercise-induced ST segment depression, one can gain a quantitative estimate of silent exertional myocardial ischaemia.[2, 18, 115] Miller[13] examined 35 patients aged from 35 to 75 years with stable angina and found a significant age-related delay in the time of myocardial ischemia to the first report of chest pain. This relationship remained even after controlling for variations in the severity of ischemia, and others have since confirmed this finding.[3, 4, 117] Also of interest, a recent study using positron emission tomography scans of regional cerebral activation in patients with and without exercise-induced angina pain suggested that painless ischemia does not result from some deficit in peripheral function, but rather from abnormal central processing of primary afferent nociceptive input.[137] These studies provide strong evidence that older adults take considerably longer to first report exercise-induced myocardial pain and that they have diminished pain intensity.[4, 13] These controlled experimental studies are of great importance because, unlike most investigations in this specialty, they demonstrate clinically significant age differences in pain perception and report while actually controlling for the strength of pathologic insult.

OTHER TYPES OF PAIN

Other scattered reports of atypical pain presentation in visceral complaints include age differences in pain associated with acute pneumothorax,[102] pneumococcal pneumonia,[39] and achalasia.[27] In all cases, these studies show a reduced frequency of pain as a presenting symptom, rather than diminished intensity of self report to pain sensation. There have also been some sporadic reports on age differences in musculoskeletal pain, although the results are more equivocal. Yunus et al[169] found no age difference in the clinical presentation of 63 younger (< 60 y) and 31 older (60–69, 70–79, 80+ y) patients with fibromyalgia. Although generalized pain, muscle soreness, and morning stiffness did occur with equal frequency in both age groups, older patients suffered fewer headaches and reported less tenderness in response to manual palpation. Another study examining patients suffering from rheumatoid arthritis found a significant increase in the reported severity of VAS rated pain in adults aged from 46 to 60 and 60 years and older, when compared with adults younger than 45 years.[163] There has also been a report of higher intensity musculoskeletal pain in the neck, back, hip or joints of older adults in a large sample survey of more than 5000 people.[76] In contrast, others have reported the opposite relationship in rheumatoid arthritis patients with a significant negative association between advancing age and self-reported pain intensity as measured on a VAS scale.[100, 128] To complicate matters, Gagliese and Melzack[43] have recently shown that age differences in pain ratings may depend on the pain assessment scale used for measurement. A sample of 79 patients with chronic arthritis showed an age-related decrease in the sensory and affective dimensions of pain using the short form McGill Pain Questionnaire (MPQ), but no age difference in pain intensity as measured by a VAS or verbal descriptor scale. It is somewhat difficult to reconcile such disparate findings, and although there is some evidence of an age-related decrease in the intensity of musculoskeletal pain, further investigation is required to resolve this issue.

CHRONIC PAIN PATIENTS ATTENDING MULTIDISCIPLINARY TREATMENT FACILITIES

The final source of evidence on age differences in clinical pain is from studies on patients attending multidisciplinary pain management centers. Most patients attending such clinics suffer from chronic musculoskeletal pain, typically in the lower back, although neuropathic pain states are also common.[54, 82] Several studies of relatively small sample size report either no age differences in self-rated pain intensity on admission to a treatment center[73, 114, 148] or a nonsignificant trend toward lower pain ratings in older adults.[6, 77] There have also been some reports of a significant age-associated decrease in pain severity as indexed by the multidimensional pain inventory[158] or by a composite pain scale including items of severity, duration, and impact.[36] Many of these studies have used a unidimensional measure of pain such as a VAS or a verbal descriptor scale. It has been argued that findings of age differences may depend on the measurement scale used,[43] and a comparison of similar findings using the MPQ provides some support for this view. Although an earlier study by Corran et al[31] found no age difference in pain ratings from the MPQ, a more recent report with a slightly larger sample size from the same study population has shown a significant age-related decline in MPQ pain ratings.[32] This latter finding is in agreement with several other reports[43, 106] and demonstrates consistently lower MPQ ratings of sensory and affective components of pain in adults of advanced age. Moreover, when multiple pain measures have been compared directly in the same sample, MPQ ratings show clear age differences but not other pain scales using a unidimensional format.[43, 106] An illustration of this point can be seen in Figure 1, which shows age differences in self-rated pain intensity as measured by the MPQ, VAS, and verbal word descriptor scale. The data comprised more than 700 individuals divided into four age groups (<40, $n = 191$; 40–59, $n = 199$; 60–79, $n = 250$; 80 and older, $n = 128$) and represent an updated extension of the study population originally described by Corran et al.[31, 32] As can be seen, MPQ ratings decrease by approximately 25% to 30% in the oldest

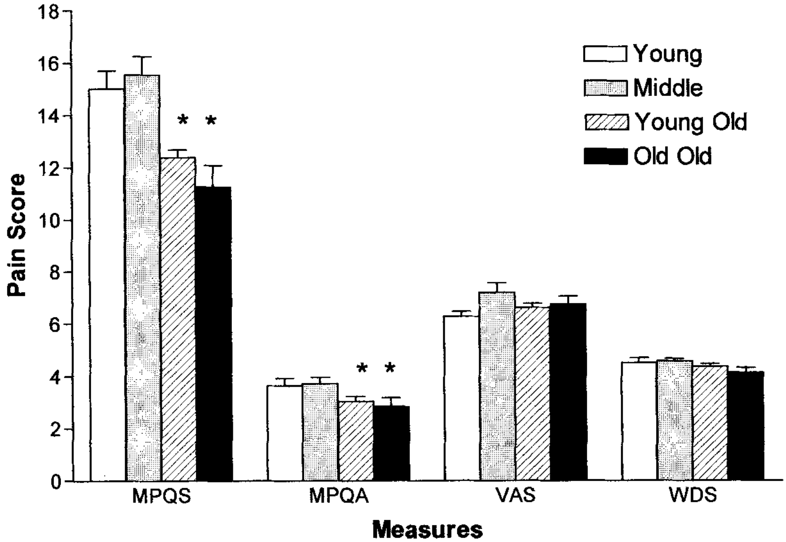

Figure 1. Self-rated severity of clinical pain using the MPQ, VAS, and an eight-item word descriptor scale in young and older adult patients on admission to a multidisciplinary pain-management center.

age cohort when compared with younger adult chronic pain patients. In contrast, VAS ratings of pain intensity did not change with advancing age, and the eight-item word descriptor scale showed a nonsignificant trend toward reduced pain report. In explaining the disassociation between MPQ scores and other pain rating scales, VAS measures may be less appropriate to use in older adult patients, and there is some recent evidence to support this view.[9, 40, 41, 84, 85, 88] On the other hand, it may be that selection bias associated with referral of patients to multidisciplinary treatment centers ensures roughly comparable levels of pain in all patients (e.g., high-intensity pain resistant to conventional treatment), regardless of age. This would presumably result in equivalent pain ratings across the age spectrum. It is also possible that there is an age-related change in the quality of the chronic pain experience of referred patients, but not in the overall intensity of pain. This situation would be even more likely, especially because of the documented difference in the types of chronic pain problems seen in most older adults compared with those seen in younger patients.[36, 53] The quality of pain does vary between different diagnostic groups, and this is known to be reflected in different MPQ ratings.[111] Regardless of the exact reason, data from pain clinic samples are less endorsing of any major change in the clinical presentation of chronic pain, although some consistent differences in MPQ ratings are still noted in adults of advanced age.

The findings from the numerous clinical studies would suggest a relative absence of pain in the presentation of some disease states in older patients. Changes in myocardial chest pain and abdominal pain associated with acute infection have been most frequently documented, although age differences in acute postoperative pain and cancer pain as well as sporadic reports of altered musculoskeletal pain are also quite common. On the basis of this evidence, it is tempting to conclude that advancing age is associated with a general decline in the perceived severity of most types of clinical pain. There are several methodologic issues, however, that should be considered before accepting this view. Because most studies in this area involve a retrospective review of medical records, conclusions are dependent on the accuracy of history notes rather than on the report of the patients themselves. Pain is usually defined as being either present or absent, instead of using a more quantitative examination of pain intensity or severity. Because most reports are based on hospital admission data, such studies could underestimate the prevalence of painless disease or injury that may occur in the community setting. On the other hand, a lack of age difference in disease presentation is unlikely to be reported or published, and this factor would tend to overemphasize age-related differences in clinical pain presentation and report. Another major difficulty with most retrospective reports relates to the potential influence of unmeasured differences between age groups, including the increased presence of concomitant disease in older patients, possible variations in medication use, and the influence of cognitive impairment. For instance, some patients designated as suffering from silent myocardial infarction were unable to provide a reliable history because of the presence of dementia or communication difficulties such as visual impairment and deafness.[105] These problems are usually more common in adults of advanced age, and inclusion of such patients is likely to overestimate the occurrence of "true" painless myocardial infarction in this age group. Another study on atypical pain presentation in patients with pneumonia noted a higher prevalence of concomitant disease in the older groups, including the presence of coronary heart disease, cancer, and dementia.[39] A greater number of older patients were taking nonsteroidal anti-inflammatory drugs and more hypnotics and sedatives. The frequency of concomitant medical problems and medication use did not differ significantly between age groups apart from the incidence of heart disease and diabetes. Nonetheless, the presence of concomitant disease could potentially compromise function in the nociceptive pathways or could affect the ability of older persons to report pain, and one must consider these factors when attempting to interpret reported age differences in the presentation of clinical pain states.

Overall, there is mounting evidence of a clinically significant reduction in frequency and intensity of pain symptoms with advancing age. Most of the disease states that show atypical pain presentation (e.g., myocardial ischemia, abdominal infection, and many types of malignancy) represent examples of visceral pain. Research focused on the underlying mechanisms of visceral pain is still in its infancy; however, visceral nociceptors respond mainly to mechanical distension or local inflammation.[20] Many parts of the inflammatory cascade are impaired in older adults, and inflammation is typically reduced.[59] In addition, because the density of innervation of viscera by nociceptive neurons is thought to be quite sparse when compared to the skin,[10] deficits resulting from any progressive age-related loss in primary afferent fibers are likely to be more noticeable in visceral complaints. These changes may help explain the apparently more frequent occurrence of atypical pain presentation in conditions involving visceral disease. Nonetheless, there are also some examples of reduced somatic pain report associated with postoperative pain, some types of musculoskeletal pain, and in the chronic pain conditions seen at multidisciplinary treatment centers. It is less clear whether these changes in the report of typical pain symptoms reflect an age-related diminution of pain sensitivity. Although the methodologic weaknesses of retrospective review of clinical case series emphasize the need for caution, the weight of currently available evidence, including more quantitative studies of experimentally controlled myocardial ischemia, would tend to support the suggestion of muted and delayed clinical pain perception in older persons.

PSYCHOPHYSICAL STUDIES OF EXPERIMENTAL PAIN PERCEPTION

Experimentally controlled levels of noxious stimulation have been used to assess age differences in pain sensitivity for more than 50 years, and there are currently more than 40 available studies in this area. Most studies have focused on either pain threshold or that minimum amount of noxious stimulation required to first elicit the report of pain.[57] Obvious differences exist between brief experimental pain and ongoing clinical pain states. Experimental pain is typically of short duration and is delivered at an intensity just sufficient to activate pain pathways in a single discrete episode. In contrast, most clinical pain persists for an extended period and the expected duration is generally unknown. The intensity is often well above threshold, and the meaning attributed to the presence of clinical pain sensations is likely to be very different. Thus, experimental pain is an oversimplification of the pain experience. Likewise, the important role of emotional and cognitive factors that shape clinical pain states cannot be adequately modeled in the experimental setting.[134] By using controlled levels of noxious input, however, it is possible to anchor the subjective pain experience against some objective physical scale (e.g., temperature, mechanical pressure) and provide a quantitative comparison of pain sensitivity between different age groups. This is more difficult with clinical pain sensation because the strength of noxious input is seldom known.

Several comprehensive reviews have discussed the age differences in laboratory pain perception.[42–44, 49, 52, 70, 71, 73, 75–77, 79, 82, 91–93, 155, 168] Harkins et al[70–73, 75–77, 79] have tended to emphasize the contradictory nature of empirical findings and note that pain sensitivity has been reported to increase, decrease, and remain unchanged over the individual's life span. Others have argued that although the findings are somewhat mixed, the weight of evidence does support an age-related decline in experimental pain sensitivity.[42–44, 49, 52, 82, 155]

Although variations in methodology, subject instructions, the psychophysical measures adopted by any particular study and the type of subject selection–exclusion criteria may all contribute to the lack of consensus, such issues are rarely considered. For instance, most psychophysical studies have screened older participants for the presence of physical and psychiatric disease. The type of disease states examined and the rigor of such assessments are often not reported, however. Most older persons suffer from some arthritis of weight-bearing joints, and although these problems are usually intermittent and very mild, previous studies demonstrate changes in pain thresholds in those patients with pre-existing clinical pain.[48, 50, 51, 56] Similarly, many older adults suffer from hypertension. Increased pain threshold has been consistently demonstrated in hypertensive adults, and there is a strong correlation between systolic blood pressure and pain sensitivity.[37, 46, 60, 61, 127] Although the reasons for this association are not completely understood, it appears that the baroreceptive system involved in cardiovascular regulation and particularly noradrenergic CNS control mechanisms may play a role.[46, 140] It is extremely unlikely that all older volunteers in previous psychophysical studies have been routinely assessed for hypertension before inclusion; however this single factor could potentially explain much of the observed age-related increase in pain threshold and may account for at least some of the disparity among studies. It is evident that the influence of disease states (e.g., arthritis, hypertension) must be excluded if the objective is to examine the effects of age. On the other hand, because of the high incidence of disease in older populations, studies based on "super" healthy elderly adults may not be representative of the typical older person in their seventh, eighth, or ninth decade of life. One final methodologic consideration involves the basic experimental design of all previous psychophysical investigations. To date, studies have used a cross-sectional comparison of different age groups, and this confounds intraindividual change with cohort effects of biocultural history. Longitudinal investigations are needed before we can reach firm conclusions about the effects of aging. Nonetheless, cross-sectional studies do allow for a comparison of differences between cohorts, and because these samples are likely to be representative of the typical older person at this time, such research is still of considerable value.

AGE DIFFERENCES IN PAIN THRESHOLD

Most psychophysical studies of age differences have focused on pain threshold, and methods of pain induction have included noxious heat, electrical stimulation, mechanical pressure or distension, and pinprick. As can be seen from Table 1, most studies demonstrate an age-related increase in thermal pain threshold, suggesting a decline in the pain sensitivity of older adults. This apparent decline in heat pain sensitivity appears to be most noticeable after the age of 70 years[47, 141, 144, 145] and may be more pronounced in the distal extremities of the body.[99, 110] The magnitude of change reported by most studies appears to be on the order of a 20% increase for

Table 1. PSYCHOPHYSICAL STUDIES OF HEAT PAIN THRESHOLDS IN YOUNG AND OLDER ADULTS

Age-Related Increase in PT

*Chapman & Jones,[23] Chapman.[22] N = 200, aged 10–85. With RH, a 20% increase in PT occurred in oldest adults.

Hall and Stride.[63] N = 400, aged 18–70. PT intensity to RH stimuli increased with advancing age (r = +0.31) in psychiatric patients.

Sherman & Robillard.[144] N = 200, aged 20–29 and 65–97. A 20% increase in RH PT occurred in older group. Some differences in quality of sensation.

Sculderman & Zubek.[141] N = 171, aged 12–83. Tested multiple sites using RH; effect of age greater in subjects aged 50+ years.

Sherman & Robillard.[145] N = 120, aged 30–64. A 16% increase in PT between adults aged 30–64; age effect greater in women.

Procacci.[132] N = 100, aged 20–79. RH PTs higher in oldest adults. All subjects trained, mean age PT data not presented.

*Procacci et al.[133, 134] N = 525, aged 18–28, 50–90. A 10% increase in time to pain report in older age group; all subjects experienced and trained in rating RH stimuli.

Clark & Mehl.[25] N = 64, aged 18–63. Used signal detection approach with RH, age differences were noted at weak, mild, and strong intensities.

Harkins et al.[72] N = 44, aged 20–36, 45–60, 65–80. Using very short-duration thermode heat, older group rated pain as less intense around PT but greater at higher intensity.

Lautenbacher & Strian.[99] N = 64, aged 17–63. Used phasic & tonic thermode heat pain stimuli, effect of age was more pronounced for tonic pain stimuli at distal sites.

Gibson et al.[47] N = 66, aged 20–99. CO_2 laser heat, PT almost doubled in adults aged 80+. Quality of sensation also rated.

Tremblay et al.[154] N = 17, aged 20–35, 65–80. Radiant heat rated as less intense by older adults. [Abstract]

Chakour et al.[21] N = 30, aged 20–40, 65–84. CO_2 laser PT almost doubled in adults aged 70+. Also examined A delta and C fiber PTs.

Heft et al.[80] N = 179, aged 20–35, 65–80. RH delivered to the lip or chin; ≈10% increase in PT between adults aged <30 and those aged 70+.

Meliala et al.[110] N = 30, aged 20–40, 65+. Tested multiple modalities of noxious stimulation; CO_2 laser PT 80% higher in elderly. [Abstract]

Scudds & Scudds.[143] N = 146, aged 20–59, 60–74, 75–84, 85+. Thermode heat PTs higher in adults aged 60+; no difference between the older groups. [Abstract]

No Age Difference in PT

*Schumacher et al,[142] Hardy et al.[66] N = 150, aged 14–70. Subjects were instructed to maintain a detached attitude; mean age data on PTs not presented.

Birren et al.[11] N = 11, aged 19–82. Age findings were incidental to main aims of the study; mean age data on PTs not presented.

Kenshalo.[93] N = 48, aged 19–31, 55–84. No age difference in PT. Used thermode with a long rise time for noxious heat stimulation (0.3°C/s).

Meh & Denislic.[108] N = 150, aged 10–73. Examined multiple sites with thermode heat pain. No age difference; mean age data on PT not presented.

Yarnitsky et al.[167] N = 106, aged 20–79. Using thermode heat stimuli, PT remained unchanged over the age range tested (<3% increase in oldest group).

Liou et al.[101] N = 100, aged 22–65. Using long-duration thermode heat, PT did not change among adults aged <30 and those aged 50–65.

*Multiple citation because data are presented more than once.
PT = pain threshold; RH = radiant heat.

radiant pain threshold[22, 23, 132–134, 144, 145] and a 50% to 100% increase in CO_2 laser pain threshold.[21, 47, 110] It should be noted there are several exceptions to the findings of age differences, although many of these studies fail to provide specific data on pain threshold as a function of age.[11, 93, 101, 108, 142, 167] For instance, Schumacher et al[142] examined 150 adults of varying age and noted a uniformity in radiant heat pain threshold; however, no information was given on the age of subjects, and the mean threshold data for each specific age group were not provided. In addition, this study used fully trained and experienced subjects who were instructed to maintain an unprejudiced and detached attitude toward the pain stimulus. This instruction could alter psychological response bias (see discussion on suprathereshold pain) or attitudes to pain, and these factors have been previously noted as a possible explanation for age differences in pain report.[25, 55] Of those studies to report an age difference in heat pain threshold, seven used short duration radiant heat (< 3 seconds), three used CO_2 laser heat pulses (0.05 seconds), and four used a contact thermode device controlled by a peltier element (> 15 seconds). In contrast, four of the six studies to report no age differences used a prolonged contact thermode heat stimulus. It is possible that stimulus duration may affect the ability to detect age differences, because the elderly are thought to adopt a more cautious attitude when processing sensory information. This bias is likely to be more evident in a shorter stimulus duration and thereby may result in higher pain threshold values.

An examination of psychophysical studies using a mechanical form of stimulation also provides clear support for age differences in pain thresholds (Table 2). Five of six studies noted increased pain threshold in adults of advanced age. In a very large study (n = 704), pressure pain threshold was shown to increase by about 15% in older adults, although the effect was considerably stronger in female subjects.[89] Pricking threshold using either a forced controlled hypodermic needle or sharpened Von Frey monofilaments has been found to increase by approximately 20% over the life span.[86, 110] Although one study using Von Frey monofilaments failed to confirm these results, there was still a nonsignificant trend toward higher thresholds in the older group, and a very small sample size was used.[170] The remaining studies using noxious mechanical stimulation have examined visceral pain threshold using gastric or esophageal distension with an inflatable balloon.[98, 112] Both studies note a significant increase in pressure pain threshold (approximately 50% increase) and suggest diminished

Table 2. PSYCHOPHYSICAL STUDIES OF MECHANICAL PAIN THRESHOLDS IN YOUNG AND OLDER ADULTS

Age-Related Increase in PT

Jensen et al.[89] N = 740, aged 25–64. Tested multiple sites using pressure algometry; found an overall 15% increase in pressure PT; age effect was more pronounced in women.

Lasch et al.[98] N = 27, aged 18–57, 65–87. PT volume in response to graded intraesophageal balloon distension increased by 70% in the older group; first experimental study of age differences in visceral PT.

Mertz et al.[112] N = 15, aged 21–55. PT volume for balloon distension of the stomach increased > 50% in older adults; also tested patients with dyspepsia and found similar age-related increases in PT.

Meliala et al.[110] N = 30, aged 20–40, 65+. Tested multiple modalities of noxious stimulation; Von Frey mechanical PT was 25% higher in elderly. [Abstract]

No Age Difference in PT

Zheng et al.[170] N = 20, aged 23–36, 73–88. Age findings incidental to the main goals of the study; nonsignificant trend for increased Von Frey pricking PT (≈40%) in older group.

PT = pain threshold.

visceral pain sensitivity with advancing age. These findings are of great interest given the consistent reports of diminished or atypical pain presentation in common visceral complaints, such as heart disease and abdominal infection (see earlier discussion).

In contrast to the threshold findings for noxious heat and mechanical pressure, the overwhelming majority of studies using electrical stimulation report no age difference in pain thresholds (Table 3). Eight studies have found no significant difference in electrical pain threshold when delivered to either cutaneous sites[97, 103, 110, 124] or to healthy unfilled tooth pulp.[67–69, 120, 121] In addition, one study reported the only example of a lower pain threshold in older persons.[29] The subjects in that study involved Army-enlisted personnel ranging in age from 18 to 53 years, however, and so it may be somewhat inappropriate to include this evidence in age-related differences. There are two reports of increased pain thresholds in older adults.[122, 157] Both studies used a very large sample size (n = 520 and n = 100), and one included an extended age range (5–105) relative to most other studies of electrical pain threshold. Tucker et al[157] also included 50 elderly subjects with mild arthritis or neurologic disease in their total sample, and this may have contributed to the documented age-related increase in cutaneous pain threshold. At best, although the findings for electrical pain threshold must be regarded as equivocal, the bulk of evidence would certainly suggest no age-related change in this modality of stimulation.

Table 3. PSYCHOPHYSICAL STUDIES OF ELECTRICAL PAIN THRESHOLDS IN YOUNG AND OLDER ADULTS

Age-Related Increase in PT

Neri & Agazzani.[122] N = 100, aged 20–82. A 14% increase in PT occurred among subjects aged 20–82.

Tucker et al.[157] N = 520, aged 5–105. Age differences in PT were most pronounced in adults aged 75+; study included subjects with concomitant disease states.

No Age Difference in PT

Mumford.[120] n = 36 aged 10–15, n = 120 aged 18–28, n = 57 aged 58–73. Trend for increased PT with increased age (≈12% increase) but not in adult age range.

Mumford.[121] N = 268, aged 10–73. Failed to find an obvious age difference in PT of healthy, unfilled teeth; formal statistical analysis not done. Sample extended from earlier 1965 study.

Collins & Stone.[29] N = 56, aged 18–53. Used cutaneous electrical stimulation and found an age-related decrease in PT (r = −0.27); limited age range of subjects.

Notermans et al.[124] N = 64, aged 10–65. Age findings were incidental to main aims of the study; mean data on age differences not presented.

*Harkins & Chapman.[67, 68] N = 20, aged 21–85. Used signal detection approach and PT measures.

*Harkins & Chapman.[68, 69] N = 20, aged 20–81. Used signal detection approach and PT measures.

Laitinen & Eriksson.[97] N = 10, aged 14–60. Age findings were incidental to main aims of the study; small sample size.

Lucantoni et al.[103] N = 40, aged 10–90. Tested multiple sites and noted age difference in detection threshold but not PT.

Meliala et al.[110] N = 30, aged 20–40, 65+. Tested multiple modalities of noxious stimulation; electrical PT did not differ among age groups regardless of frequency. [Abstract]

*Multiple citation because data were presented more than once.
PT = pain threshold.

One can reasonably ask why this should occur? Why should the findings from electrical stimulation differ so markedly from those using heat or mechanical stimulation? In a recent study, the authors examined electrical, mechanical, and heat pain threshold in the same group of younger (20–40 years) and older adults subjects (75–91 years). Although significant age differences in CO_2 laser heat pain threshold and Von Frey monofilament pricking pain threshold were noted, there was no significant difference in electrical pain threshold regardless of the stimulation frequency.[110] Electrical stimulation is known to activate primary afferent fibers directly, whereas heat and mechanical stimulation require mechanisms of receptor activation and energy transduction to stimulate sensory fibers. Thus, a selective age-related change in receptor morphology or function could be used to explain the altered heat or mechanical pain perception in the absence of altered electrical pain thresholds. If true, such a change would parallel the documented decline in other sensory receptor systems, including touch, vision, hearing, taste, and smell.[19, 33] In this regard it is also pertinent to mention age-related changes of the skin,[90] including thinning of the epidermis, reductions in elasticity, and flattening and separation of the dermal epidermal junction.[90] These factors are likely to affect the energy transduction process for noxious heat or mechanical stimuli, thereby reducing the information reaching cutaneous primary afferent nociceptors.

AGE DIFFERENCES IN SUPRATHRESHOLD SCALING

To date, relatively few studies have compared subjective ratings of fixed intensity, suprathreshold, experimental pain stimuli across different age groups. Harkins et al[72] compared VAS ratings of intensity and unpleasantness in response to six different levels of noxious heat in three age groups. Although older adults rated the intensity of heat stimuli at 41°C to 45°C as being significantly lower than young adults, no difference was noted in ratings of higher-level heat stimuli. Tremblay et al[154] have reported similar findings and also have noted that both intensity and unpleasantness ratings are diminished in older adults for all heat stimuli above 46°C. Using fixed intensity CO_2 laser heat pulses, Gibson et al[47] found that the quality of pain was rated as stinging, burning, or penetrating on 62% of occasions for older adults (80–99 years), but on 90% of occasions by the young adults (20–39 years). Older adults were more likely to use non-noxious word descriptors such as tingling, warm, hot, or touching and rate the stimulus as one third less intense when compared with the young adult group. These studies would tend to agree with the age findings for heat pain thresholds and demonstrate a corresponding decrease in the subjective rating of high-intensity noxious heat stimuli.

Age differences in the rating of suprathreshold pain stimuli have also been examined using the principles of signal detection theory.[58] This psychophysical theory argues that pain report depends on the accuracy of sensory processing and a willingness to label a sensation as being painful. Each of these factors can be assessed independently allowing for sensory variables to be separated from psychological response bias. Using noxious heat, Clark and Mehl[25] found that middle-aged adults (30–63 years) used a more stringent response criterion for the report of pain when compared with young adults (18–28 years). Sex differences were also noted with older women showing a decrease in sensory discrimination, whereas older men were not different from the young. Because discrimination was the same for young and older men, Clark and Mehl concluded that both groups were equally sensitive to pain, but that older men were more stoic in their reports. In the case of women, the observed age difference in pain sensitivity was thought to be caused by deficits in sensory processing and by a reluctance to report the heat stimulus as painful. Harkins and Chapman[67–69] have also examined age differences in response bias and sensory discrimination. Elderly subjects were less accurate than young adults in discriminating between different levels of noxious electrical stimulation, and in accordance with Clark and Mehl's[25] findings, older persons adopted a more stringent response criterion for the report of pain. The age difference in response bias was most noticeable at low-intensity shocks. At high-intensity electrical stimulation, the elderly were either as willing[69] or even more willing than young adults to label the noxious stimuli as painful.[67] This interaction between response bias and stimulus intensity is consistent with Botwinick's[13] arguments regarding increased caution and a need for higher levels of stimulation before committing to a response. In combination, these studies have been used to support the idea that the elderly adopt a more conservative attitude toward painful sensations and are more reluctant to report pain when it does occur.

In combination, these data emphasize age differences in psychological response bias rather than physiologic function. It should be noted, however, that signal detection theory techniques have been soundly criticized when applied to the study of pain.[30, 56, 136] In particular, it has been argued that any change in sensory discrimination would also alter the willingness to label a sensation, and so the two factors are not independent as originally claimed. Despite these methodologic concerns, the findings add further weight to the claim of diminished pain sensitivity in older adults and highlight the role of possible age differences in labeling bias as a possible explanation for increased pain threshold and altered pain report.

AGE DIFFERENCES IN PAIN TOLERANCE

Although most of the studies on pain threshold would suggest a modest decrease in cutaneous pain sensitivity and report during the later years of life, the effect of aging would appear to be completely opposite at the upper limits of the pain sensitivity range. Of the four studies to examine maximum tolerable pain intensity, three report increased pain sensitivity with advancing age,[29, 161, 165] and the remaining study found no significant age difference.[122] The consistency of the decrease in pain tolerance is even more remarkable given the different types of pain induction methods, including mechanical pressure of the Achilles tendon,[165] electrical stimulation of the fingers,[29] and immersion of the hand in ice cold water.[161] Although pain tolerance to noxious heat has yet to be investigated, the findings by Harkins et al[72] of increased pain report in older adults at high-intensity noxious heat are consistent with the general trend of an age-dependent decline in the ability to tolerate strong painful sensation.

OTHER EXPERIMENTAL STUDIES

It is widely recognized that noxious stimulation can often evoke a double pain sensation. First pain, which is associated with finely myelinated A delta nociceptive fibers, has been characterized as a brief, well-localized, sharp pricking sensation and is associated with early warning of impending damage. Second pain results from activation of slowly conducting unmyelinated C fibers and is a diffuse, poorly localized, dull burning sensation that may be more involved with healing and protective processes. Recently, Chakour et al[21] examined the possibility of a differential age-related change in heat pain sensitivity subserved by A delta and C fibers. Using noxious CO_2 laser heat pulses, pain threshold was examined before, during, and after a compression block, which selectively impairs A delta fiber conduction while leaving C fiber function intact. Although younger adults exhibited a significant increase in heat pain threshold during the compression block (120% increase above baseline), pain threshold in older volunteers remained relatively stable (32% increase) despite the impairment of A delta fiber function. These findings suggest a selective age-related impairment in first pain and indicate a possible deficit in the early warning function of nociceptive A delta fibers. Harkins et al[78] have also examined age differences in first and second pain under conditions of repeated stimulation. Temporal summation or "windup" refers to the enhancement of pain caused by repeated noxious input. It is thought to result from a sensitization of nociceptive or multireceptive neurons in the dorsal horn of the spinal cord and may play an important role in the initiation of postinjury tenderness and hyperalgesia.[113] In an examination of age differences in temporal summation, Harkins et al[78] found an increase of 21% in pain intensity ratings of young adults and an 83% increase in older subjects over the course of repetitive heat stimulation of the arm. In contrast, when noxious heat stimuli were delivered to the leg, the older group failed to exhibit temporal summation of second pain. This failure in temporal summation at the leg indicates an age-related change in CNS nociceptive processing and could potentially modify the development and expression of postinjury hyperalgesia.

Recently, Zheng et al[170] have extended these observations by examining age differences in the time course of capsaicin-induced hyperalgesia. Although older adults took slightly longer to first report the presence of pain following the administration of the chemical irritant, capsaicin, no age difference was noted in the magnitude and size of hyperalgesia. The area of heat hyperalgesia rapidly decreased over time in both age groups. In marked contrast, the area of mechanical hyperalgesia or tenderness was maintained for the entire three-hour test period in older adults but had resolved within one hour in the young. Because mechanical tenderness is known to be mediated by sensitized dorsal horn neurons,[146,153] these findings may indicate age differences in the plasticity of spinal cord neurons following acute injury. In particular, the slower resolution of mechanical hyperalgesia may reflect a reduced capacity of the aged CNS to reverse the sensitization process once it has been initiated. In terms of more direct clinical implications, it appears that postinjury pain and tenderness may resolve more slowly in older persons, and this is consistent with much previous evidence of delayed healing responses in the elderly.[59]

Although neurophysiologic studies of age differences have focused almost exclusively on the afferent pathways involved in pain transmission, a powerful descending pain inhibitory system is also known to shape the clinical pain experience. Washington et al[162] have recently examined possible differences in the magnitude of endogenous analgesic responses in young (n = 15; 22–27 years) and older (n = 15; 67–87 years) adult volunteers. Repeated ice water immersion of the hand was used as a conditioning stimulus to activate endogenous analgesic systems. Measurement of electrical pain thresholds taken before, immediately after, and one hour after the conditioning stimulus was used to index the analgesic response. As can be seen from Figure 2, the cold water immersion was effective in eliciting a powerful analgesic response, regardless of age. Although pain threshold was shown to increase by more than 100% immediately after the conditioning stimulus, this effect was relatively transient, with threshold returning to baseline within one hour. Of perhaps greater importance, the magnitude of analgesic response was found to be significantly less in persons of advanced age (a 40% increase in threshold) when compared with younger adults (a 150% increase in threshold). These findings strongly suggest an age-related reduction in the efficacy of endogenous analgesic responses and are consistent with several previous animal studies.[12,64,65,96] Further work is needed to identify the underlying neurophysiologic mechanisms of age differences in analgesia, including the possible role of neural versus hormonal systems and opioid versus nonopioid components. Nonetheless, a reduction in the efficacy of endogenous analgesic systems would make

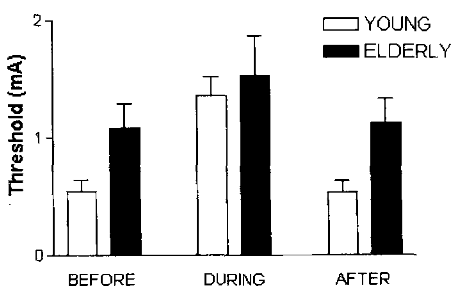

Figure 2. Electrical pain threshold before, during, and after activation of endogenous pain inhibitory systems in young (n = 15) and older (n = 15) adults.

it more difficult for older adults to cope with severe or persistent clinical pain states, and this finding may help explain some of the reported age variation in pain tolerance levels.

SUMMARY

The present chapter has focused on one of the most fundamental issues relevant to understanding the pain experience of older persons: age related differences in pain perception and report. A systematic review of the literature suggests some consistent, although not invariable, age differences in many types of clinical pain and in most types of experimental pain studied in the laboratory. There appears to be a modest age-related increase in experimental pain threshold, altered pain quality, and diminished sensitivity to lower levels of noxious stimulation, but an increased response to higher intensity stimuli and a reduced tolerance of strong pain. In addition, recent experimental pain studies demonstrate some alterations in peripheral A delta and C fiber nociceptive function as well as CNS changes, including an apparent deficit in postinjury CNS plasticity and a reduced efficacy of endogenous analgesic mechanisms. Clinically, the evidence suggests a relative absence of pain symptoms in the presentation of myocardial complaints, intra-abdominal infections, various types of malignancy, and other conditions involving acute inflammation. The reported intensity of postoperative pain may be somewhat reduced, and the quality of pain sensation reported by older patients attending multidisciplinary pain treatment centers may vary when compared with younger adult patients.

Although this evidence is supportive of clinically significant changes in pain sensitivity and report in older persons, there are several methodologic limitations and issues relating to interpretation that demand prudent consideration. Of perhaps most importance, diminished sensitivity to threshold painful stimulation does not mean that older adults experience less pain when they actually report it. To the contrary, only the threshold for report has changed, not the experience itself. Indeed, if anything, an increased pain threshold would suggest even greater levels of underlying pathology in the older person who chooses to make a report of pain. It must also be remembered that the change in pain sensitivity is not uniform across the intensity range. Psychophysical studies show that older persons may be less able to endure strong painful input and would therefore require more potent pain management strategies in such situations. Issues relating to methodologic limitations include a lack of longitudinal investigations, a reliance on retrospective case reports in studies of clinical pain and variations in psychophysical procedures, subject instructions, and the age groups selected for comparison in studies of experimental pain. Another important methodologic issue common to both clinical and experimental pain studies concerns the often unmeasured influence of comorbidity. The vast majority of reported studies have not provided clear detail on the extent to which persons with comorbid disease have been excluded; however, such information is essential if we are to accept that observed age differences in pain sensitivity reflect the aging process. A commonsense view would suggest that the older person who suffers from multiple disease states, increased frailty, and reduced physiologic reserve might show profound deficits in pain sensibility. On the other hand, the rare individual who remains totally disease-free into the ninth or tenth decade of life may display little or no change in pain sensitivity and report. Although the potential influence of this unmeasured factor is presently unclear, it seems likely that a significant proportion of older adult samples will suffer from some form of comorbid illness, even if only a subclinical elevation in blood pressure. This could help explain some of the disparity between different experimental pain studies and may provide a reasonable explanation for much of the observed age-associated change in pain sensitivity and report.

Our current knowledge of age differences in pain perception and report remains incomplete. Future research should explore some of the possible reasons for observed age differences in pain report, including the physiologic, psychological, and social changes that accompany advancing age. There is also a clear need for more rigorous and better quality studies of clinical and experimental pain over the age spectrum, rather than further repetition of existing data. Moreover, the clinical relevance of experimental pain studies needs to be improved by applying models that better mimic ongoing and persistent clinical pain states. Such efforts should ultimately lead to a more comprehensive understanding of age differences in the pain experience and thereby improve management strategies for the large number of older persons who suffer from persistent and bothersome pain.

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Address reprint requests to

Stephen J. Gibson, PhD, MAPsS
National Ageing Research Institute
PO Box 31
Parkville 3052
Victoria
Australia