



DALHOUSIE UNIVERSITY

Retrieved from DalSpace, the institutional repository of
Dalhousie University

<https://dalspace.library.dal.ca/handle/10222/73350>

Version: Post-print

Publisher's version: Birnie, K.A., Petter, M., Boerner, K.E., Noel, M., & Chambers, C.T. (2012).
Contemporary use of the cold pressor task in pediatric pain research: A systematic review of methods.
The Journal of Pain, 13, 817-826. doi: 10.1016/j.jpain.2012.06.005

© 2012. This manuscript version is made available under the CC-BY-NC-ND 4.0 license

Birnie, K.A., Petter, M., Boerner, K.E., Noel, M., & Chambers, C.T. (2012). Contemporary use of the cold pressor task in pediatric pain research: A systematic review of methods. *The Journal of Pain*, 13, 817-826. [doi: 10.1016/j.jpain.2012.06.005](https://doi.org/10.1016/j.jpain.2012.06.005).

Contemporary Use of the Cold Pressor Task in Pediatric Pain Research: A Systematic Review of

Methods

Kathryn A. Birnie^{1,3}

Mark Petter^{1,3}

Katelynn E. Boerner^{1,3}

Melanie Noel^{1,3}

Christine T. Chambers^{1,2,3}

¹Psychology and ²Pediatrics, Dalhousie University, Halifax, Nova Scotia, Canada

³Centre for Pediatric Pain Research, IWK Health Centre, Halifax, Nova Scotia, Canada

Correspondence should be addressed to:

Kathryn A. Birnie

Centre for Pediatric Pain Research

K8536 (8th floor, Children's site), IWK Health Centre

5850/5980 University Avenue

Halifax, Nova Scotia, Canada B3K 6R8

Telephone: 1-902-470-6769

Facsimile: 1-902-470-7118

E-mail: kbirnie@dal.ca

URL: www.pediatric-pain.ca

Words for Indexing: cold pressor task, cold pressor test, pediatric pain, experimental pain, children

Abstract

The cold pressor task (CPT) is an ethical experimental pain task widely used by pediatric pain researchers to examine a variety of important theoretical and clinical questions. The purpose of this systematic review was to describe contemporary use of the CPT in pediatric pain research to identify possible methodological and procedural inconsistencies and inform future research. All papers using the CPT to examine pain-related outcomes with children ≤ 18 years old published after 2005 were identified, when published pediatric CPT studies were last reviewed and guidelines for pediatric use of the CPT were published. Information related to samples, CPT methodology, and pain outcomes was recorded. Thirty-six published papers, involving 2242 children (aged 3-18 years) from both healthy and clinical samples, met review inclusion criteria. Several aspects of CPT methodology with significant potential to impact pain outcomes were found to be inconsistently implemented and reported, including water temperature, use of informed versus uninformed ceilings, and the presence of observers during the CPT. Self-report child pain intensity and pain tolerance were common outcomes. A number of refinements for use of the CPT in pediatric pain research are suggested.

Perspective: The cold pressor task is a commonly used experimental method in pediatric pain research. This systematic review reveals important methodological inconsistencies in its use and suggestions for improvements to previously published guidelines.

Keywords: cold pressor task, cold pressor test, pediatric pain, experimental pain, children

Contemporary Use of the Cold Pressor Task in Pediatric Pain Research:
A Systematic Review of Methods

The cold pressor task (CPT) is the most commonly used experimental pain induction technique in pediatric pain research²⁴. To induce pain of mild to moderate intensity, the CPT requires children to submerge their hand or forearm in cold (typically 10°C) water for a period of up to several minutes⁴⁹. The appeal of the CPT to pediatric pain researchers is likely related to its ethical acceptability². Children retain control over the process by being able to remove their hand from the cold water at any time, thereby quickly reducing any experienced pain.

While historically used to induce stress, Feuerstein et al.¹⁵ published the first pediatric CPT study examining pain as an outcome. By 2005, the number of published pediatric CPT studies had grown to 24, culminating in the publication of guidelines in *The Journal of Pain* intended to direct safe and consistent use of the CPT with children⁴⁹. Recommendations focused on CPT equipment and procedural variables (e.g., preparation, initial warm water bath), with particular consideration of study exclusion criteria (i.e., when cold water submersion contraindicated, as in the case of children with Raynaud's phenomenon), water temperature (10°C±1°C), maximum immersion time (3 minutes), measurement of water circulation rate, depth and position of submersed hand (i.e., up to wrist with palm up), armrest, instructions to the child, outcome measures (e.g., pain intensity, tolerance, threshold, distress), and audience and demand effects (i.e., minimized presence of others in the room)⁴⁹.

Despite the availability of these guidelines, there has been no systematic assessment of contemporary use of the CPT in pediatric pain research. This is potentially problematic, as subtle methodological variations, such as the presence of others in the room during the task⁴⁹, providing temporal information to the child⁵, water temperature³⁰, or water circulation and turbulence⁴⁸,

could contribute to important differences in study results. A recent international survey of pediatric researchers examining the ethical acceptability of the CPT, highlighted potential methodological inconsistencies, particularly relating to water temperature, maximum allowable immersion time of the child's hand in the water, and monitoring of the child during the task².

Further, a number of recent pediatric pain CPT studies have reported using colder (5-7°C) water than the 10°C recommended in the 2005 guidelines as a means of increasing variability in pain tolerance times and pain intensity ratings⁹. Approximately 20-50% of children have been found to reach a ceiling immersion time of three minutes when water at 10°C is used^{39, 48}. Small variations in water temperature have been associated with significant changes in pain intensity and tolerance in adults completing the CPT³⁰.

The main objective of this review was to systematically describe contemporary use of the CPT in pediatric pain research. This is of particular importance as a major advantage of the CPT is its high degree of experimental control and, given that small methodological variations may significantly influence outcomes^{5, 30, 48, 49}, comparisons across studies are more difficult. Based on previous research², as well as the authors' familiarity with the methodology, a number of methodological inconsistencies were expected, particularly relating to the CPT apparatus used, water temperature and flow rate, preparation procedures, and use of informed versus uninformed ceiling times.

Method

Inclusion/Exclusion Criteria

Papers were selected for inclusion based on the following criteria: (1) empirical investigation requiring participants to complete the CPT; (2) examined pain-related outcomes; (3) studies published after 2005, including available advance access publications; (4) studies

including only children between 0 and 18 years of age; (5) published in a peer-reviewed journal; and (6) published in English.

Search Strategies

A search of key electronic databases (PsycINFO, EMBASE, CINAHL, and PubMed) was employed using the following search terms: cold pressor, pain, AND pediatrics, children, OR adolescents. Given study inclusion criteria, database searches were restricted to papers published during or after 2006. The first author (KAB) performed an initial screening using titles and abstracts, obtaining full articles when necessary to determine eligibility. Details were recorded regarding the number of studies found, number of studies meeting inclusion criteria, number of studies excluded, and reasons for exclusion. To ensure inclusion of all relevant publications, a final updated search of electronic databases was completed on April 19, 2012; two additional studies were identified for inclusion^{34, 35}.

Once eligible papers were identified, all corresponding authors were contacted by e-mail outlining which of their study/studies were identified for inclusion in the systematic review and inquiring as to whether other potentially eligible studies published by their research group were available. All authors responded and three additional papers were identified, including one that was published in 2008¹³, one in 2011¹⁷, and one in 2012⁴¹. Additionally, information was requested regarding potential overlapping samples included in multiple eligible papers (i.e., several papers reporting outcomes from the same group of participants in a single CPT study).

Coding of Papers

Eligible papers were coded by four independent reviewers (KAB, KEB, MN, MP) using a customized form developed by the first author described in greater detail below. Items included in the 60-item form were largely based on recommended CPT guidelines⁴⁹. Additional items

were included to capture basic study-related information and issues of growing discussion in the field (e.g., use of informed vs. uninformed ceilings), as informed by previous research and the authors' own direct experience conducting research involving the CPT.

In cases where papers reported on two unique studies³, only information from studies using the CPT were included. Similarly, if only a subsample of study participants completed the CPT^{18,44}, only data relevant to the subsample was collected. If multiple unique CPT studies were reported in a single published paper⁴⁷, studies were coded separately considering all available information in the paper. When corresponding authors identified overlapping samples, the earliest published paper meeting inclusion criteria was used as the primary source of information; however, all papers reporting on this sample were coded separately and identified in the results. This was done as several later papers reported additional information on the complete original sample or on new groups of participants.

To assess inter-rater reliability, eight randomly selected papers (21.6%) were coded by a second reviewer. Reviewers were not blind to study authors or study findings. Due to the variety of response types for coding of papers (i.e., responses of non-categorical nature), inter-rater reliability was calculated using percent agreement. Calculated inter-rater agreement was 94.2%. Results from the first coder are reported herein.

After the initial coding of included studies, 18 corresponding authors were contacted by e-mail regarding specific methodological details not reported in the respective published paper(s); 13 authors responded with requested information.

Coding Form

Published papers were coded for the inclusion of a description of study recruitment methods, inclusion/exclusion criteria, attrition, participant sex and age (range, mean, and

standard deviation), ethnicity, height, weight, body mass index, and pubertal status. The 2005 guidelines recommend measurement of these demographic variables as they may need to be controlled for in subsequent data analyses⁴⁹.

The 2005 guidelines describe several potential CPT apparatus (i.e., ice or electric-cooled), but recommend standardized procedures around water temperature ($10^{\circ}\text{C}\pm 1^{\circ}\text{C}$), depth of hand immersion (submerge to 5cm above the wrist, palm up), maximum allowable immersion time (three minutes for uninformed ceiling), water flow rate, and preparation of the child before the CPT⁴⁹. Preparation recommendations include offering the child fruit juice, having the child wash their hands, implementing a five minute acclimatization period in the lab, and having the child submerge their hand in warm water ($36^{\circ}\text{C}\pm 1^{\circ}\text{C}$) for two minutes prior to the CPT⁴⁹. Published reports were coded for these variables of interest.

Additional coding items included details of any experimental manipulation, number of CPT immersions, use of a warm water bath between multiple immersions, measured pain outcomes (e.g., intensity, threshold, tolerance, and affect), pain intensity and affect scales used, other study outcomes, presence of others in the room with the child during the CPT, and the use of an informed versus uninformed ceiling. When an informed ceiling is used, children are told the maximum allowable immersion time for their hand in the CPT, whereas they are unaware of this information when an uninformed ceiling is used.

Results

Included Papers

Preliminary searches yielded 98 possible papers, in addition to three that were identified through correspondence with authors of previously published work and two identified through a follow-up database search. Of these papers, 67 did not meet inclusion criteria. Papers were

excluded for the following reasons: included individuals > 18 years of age ($n=62$), study did not use the CPT ($n=2$), study was not empirical ($n=1$), study did not examine pain-related outcomes ($n=1$), and participants did not complete the CPT ($n=1$). Table 1 presents results pertaining to the final 36 papers that met inclusion criteria. Results are also summarized below. Overlapping samples were identified by three different research groups pertaining to 17 papers and are subsumed in the table under the earliest paper to meet review inclusion criteria. Specifically, 11 published papers report on variations of the same sample of healthy children^{1, 12-14, 17, 27, 33, 40-43} with one study including an additional sample of children with chronic pain⁴¹. Two other research groups published two papers each reporting results from overlapping samples of healthy children^{3, 34, 35, 45}. Additionally, the sample of schoolchildren from one study⁴⁶ was used as the control group for another⁴⁴. One paper reported on two unique CPT studies⁴⁷ that are included individually in the results as they involve different samples of children. Unique studies described within the same published paper are counted separately, thus, the final analyses are based on 37 pediatric CPT studies.

Results below reflect methodological details obtained in published papers or via author correspondence. Information is described as ‘not available’ when not obtained through either source. Based on author response, fourteen of 31 (45.2%) studies began recruitment during 2006 or later^{3, 8, 9, 23, 31, 34, 35, 39, 44-47, 50}, when it can be reasonably assumed that pediatric CPT guidelines⁴⁹ published in 2005 would have been available to researchers during study design. Information regarding year study recruitment began was not available for six studies^{10, 11, 16, 18, 29, 37}.

Several of the studies involved an experimental manipulation ($n=14$; 37.8%), most often involving examination of the impact of various interventions on pain ($n=10$; 27.0%, e.g.,

distraction techniques, humor, sucrose). Included papers were most frequently published in pain-related journals ($n=18$; 48.6%), in addition to journals with a focus in pediatrics/pediatric psychology ($n=10$; 27.0%), cognitive/behavioural interventions ($n=3$; 8.1%), or other ($n=5$; 13.5%).

Description of Samples

Taking into account overlapping samples in included studies, 2242 individual children (55.9% female) aged 3-18 years participated in at least one CPT exposure (weighted $M=10.76$ years). In one paper, sex and age of participants was not reported in the subsample of children completing the CPT and are not included in the above calculated demographics²⁹. Two other studies did not report the mean age for children completing the CPT but this information was obtained from study authors^{19, 20}. As described in Table 1, most studies included only healthy children ($n=31$; 83.8%), one included only a clinical sample (2.7%), four compared healthy and clinical samples (10.8%), and one included a mixed sample (2.7%). Clinical samples were comprised of children with chronic pain ($n=4$), children with anxiety ($n=1$), children with higher than average depression scores ($n=1$), or children born prematurely ($n=1$).

The majority of studies described inclusion/exclusion criteria ($n=32$; 86.5%). Most studies ($n=24$; 64.9%) followed at least some of the recommended exclusionary criteria for participation in the CPT, such as history of Raynaud's phenomenon ($n=22$), history of cardiovascular disorder ($n=22$), open cuts or sores on the hand to be submersed ($n=22$), history of fainting or seizures ($n=21$), fracture of the limb to be submersed ($n=17$), or history of frostbite ($n=15$). Information was not available for six studies, although few studies ($n=10$; 27.0%) indicated assessing for contraindication of CPT participation in the published paper.

Most studies described recruitment methods ($n=34$; 91.9%) and sample ethnicity ($n=30$;

81.2%); however, fewer reported sample socioeconomic status ($n=16$; 43.2%), pubertal status ($n=2$; 5.4%), or body mass index ($n=1$; 2.7%) No studies described sample height or weight. Sample attrition was reported in one study requiring multiple lab visits³⁵; sample attrition was not examined in other studies as all CPT exposures were completed in single visits.

CPT Procedures and Methodology

CPT apparatus

Table 1 outlines CPT procedures and methodology described in all 37 reviewed studies. Most studies included a description of the CPT apparatus used ($n=34$; 91.9%) and identified the occurrence of water circulation ($n=33$; 89.2%). Water was typically ice-cooled ($n=24$; 64.9%) as opposed to electric-cooled ($n=10$; 27.0%) with information not available for three studies (8.1%)^{16, 18, 29}. Water flow rate was never reported.

CPT exposures

In most studies, participants were required to undergo only one CPT exposure ($n=24$; 64.9%). Thirteen studies required two ($n=7$; 18.9%), three ($n=1$; 2.7%), or three or four exposures (depending on experimental group; $n=5$; 13.5%). CPT exposures were always completed within the same testing session with the exception of one study that required completion of one CPT in each of two testing sessions on different days³⁵. Generally, multiple CPTs completed within the same study used the same CPT methodology ($n=11$; 84.6%). In the two instances where CPT methodology changed with multiple CPT immersions, both required a lesser maximum immersion time for the second CPT (from three minutes to one minute^{41, 43}) and one changed from an uninformed to an informed ceiling⁴¹.

CPT preparation procedures

Offering juice to children ($n=14$; 40.5%) was more common than requiring children to

wash their hands ($n=6$; 16.2%) prior to the CPT, with information not available for six studies (16.2%). These details were rarely reported in published papers ($n=2$; 5.4%). Several studies reported use of a warm water bath prior to the initial CPT immersion ($n=11$; 29.7%), which ranged in temperature from 21-37°C for 1-2 minutes. Of the 12 studies reporting multiple CPT exposures in the same study visit, six (50.0%) used a warm water bath between immersions and one (8.3%) involved wrapping the hand in a warm towel. When use of a warm water bath prior to or between CPTs was not reported in published papers ($n=20$), information from authors typically indicated that it was not done ($n=16$; 80.0%).

Water temperature and immersion time

The most commonly reported water temperature was 10°C ($n=24$; 64.9%); however, this varied widely with 1°C ($n=1$; 2.7%), 5°C ($n=4$; 10.8%), 6°C ($n=2$; 5.4%), 7°C ($n=2$; 5.4%), 11°C ($n=1$; 2.7%), 12°C ($n=2$; 5.4%), and 13°C ($n=1$; 2.7%) also reported. Maximum immersion times of three ($n=17$; 45.9%) and four ($n=13$; 35.1%) minutes of the child's hand in the water were common; however, 20 seconds ($n=1$; 2.7%), one minute ($n=5$; 13.5%), and five minutes ($n=1$; 2.7%) were also reported.

The use of an uninformed ceiling was more common ($n=19$; 51.4%) than an informed ceiling ($n=13$; 35.1%) with information not available for five studies (13.5%). Of note, this information was not reported in almost half of the published papers ($n=14$; 37.8%).

Hand immersion

Submersion of the hand to just above the wrist was observed in most cases ($n=28$; 75.7%) with information not available for three studies (8.1%). When not followed ($n=6$; 16.2%), submersion of a greater proportion of the arm was directed (e.g., up to elbow). In many studies, children were instructed to submerge their non-dominant hand ($n=18$; 48.6%). Other options

included dominant ($n=6$; 16.2%), left ($n=3$; 8.1%), right ($n=1$; 2.7%), child chose ($n=1$; 2.7%), and alternating ($n=4$; 10.8%) or counterbalanced ($n=1$; 2.7%) when multiple CPTs were required in the same study visit. Information indicating which hand participants were instructed to submerge was not available for three studies^{10, 11, 18}. Instructing the child to submerge their hand with the palm facing up was rarely reported ($n=5$; 13.5%)

Audience and demand effects

In the majority of studies at least one experimenter was present in the room with the child when they completed the CPT ($n=30$; 81.2%), with one study indicating the absence of an experimenter (2.7%) and six studies with no information available (16.2%). When an experimenter was present, some studies ($n=13$) included attempts to minimize audience effects (e.g., positioned behind a screen or behind the participant). Importantly, over half of the studies did not explicitly indicate in the published paper whether or not an experimenter was in the room while the child completed the CPT ($n=20$; 54.1%). Three studies (8.1%) indicated the presence of a parent in the room; however, it was unclear if this was in addition to or instead of an experimenter. In all three instances, the presence of the parent during the CPT was necessitated by study design (e.g., observing parent-child interactions during the CPT³²).

Study Outcomes

Pain intensity, tolerance, threshold, and affect

See Table 1 for a description of pain outcomes measured in each study. Children's self-report of pain intensity was measured in most studies ($n=30$; 81.2%), although mean scores were only reported in 21 (70.0%) of those studies. Of the studies measuring pain intensity, pain intensity was assessed following completion of the CPT ($n=19$; 63.3%) or at a specific time/set intervals during immersion ($n=9$; 30.0%). One study did not indicate when pain intensity was

assessed⁴². Scales used to assess pain intensity included a visual analogue scale ($n=16$; 53.3%), numeric rating scale ($n=6$; 20.0%), colour analogue scale ($n=3$; 10.0%), the Faces Pain Scale-Revised ($n=5$; 16.7%), or was not reported ($n=1$; 3.3%).

Pain affect was less consistently assessed ($n=12$, 32.4%) using a visual analogue scale ($n=7$), the Facial Affective Scale ($n=2$), the Children's Fear Scale ($n=2$) or a numeric rating scale ($n=1$). Means of pain affect were described in nine of twelve studies. Pain tolerance was measured in the majority of studies ($n=22$; 59.5%), but means were not always reported ($n=18$; 81.8%). Means for pain threshold were described in all instances where threshold was measured ($n=7$; 18.9%).

Due to overlapping samples between studies, inconsistent timing of pain intensity assessments, inconsistent measurement of pain outcomes, and differing exclusion of children's pain tolerance from the final analyses, overall mean pain ratings were not calculated.

Other outcomes

Additional measured outcomes included physiological (e.g., salivary and blood cortisol, heart rate, blood pressure) and behavioural (e.g., facial action coding) responses to the CPT. Studies explored the potential influence of child sex, race, medical history (e.g., health care utilization, preterm birth), psychological factors (e.g., anxiety, depression), cognitive factors (e.g., coping, memory), and parents' own pain and life history (e.g., maternal somatization and negative life events) on child pain outcomes. Parental outcomes, such as estimates of the child's pain and responses during the CPT (e.g., parent-child interactions, parental distress, sympathy, catastrophizing, stop tendency) were also reported.

Discussion

The purpose of this review was to systematically describe contemporary use of the CPT

in pediatric pain research and identify inconsistencies in its use. Thirty-six papers describing 37 CPT studies published after 2005 were included, involving 2242 children aged 3-18 years from healthy and clinical samples. The majority of studies described the CPT apparatus and largely aligned with recommendations regarding water circulation and maximum immersion time⁴⁹. Studies infrequently reported water flow rate, having the child drink juice or wash their hands prior to a CPT, or the presence of others in the room with the child. Inconsistencies were noted in several areas with the potential to significantly impact CPT outcomes, particularly water temperature, water cooling method, use of informed or uninformed ceilings, hand submersion, and presence of others during the CPT.

Sample Characteristics

Child age, sex, and ethnicity were commonly indicated, although demographic variables shown (e.g., pubertal status²⁶) or proposed (e.g., BMI⁴⁹) to impact experimental pain outcomes in children were rarely reported. Although infrequently reported in published papers, most studies assessed for contraindication of CPT participation⁴⁹. Although inclusion of children younger than 7 years was rare⁵⁰, inclusion of young children or children with developmental disabilities raises potential ethical issues in light of possible difficulties with task comprehension, provision of assent, safety, and availability of psychometrically sound assessment tools.

Researchers should also consider whether to include children who have previously completed the CPT, as children's experience with the task and subsequent pain memories can influence their pain reporting at later CPT immersions³⁵. This can be addressed through exclusion of participants with previous CPT experience, measuring and controlling for the amount and quality of previous CPT experience, or using study designs that include a baseline CPT. Ultimately, how to best handle previous experience will be influenced by each individual

research question. Finally, researchers should assess for chronic pain in community samples, as it is common among children and adolescents²¹ and can impact CPT outcomes^{11,41}.

Characteristics of the CPT

Preparation and CPT exposures

Most studies involved only one CPT exposure; however, up to four CPT trials in a single testing session was reported. Approximately one third of studies used a warm water bath prior to the CPT; however, temperature of the water bath varied (21-37°C). Only half of studies requiring multiple CPT exposures reported using a warm water bath between exposures. While the purpose of the warm water bath is to standardize hand temperature, its impact has not been examined. Cold pain receptors are activated when skin temperature reaches approximately 12-18°C⁴⁸. As such, use of a warm water bath between multiple CPT immersions is recommended, as the hand is likely to decrease in temperature, potentially influencing pain outcomes during subsequent immersions.

Although most studies instructed hand submersion to the wrist, several studies required submersion of the arm up to the elbow. Instructing participants to place their hand palm up was rarely reported, and the hand chosen for submersion varied. Although exposure of larger areas of the hand during CPT immersion has not been shown to influence pain intensity⁵¹, in order to standardize procedures, submersion of the hand to the wrist, palm up and open, with minimized hand movement is recommended.

CPT apparatus and water temperature

Consistent with guidelines⁴⁹, 10°C±1°C was the most common water temperature; however, temperatures ranged from 1°C to 13°C. The initial recommendation was based on the belief that this temperature would be warm enough to allow submersion of the hand for durations

exceeding a few seconds, yet cold enough to minimize participants reaching maximum immersion times⁴⁹. However, upwards of 50% of participants are reaching immersion ceilings⁴⁸, most problematic among older children who demonstrate higher tolerance^{36, 39}. Therefore, when pain tolerance is of interest, researchers should consider using water less than 10°C, particularly for older children (>8 years of age). Although small changes in water temperature influence pain tolerance and intensity among adults³⁰, this has yet to be examined among children. The ethical appropriateness of using colder water should be considered and empirically examined².

Although not reported in reviewed studies, water flow may impact pain intensity and tolerance⁴⁸. Attempts have been made to standardize the use of electric-cooled CPT apparatus⁴⁸, however the inconsistent water-cooling methods reported in this review, even amongst studies beginning recruitment after 2005, suggests that this standardization has not yet been widely adopted. To date, no research has examined the impact of water flow or type of CPT apparatus on pain outcomes.

CPT immersion time

Three or four minute maximum immersion times were common (though ranging from 20 seconds to 5 minutes). Use of an uninformed ceiling was most common, although this detail was absent from over one third of published papers. Inconsistent use of informed versus uninformed ceilings adds potential variability in pain outcomes as differences have been observed between children with chronic pain and their healthy peers⁴¹. Informed ceilings increase demand characteristics, as participants may believe that they “should” be able to endure the full duration. Moreover, children may focus on the passage of time, increasing their perception of control which has been shown to influence pain tolerance²⁵.

According to guidelines⁴⁹, an informed ceiling should be used when pain intensity is the

primary outcome whereas an uninformed ceiling is preferred when pain tolerance is of interest. Of the 22 studies examining tolerance, only four used an informed ceiling; however, many of these studies concurrently assessed pain intensity. It is our recommendation that uninformed ceilings should be used any time that pain tolerance is assessed. Additionally, we recommend that researchers remove potential sources of temporal information available to the child (e.g., clocks), as this may impact pain intensity⁵ or anxiety⁶.

Audience Effects

Despite being infrequently reported, at least one experimenter remained in the room with the child during the CPT in most studies. The experimenter's presence may be required to maximize standardization of procedures, to collect data during the task (e.g., pain ratings), or for safety monitoring. Nevertheless, researchers should be aware of audience effects, as the presence of others, particularly parents, can significantly impact children's experience and expression of pain^{4, 38, 52}. Several studies videotape the CPT, which may impact children's expressions of pain if they are aware of being filmed. Potential audience effects should be minimized by eliminating the presence of others and placing experimenters out of the child's sight when not necessitated by study design. Individuals present with the child, as well as their location in the room, should be clearly reported.

Outcome Measures

A strength of the CPT is its flexible application to a number of important theoretical and clinically relevant questions in pediatric pain. Pain intensity and tolerance were more commonly examined than pain affect or threshold. The variable measures and timing of pain intensity assessments (i.e., during or following the task) made it difficult to compare across studies. Reports of pain intensity immediately following the CPT have the advantage of limiting

audience effects and lowering distraction during the task, and should be used whenever possible. Several researchers excluded participants who reached ceiling tolerance times from analyses. We advise against this, as it misrepresents the range of participants' experiences, may bias results, and may be better solved by lowering water temperature, using an uninformed ceiling, or through data transformations. Results suggest a trend towards measurement of pain threshold, even with children as young as 5 years. We reiterate the suggestion of von Baeyer and colleagues⁴⁹ to use tolerance instead of threshold given potential difficulties with task comprehension and reliability with younger children. In order to help synthesize research using the CPT, we recommend use of evidence-based recommendations for measurement of pediatric pain outcomes (e.g., PedIMMPACT²⁸).

Limitations

While all included papers were published after 2005 when guidelines became available, almost half of studies began recruitment prior to this time. Generalizations of methodological trends must consider that a substantial number of papers ($n=11$) report variations of the same sample of participants from a single study that began recruitment prior to 2005^{1, 12-14, 17, 27, 33, 40-43}. While this review focused on information from published papers and author correspondence, it is possible that inconsistencies are due to a lack of reporting in papers and incomplete author response as opposed to real methodological differences. To improve interpretability of results, journals' publishing CPT research should encourage inclusion of methodological details that may significantly impact pain outcomes. Specifically, instructions to participants, water temperature, use of informed versus uninformed ceilings, and the presence of others during the CPT.

Conclusions

This review synthesizes contemporary CPT pediatric pain research. Although existing guidelines for use of the CPT with children appear to have brought some uniformity to the area⁴⁹, a number of aspects of CPT methodology remain highly inconsistent. This review highlights some of the discrepancies and offers updated recommendations to facilitate continued advancement of CPT methodology in pediatric pain. Although several questions remain concerning how to best standardize its use with pediatric pain populations, the CPT will undoubtedly continue as a useful tool to investigate a variety of aspects of the pain experience in an experimental setting.

Disclosures

K.A. Birnie is a Vanier Canada Graduate Scholar (Canadian Institutes of Health Research). K.A. Birnie, M. Petter, and M. Noel are Killam Scholars. M. Petter and M. Noel are supported by CGS Doctoral Awards from the Canadian Institutes of Health Research (CIHR). K.E. Boerner is supported by an IWK Graduate Student Research Scholarship and the McCarlie Graduate Student Award. K.A. Birnie, M. Petter, K.E. Boerner, and M. Noel are all trainee members of Pain in Child Health, a strategic research training initiative of CIHR. C.T. Chambers holds a Canada Research Chair and her research is supported by the Canadian Foundation for Innovation and CIHR. The authors have no conflicts of interest to declare.

References

1. Allen LB, Lu Q, Tsao JCI, Worthman CM Zeltzer LK: Sex differences in the association between cortisol concentrations and laboratory pain responses in healthy children. *Gen Med* 6 Suppl 2:193-207, 2009
2. Birnie KA, Noel M, Chambers CT, von Baeyer CL Fernandez CV: The cold pressor task: Is it an ethically acceptable pain research method in children? *J Pediatr Psychol* 36 10:1071-1081, 2011
3. Caes L, Vervoort T, Eccleston C, Vandenhende M Goubert L: Parental catastrophizing about child's pain and its relationship with activity restriction: The mediating role of parental distress. *Pain* 152 1:212-222, 2011
4. Chambers CT, Craig KD Bennett SM: The impact of maternal behavior on children's pain experiences: An experimental analysis. *J Pediatr Psychol* 27 3:293-301, 2002
5. Coldwell SE, Kaakko T, Gärtner-Makihara AB, Williams T, Milgrom P, Weinstein P Ramsay DS: Temporal information reduces children's pain reports during a multiple-trial cold pressor procedure. *Behav Ther* 33 :45-63, 2002
6. Crombez G, Baeyens F Eelen P: Sensory and temporal information about impending pain: The influence of predictability on pain. *Behav Res Ther* 32 6:611-622, 1994
7. Dahlquist LM, McKenna KD, Jones KK, Dillinger L, Weiss KE Ackerman CS: Active and passive distraction using a head-mounted display helmet: Effects on cold pressor pain in children. *Health Psychol* 26 6:794-801, 2007
8. Dahlquist LM, Weiss KE, Clendaniel LD, Law EF, Ackerman CS McKenna KD: Effects of videogame distraction using a virtual reality type head-mounted display helmet on cold pressor pain in children. *J Pediatr Psychol* 34 5:574-584, 2009
9. Dahlquist LM, Weiss KE, Law EF, Sil S, Herbert LJ, Horn SB, Wohlheiter K Ackerman CS: Effects of videogame distraction and a virtual reality type head-mounted display helmet on cold pressor pain in young elementary school-aged children. *J Pediatr Psychol* 35 6:617-625, 2010
10. Dufton LM, Konik B, Colletti R, Stanger C, Boyer M, Morrow S Compas BE: Effects of stress on pain threshold and tolerance in children with recurrent abdominal pain. *Pain* 136 1-2:38-43, 2008
11. Dufton LM, Dunn MJ, Slosky LS Compas BE: Self-reported and laboratory-based responses to stress in children with recurrent pain and anxiety. *J Pediatr Psychol* 36 1:95-105, 2011
12. Evans S, Lu Q, Tsao JCI Zeltzer LK: The role of coping and race in healthy children's experimental pain responses. *J Pain Manag* 1 2:151-162, 2008

13. Evans S, Tsao JCI, PhD. Zeltzer LK, M.D.: Relationship of child perceptions of maternal pain to children's laboratory and nonlaboratory pain. *Pain Res Manag* 3:211-218, 2008
14. Evans S, Tsao JCI, Lu Q, Kim SC, Turk N, Myers CD Zeltzer LK: Sex differences in the relationship between maternal negative life events and children's laboratory pain responsivity. *J Dev Behav Pediatr* 30 4:279-288, 2009
15. Feuerstein M: Potential biobehavioral mechanisms of recurrent abdominal pain in children. *Pain* 13 3:287-298, 1982
16. Goffaux P, Lafrenaye S, Morin M, Patural H, Demers G Marchand S: Preterm births: Can neonatal pain alter the development of endogenous gating systems? *Eur J Pain* 12 7:945-951, 2008
17. Haas K, Lu Q, Evans S, Tsao JCI Zeltzer LK: Relationship Between Resting Blood Pressure and Laboratory-Induced Pain Among Healthy Children. *Gend Med* 8 6:388-398, 2011
18. Hermann C, Zohsel K, Hohmeister J Flor H: Dimensions of pain-related parent behavior: Development and psychometric evaluation of a new measure for children and their parents. *Pain* 137 3:689-699, 2008
19. Jaaniste T, Hayes B von Baeyer CL: Effects of preparatory information and distraction on children's cold-pressor pain outcomes: A randomized controlled trial. *Behav Res Ther* 45 11:2789-2799, 2007
20. Keenan K, Hipwell AE, Hinze AE Babinski DE: The association of pain and depression in preadolescent girls: Moderation by race and pubertal stage. *J Pediatr Psychol* 34 7:727-737, 2009
21. King S, Chambers CT, Huguet A, MacNevin RC, McGrath PJ, Parker L MacDonald AJ: The epidemiology of chronic pain in children and adolescents revisited: A systematic review. *Pain* 152 12:2729-2738, 2011
22. Larochette A, Chambers CT Craig KD: Genuine, suppressed and faked facial expressions of pain in children. *Pain* 126 :64-71, 2006
23. Law EF, Dahlquist LM, Sil S, Weiss KE, Herbert LJ, Wohlheiter K Horn SB: Videogame distraction using virtual reality technology for children experiencing cold pressor pain: The role of cognitive processing. *J Pediatr Psychol* 36 1:84-94, 2011
24. LeBaron S, Zeltzer LK Fanurik D: An investigation of cold pressor pain in children: I. *Pain* 37 2:161-171, 1989
25. Litt MD: Self-efficacy and perceived control: Cognitive mediators of pain tolerance. *J Pers Soc Psychol* 54 1:149-160, 1988

26. Lu Q, Zeltzer LK, Tsao JCI, Kim SC, Turk N Naliboff BD: Heart rate mediation of sex differences in pain tolerance in children. *Pain* 118 :185-193, 2005
27. Lu Q, Tsao JCI, Myers CD, Kim SC Zeltzer LK: Coping predictors of children's laboratory-induced pain tolerance, intensity, and unpleasantness. *J Pain* 8 9:708-717, 2007
28. McGrath PJ, Walco GA, Turk DC, Dworkin RH, Brown MT, Davidson K, Eccleston C, Finley GA, Goldschneider K, Haverkos L, Hertz SH, Ljungman G, Palermo T, Rappaport BA, Rhodes T, Schechter N, Scott J, Sethna N, Svensson OK, Stinson J, Baeyer CLv, Walker L, Weisman S, White RE, Zajicek A Zeltzer L: Core Outcome Domains and Measures for Pediatric Acute and Chronic/Recurrent Pain Clinical Trials: PedIMMPACT Recommendations. *J Pain* 9:771-783, 2008
29. Mennella JA, Pepino MY, Lehmann-Castor S Yourshaw LM: Sweet preferences and analgesia during childhood: Effects of family history of alcoholism and depression. *Addiction* 105 4:666-675, 2010
30. Mitchell LA, MacDonald RAR Brodie EE: Temperature and the Cold Pressor Test. *J Pain* 5 4:233-238, 2004
31. Moon EC, Chambers CT McGrath PJ: "He Says, She Says": A Comparison of Fathers' and Mothers' Verbal Behavior During Child Cold Pressor Pain. *J Pain* 12 11:1174-1181, 2011
32. Moon EC, B.A., Chambers CT, PhD., Larochette A, Hayton K, Craig KD, PhD. McGrath PJ, PhD.: Sex differences in parent and child pain ratings during an experimental child pain task. *Pain Research & Management : The Journal of the Canadian Pain Society* , 2008
33. Myers CD, Tsao JCI, Glover DA, Kim SC, Turk N Zeltzer LK: Sex, Gender, and Age: Contributions to Laboratory Pain Responding in Children and Adolescents. *J Pain* 7 8:556-564, 2006
34. Noel M, Chambers CT, McGrath PJ, Klein RM Stewart SH: The Role of State Anxiety in Children's Memories for Pain. *J Pediatr Psychol*, 2012 Feb 23; [Epub ahead of print]
35. Noel M, Chambers CT, McGrath PJ, Klein RM Stewart SH: The influence of children's pain memories on subsequent pain experience. *Pain*, 2012 May 2; [Epub ahead of print]
36. Piira T, Hayes B, Goodenough B von Baeyer CL: Effects of attentional direction, age, and coping style on cold-pressor pain in children. *Behav Res Ther* 44 6:835-848, 2006
37. Stuber M, Hilber SD, Mintzer LL, Castaneda M, Glover D Zeltzer L: Laughter, Humor and Pain Perception in Children: A Pilot Study. *Evid Based Complement Alternat Med* 6 2:271-276, 2009
38. Sullivan MJL, Adams H Sullivan ME: Communicative dimensions of pain catastrophizing: social cueing effects on pain behaviour and coping. *Pain* 107 3:220-226, 2004

39. Trapanotto M, Pozziani G, Perissinotto E, Barbieri S, Zacchello F Benini F: The cold pressor test for the pediatric population: Refinement of procedures, development of norms, and study of psychological variables. *J Pediatr Psychol* 34 7:749-759, 2009
40. Tsao JCI, Evans S, Seidman LC Zeltzer LK: Healthcare utilization for pain in children and adolescents: A prospective study of laboratory and non-laboratory predictors of care-seeking. *Int J Adolesc Med Health* 23 3:287-292, 2011
41. Tsao JCI, Evans S, Seidman LC Zeltzer LK: Experimental pain responses in children with chronic pain and healthy children: How do they differ? *Pain Res Manag* 2:103-109, 2012
42. Tsao JCI, Lu Q, Kim SC Zeltzer LK: Relationships among anxious symptomatology, anxiety sensitivity and laboratory pain responsivity in children. *Cogn Behav Ther* 35 4:207-215, 2006
43. Tsao JCI, Lu Q, Myers CD, Kim SC, Turk N Zeltzer LK: Parent and Child Anxiety Sensitivity: Relationship to Children's Experimental Pain Responsivity. *J Pain* 7 5:319-326, 2006
44. Verhoeven K, Goubert L, Jaaniste T, Ryckeghem DMLV Crombez G: Pain catastrophizing influences the use and the effectiveness of distraction in schoolchildren. *Eur J Pain*:256-267, 2011 Jul 26; [Epub ahead of print]
45. Vervoort T, Goubert L Crombez G: The relationship between high catastrophizing children's facial display of pain and parental judgment of their child's pain. *Pain* 142 1-2:142-148, 2009
46. Vervoort T, Caes L, Trost Z, Sullivan M, Vangronsveld K Goubert L: Social modulation of facial pain display in high-catastrophizing children: An observational study in schoolchildren and their parents. *Pain* 152 7:1591-1599, 2011
47. Vierhaus M, Lohaus A Schmitz A: Sex, gender, coping, and self-efficacy: Mediation of sex differences in pain perception in children and adolescents. *Eur J Pain* 15 6:e1-e8, 2011
48. von Baeyer CL, Torvi D, Hemingson H Beriault D: Water circulation and turbulence in the cold pressor task: Unexplored sources of variance among experimental pain laboratories. *Pediatric Pain Letter* 13 1:13-16, 2011
49. von Baeyer CL, Piira T, Chambers CT, Trapanotto M Zeltzer LK: Guidelines for the Cold Pressor Task as an Experimental Pain Stimulus for Use With Children. *J Pain* 6 4:218-227, 2005
50. Weiss KE, Dahlquist LM Wohlheiter K: The effects of interactive and passive distraction on cold pressor pain in preschool-aged children. *J Pediatr Psychol* 36 7:816-826, 2011
51. Wolf S Hardy JD: Studies on pain. Observations on pain due to local cooling and on factors involved in the "cold pressor" effect. *J Clin Invest* 22 5:521-533, 1941
52. Zeman J Garber J: Display Rules for Anger, Sadness, and Pain: It Depends on Who Is Watching. *Child Dev* 67 3:957-973, 1996

Table 1

Summary of Reporting of Sample Characteristics and CPT Methodologies Across Studies

Authors	Participants			CPT Methodology								
	N	Sample	Age Range (years)	Method Cooled	Water Temp	Max. Immersion Time	# of CPTs	Warm Water Bath	Ceiling	Hand Submersed	Observer in Room	Pain Outcome
1. Dahlquist et al. ⁷	40	Healthy	5-13	Ice	5 ⁰ C	4 min	3 or 4	Between	Uninformed*	Non-dominant	Experimenter	Threshold, Tolerance
2. Dahlquist et al. ⁸	41	Healthy	6-14	Electric	5 ⁰ C	4 min	3 or 4	Between	Uninformed*	Non-dominant	Experimenter	Threshold, Tolerance
3. Dahlquist et al. ⁹	50	Healthy	6-10	Electric	7 ⁰ C	4 min	3 or 4	Between	Uninformed*	Non-dominant	Experimenter	Threshold, Tolerance
4. Dufton et al. ¹⁰	49	Clinical	9-17	Ice	5 ⁰ C	4 min	1	NR	NR	NR	NR	Intensity, Threshold, Tolerance
5. Dufton et al. ¹¹	63	Both	8-16	Ice	5 ⁰ C	4 min	1	NR	NR	NR	NR	Intensity, Tolerance
6. Goffaux et al. ¹⁶	26	Both	7-11	NR	13 ⁰ C	3 min	1	NR	NR	Right	NR	Intensity
7. Hermann et al. ¹⁸	47	Both	8-16	NR	10 ⁰ C	5 min	1	NR	NR	NR	Mother	Intensity
8. Jaaniste et al. ¹⁹	79	Healthy	7-12	Ice	1 ⁰ C	4 min	1	Prior	Uninformed*	Non-dominant	Experimenter	Intensity, Tolerance
9. Keenan et al. ²⁰	224	Both*	10-11	Ice	10 ⁰ C	3 min	1	Prior	Informed*	Dominant	Experimenter*	Intensity, Threshold, Tolerance
10. Larochette et al. ²²	50	Healthy	8-12	Ice	10 ⁰ C	20 sec	2	No*	Informed*	Counter-balanced	Experimenter	-
11. Law et al. ²³	79	Healthy	6-15	Electric	7 ⁰ C	4 min	3 or 4	Between	Uninformed*	Non-dominant	Experimenter	Tolerance
12. Mennella et al. ²⁹	250	Healthy	5-12	NR	10 ⁰ C	4 min	2	Prior	NR	Non-dominant	NR	Threshold, Tolerance
13. Moon et al. ³²	73	Healthy	4-12	Ice	11 ⁰ C	1 min	1	No*	Informed	Non-dominant*	Parent	Intensity
14. Moon et al. ³¹	40	Healthy	8-12	Ice	10 ⁰ C	4 min	2	No*	Informed	Alternate	Parent	Intensity, Tolerance, Affect
15. Noel et al. ³⁴	110	Healthy	8-12	Ice	10 ⁰ C	4 min	1	No*	Informed	Non-dominant	Experimenter*	Intensity, Affect
b. Noel et al. ³⁵	110	Healthy	8-12	Ice	10 ⁰ C	4 min	2	No*	Informed	Non-dominant	Experimenter*	Intensity, Affect

	N	Sample	Age Range (years)	Method Cooled	Water Temp	Max. Immersion Time	# of CPTs	Warm Water Bath	Ceiling	Hand Submersed	Observer in Room	Pain Outcome
15. Piira et al. ³⁶	120	Healthy	7-14	Ice	10 ⁰ C	4 min	1	Prior	Uninformed*	Non-dominant	Experimenter	Intensity, Tolerance
16. Stuber et al. ³⁷	18	Healthy	7-16	Ice	10 ⁰ C	3 min	3	Between (Towel)	Uninformed	Child Chose	Experimenter	Intensity, Tolerance
17. Trapanotto et al. ³⁹	141	Healthy	8-12	Electric	10 ⁰ C	3 min	1	Prior	Uninformed	Non-dominant	Experimenter	Intensity, Threshold, Tolerance, Affect
18. Tsao et al. ⁴²	234	Healthy	8-18	Ice	10 ⁰ C	3 min	1	No*	Uninformed	Non-dominant	Experimenters*	Intensity
b. Tsao et al. ⁴³	211	Healthy	8-18	Ice	10 ⁰ C	3 min	2	No*	Uninformed	Alternate	Experimenters*	Intensity
c. Myers et al. ³³	240	Healthy	8-18	Ice	10 ⁰ C	3 min	1	No*	Uninformed	Non-dominant	Experimenters*	Intensity, Tolerance, Affect
d. Lu et al. ²⁷	244	Healthy	8-18	Ice	10 ⁰ C	1 min	1	No*	Informed	Dominant	Experimenters*	Intensity, Tolerance, Affect
e. Evans et al. ¹³	186	Healthy*	8-18	Ice	10 ⁰ C	1 min	1	No*	Informed	Dominant	Experimenters*	Intensity
f. Evans et al. ¹²	123	Healthy	8-17*	Ice	10 ⁰ C	3 min	1	No*	Uninformed	Dominant	Experimenters*	Intensity
g. Allen et al. ¹	235	Healthy	8-18	Ice	10 ⁰ C	3 min	1	No*	Informed	Dominant	Experimenters*	Intensity, Tolerance, Affect
h. Evans et al. ¹⁴	176	Healthy	8-18	Ice	10 ⁰ C	3 min	1	No*	Uninformed	Non-Dominant	Experimenters*	Intensity, Tolerance
i. Haas et al. ¹⁷	235	Healthy	8-18	Ice	10 ⁰ C	3 min	1	No*	Uninformed	Dominant	Experimenters*	Intensity, Tolerance, Affect
j. Tsao et al. ⁴⁰	210	Healthy	8-18	Ice	10 ⁰ C	3 min	1	No*	Uninformed	Non-dominant	Experimenters*	Intensity, Affect
k. Tsao et al. ⁴¹	52	Both	8-18	Ice	10 ⁰ C	3 min	2	No*	Uninformed	Alternate	Experimenters*	Intensity, Tolerance, Affect
19. Vervoort et al. ⁴⁵	62	Healthy	9-15	Electric	10 ⁰ C	3 min	1	Prior	Informed	Left	Experimenter	Intensity, Affect

	N	Sample	Age Range (years)	Method Cooled	Water Temp	Max. Immersion Time	# of CPTs	Warm Water Bath	Ceiling	Hand Submersed	Observer in Room	Pain Outcome
b. Caes et al. ³	62	Healthy	9.25-15.5	Electric	10 ⁰ C	3 min	1	Prior	Informed	Left	Experimenter	Intensity
20. Vervoort et al. ⁴⁶	38	Healthy	10-18	Electric*	12 ⁰ C	1 min	2	Prior and Between	Informed*	Alternate	Experimenter	Intensity
b. Verhoeven et al. ⁴⁴	87	Healthy	9-18	Electric	12 ⁰ C	1 min	1	Prior	Informed	Left	Experimenter	Intensity, Affect
21. Vierhaus et al. ⁴⁷	118	Healthy*	10-17	Electric	6 ⁰ C	3 min	1	Prior	Uninformed	Non-dominant	Experimenter	Intensity, Tolerance
22. Vierhaus et al. ⁴⁷	148	Healthy*	10-17	Electric	6 ⁰ C	3 min	1	Prior	Uninformed	Non-dominant	Experimenter	Intensity, Tolerance
23. Weiss et al. ⁵⁰	61	Healthy	3-5	Ice	10 ⁰ C	4 min	3 or 4	Between	Uninformed	Non-dominant	Experimenter	Tolerance

Note. Studies with overlapping samples are subsumed in the table under the earliest paper to meet review inclusion criteria. * denotes that information was not reported in published paper, but was obtained through e-mail correspondence with study author(s). NR = information was not reported in published paper and was not provided by study author(s).