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A systematic review of measures of breakthrough pain and their psychometric properties

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ABSTRACT:
Context: Breakthrough pain (BTP) is common in cancer and other conditions yet there is a lack of validated BTP measurement tools.
Objectives: We aimed to identify all tools assessing or characterising BTP in patients of any age with any condition, and to critically appraise their psychometric properties.
Methods: The Cochrane Library, PROSPERO, Embase, CINAHL, Medline, PsycINFO, Web of Science, Google Scholar, ProQuest, Evidence Search and OpenGrey were searched to identify all available tools used to assess BTP. A second search identified studies that had evaluated psychometric properties of tools identified in Search 1. Databases were searched from inception to November 2020. Studies were assessed using COSMIN criteria and GRADE guidelines.
Results: Search 1 found 51 tools used to assess BTP. Search 2 found six tools that had a development study and/or a study evaluating a tool psychometric property. No tool had more than one study evaluating psychometric properties so a meta-analysis could not be conducted. Studies were of inadequate to very good quality. Only the Breakthrough Pain Assessment Tool (BAT) had sufficient content validity and at least low-quality evidence for sufficient internal consistency.
Conclusion: The BAT is recommended to characterise BTP in adults with cancer; its applicability to other conditions is unknown. The remaining tools need further evaluation. Only the Breakthrough Pain Questionnaire for Children was designed for children with cancer, but no psychometric properties were evaluated. There is a need for a tool to assess and characterise BTP in children with non-cancer diagnoses and those who cannot self-report.

KEYWORDS
Breakthrough pain
Pain assessment
Measurement properties
Patient-reported outcome measures (PROMs)
COSMIN guidelines
Pediatric

KEY MESSAGE

This systematic review aimed to identify all tools assessing or characterising breakthrough pain, and to critically appraise their psychometric properties. The Breakthrough Pain Assessment Tool is recommended to characterise breakthrough pain in adults with cancer; its applicability to other conditions and ages is unknown. The remaining tools need further evaluation.

INTRODUCTION

Breakthrough pain (BTP) is common in both adults (1, 2) and children (3) with cancer (4), life-limiting conditions (5, 6) and at end-of-life (7-9). BTP was initially described as a transitory pain increase occurring in patients experiencing mild to moderate background pain (10). A recent consensus statement produced by 12 experts in cancer pain proposed that these episodes are of moderate-to-high pain intensity, occur rapidly and last about an hour (1). Episodes may be initiated by a voluntary or involuntary act or a therapeutic intervention (incident BTP) or spontaneous (idiopathic and unpredictable) (11). The definition has been narrowed down to episodes of severe pain in patients on a stable opioid regime for background pain (12, 13). However, a review of international cancer BTP guidelines found that only one (14) of the 10 guidelines include opioid treatment as a prerequisite for a BTP diagnosis (15). Indeed, the European Association for Palliative Care Research Network proposed that the term 'episodic' could be used for all significant transient cancer pain exacerbations, including those that occur with or without background pain or regular pain relief (16).

The lack of agreement on the precise definition of BTP in the literature, and the fact that BTP can have different causes, comorbidities and pathophysiology, can make it complex to diagnose, assess and manage. As such, prevalence of BTP is hard to estimate, with a systematic review of over 6000 adult cancer patients reporting that between 33-95% experienced BTP, with nearly 50% being undertreated (4). There is less data on BTP in non-cancer populations but a US survey of 2198 outpatients with non-cancer opioid-treated chronic pain found that 80% reported BTP (17). The BTP prevalence in children is even less certain, though one study reported that, of 27 children with cancer aged 7-18 years being treated with opioids, 57% experienced BTP in the last 48 hours (7). A medical records review also reported that 7-12-year-olds were more likely to experience BTP compared to older children, despite controlled background pain (5).

Unsurprisingly, mental and physical wellbeing, quality of life, productivity and daily functioning are all lower in adults with BTP compared to those without pain or with background pain only (17). Reports indicate that BTP may reduce carer wellbeing (18, 19) though little is known about how BTP effects paediatric patients. BTP also has a significant financial impact on health services and patients (20).

Although a recent systematic review found that guidelines for managing BTP in cancer were generally in agreement, there is a lack of consistent evidence to support these (15). A barrier to high-quality research is a lack of consistency in characterising and assessing BTP. It is important that BTP is distinguished from background pain (11, 13), 'end-of-dose failure' of around-the-clock treatment or pain occurring when opioids are started or titrated (11, 21). There is also a lack of research on BTP tools for children and people with non-cancer diagnoses. One study piloted a paediatric BTP data extraction form designed to generate information from clinical records (5). However, this showed poor agreement between raters, indicating that validated tools for assessing and managing paediatric BTP are needed.

BTP must be assessed and monitored accurately to allow for successful treatment and particularly to avoid under-management (13, 22) or over-treatment with opioids (23). However, failures to detect and treat BTP remain common (14, 24). Inadequate pain assessment is cited by physicians as the main barrier to correct BTP diagnosis and management (25) while a recent review reported the lack of validated pain tools and poor uptake of existing tools as barriers to BTP management (26). Thus, the main objectives of this systematic review were to

1) Identify all available instruments diagnosing, measuring, or characterising self-, or caregiver-reported BTP in infants, children or adults with any diagnoses and conditions

2) Critically appraise, compare and summarise the quality of the measurement properties of the identified instruments using COSMIN (COnsensus-based Standards for the selection of health Measurement Instruments) criteria (27)

Where possible, we then aimed to formulate recommendations for the most appropriate tools to assess and characterise BTP for different populations.

METHODS

This systematic review followed the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) (28) and COSMIN guidelines (29). A detailed description of the methods is included in our published protocol (30) and on PROSPERO (CRD42019155583)(31).

Searches

Two searches were run. The first aimed to identify all available instruments used to diagnose, measure, or describe BTP in patients of any age and with any diagnoses (see Table 1 for Search 1 study inclusion and exclusion criteria). The second search aimed to identify all studies that developed a BTP instrument or evaluated psychometric properties of BTP instruments (see protocol for a complete list).

Electronic sources:

To check for any existing systematic reviews in this area, the Cochrane Library and PROSPERO were searched first, followed by EMBASE, CINAHL (Cumulative Index of Nursing and Allied Health Literature), MEDLINE (both via Ebsco), PsycINFO, the Web of Science Core Collection, the ProQuest Dissertations & Theses Database, Evidence Search and OpenGrey. Searches were also undertaken using the advanced Google Scholar search facility (first 50 records for each search). Searches were first run between October 2019 and January 2020. The searches were re-run in November 2020 to check for any articles published between February-November 2020. The reference lists of relevant studies were searched and researchers who had developed a BTP tool identified in Search 1 were contacted to check for any published or unpublished relevant studies. All records were saved to Endnote X8 (32), which was used to identify potential duplicates and removed confirmed ones.

Search 1

Search 1 comprised of two concept blocks: 1) Breakthrough pain; and 2) Assessment tools. Since there is no consensus on the definition of BTP, terms describing incidental, episodic, transient, or spontaneous pain or pain flares were included in block 1.

Two reviewers (KG and SH) screened each article identified in Search 1 by title and abstract, and full text where necessary, to identify if BTP was assessed. All articles in which BTP was assessed were then grouped into one of the following categories, depending on whether the study involved 1) a named BTP assessment; 2) a generic pain assessment tool used to assess BTP; 3) a bespoke BTP assessment developed by the authors for the purposes of the study; 4) BTP assessed using only a visual analogue scale; or 5) BTP assessed using only a numerical scale. The articles identified in Search 1 were not assessed further unless they met criteria for search 2.

Search 2

The named BTP assessment tools and generic (named) pain assessment tools used to assess BTP in studies found in Search 1 were searched for in Search 2. Search 2 comprised of two concept blocks: 1) The names of the tools used to assess BTP as identified in Search 1; and 2) Measurement properties of these assessments. For Search 2 – block 2, COSMIN search filters were used in Medline, Embase, PsycINFO and CINAHL for identifying studies that evaluate measurement properties of assessments. No search filters were available for the remaining databases so only block 1 was used for these. *S*earch strategies were piloted with terms chosen and adapted for each database to optimise the sensitivity and specificity of the search (See Supplementary File 1 and 2 for the full search strategies).

For Search 2, KG and SH screened all articles by title and abstract and judged them as either ‘not relevant’ or ‘potentially relevant’. Both reviewers read the full text of all potentially relevant articles to make the final inclusion decision.

Data extraction

Data was extracted from all identified studies in Search 1 group 1 and group 2 on the characteristics of the *tools* used to diagnose, measure, or describe BTP. Data was then extracted from all identified studies in Search 2 on the characteristics of the *studies* that either developed these tools or assessed their measurement properties. All data was extracted by KG and checked by DES. KG and DES appraised the quality of all included studies from Search 2 using the COSMIN guidelines and user manual (27, 33). Differences in ratings were resolved by discussion between KG, DES, and CL.

Data Assessment

Two researchers (KG and DS) assessed the data, graded the quality of the evidence and formulated recommendations. Any disagreements in ratings were resolved via discussion with a third researcher (CL).

Assessing methodological quality: The COSMIN Risk of Bias checklist (34) was used to assess the methodological quality of each individual study on a psychometric property. The checklist comprises of 10 separate boxes for assessing content validity; structural validity; internal consistency; cross-cultural validity; reliability; measurement error; criterion validity; hypotheses testing for construct validity; and responsiveness (see protocol for assessment criteria). Only psychometric properties that were assessed in each included study were completed. Studies were then given an overall rating of very good, adequate, doubtful, or inadequate methodological quality.

Assessing the results of psychometric properties: The result of each study on a psychometric was rated as sufficient, insufficient, inconsistent or indeterminate using the COSMIN updated criteria for good measurement properties (33).

Grading the quality of the evidence: the quality of the evidence for each evaluated psychometric property per BTP assessment was graded using a version of The GRADE guidelines (35) modified by COSMIN. This involves grading the evidence as high, moderate, low, or very low quality based on four factors: risk of bias, inconsistency, indirectness, and imprecision. Inconsistency refers to inconsistent results between studies of the same assessment tool; indirectness occurs when a tool has been assessed in a population different to the intended population; and imprecision refers to wide confidence intervals calculated from quantitatively pooling results across studies. However, since only one study per measurement property per tool were found and we included all populations in this review, inconsistency, indirectness and imprecision could not be assessed thus the quality of the evidence was based on the studies' risk of bias only.

Interpretability and Feasibility: The interpretability (the extent to which clinical or commonly understood meanings can be assigned to scores) and feasibility (ease of application) of the BTP assessment tools were rated using COSMIN criteria.

RESULTS

The flow diagrams of search results are shown in Figure 1 (Search 1) and Figure 2 (Search 2). After duplicate removal, 11,109 records were identified in Search 1. After sifting, we found 56 studies using a named tool designed to assess BTP; 13 using a generic pain assessment tool to assess BTP (either the BPI (36) or the McGill Pain Questionnaire (37)); 42 using a bespoke BTP assessment developed for the purposes of the study; 24 studies assessing BTP using only a visual analogue scale and 81 assessing BTP using only a numerical scale. Since the search strategy aimed at finding BTP assessment tools, it is unlikely that this is an exhaustive list of all studies that have assessed BTP using only a visual analogue or numerical scale. Inter-coder agreement for article inclusion/exclusion by full text for Search 1 was 1 (Cohen's kappa coefficient). The characteristics of the tools used to diagnose, measure, or describe BTP in groups 1-3 are shown in Supplementary File 3.

Of the 14 named tools used to assess BTP, three were comprised of a diagnostic algorithm only: Webber's Breakthrough Cancer Pain Algorithm (38, 39); and the Davies Algorithm (2009 and 2011 versions) (13,

40). Seven involved both a diagnostic algorithm and an assessment of the characteristics of the BTP: the Breakthrough Pain Questionnaire (BPQ) (10), the Breakthrough Pain Questionnaire for Children (BPQC) (7), the Questionnaire for Intense Episodic Pain (QUDEI) (41), the Episodic Pain Documentation Sheet (EPDS) (42), the Italian Questionnaire for Breakthrough Pain (IQ-BTP) (43), the Pain Guard Mobil App (44) and the INES-DIO Mobile App (45). Two comprised of an assessment of the BTP characteristics only: The Alberta Breakthrough Pain Assessment Tool (ABPAT) (46) and the Breakthrough Pain Assessment Tool (BAT) (38, 47). Seven tools were developed to assess cancer BTP specifically (13, 39, 44-47), one was developed for cancer or non-cancer pain (37) and the remaining tools did not specify the patient population (7, 10, 41-43). Only the BTPC was designed to assess BTP in children. Two tools were mobile apps (44, 45) and the remainder were paper and pencil questionnaires. There was also a translation of the APBAT into Italian (48) and translations of the BAT into Dutch (49) and Korean (50).

For Search 2, 6905 records were found after removing duplicates. After sifting, 11 studies were included by full text. Search 2 found no development studies or studies evaluating any measurement property of the 2009 or the 2011 Davies Algorithm; the BPQ; the BPQC; the EPDS; the INES DIO mobile app; the BPI or the McGill Pain Questionnaire when used to measure breakthrough pain. For the remaining tools, one study per tool was identified that developed the tool and/or evaluated one or more measurement property. Characteristics of development studies and studies assessing measurement properties of BTP assessment tools are shown in Table 2. Since no more than one study per tool was found (translations were treated as different tools), a meta-analysis or other method of summarising the results per tool was not possible.

Eight tools had a published development study (39, 43, 44, 46-50), none of which were of adequate or higher quality. The COSMIN (33) quality ratings of these development studies are shown in Table 3a. The quality ratings of all studies that assessed one or more psychometric property of a BTP tool are shown in Table 3b. Agreement between raters for risk of bias results shown in Table 3a and 3b (combined) was high ($k = 0.792$, $p < 0.001$). Ratings for the results of psychometric property evaluations and their corresponding quality ratings are presented in Table 3c. There was moderate agreement between raters for overall risk of bias results, $k = 0.638$, $p < 0.001$ (kappa was calculated separately for Table 3c since the rating categories were different to those used in Tables 3a and 3b).

Interpretability and feasibility of BTP assessment tools assessed using COSMIN criteria are shown in Tables 4 and 5. Interpretability was challenging to rate for most tools. Since the goal of the tools was either to diagnose the presence or absence of BTP (binary outcome) or to characterise the nature of the BTP, it was not possible to assess distribution of the scores, floor/ceiling effects or information on response shifts, as recommended by COSMIN. Percentage of missing data was only reported in two studies (both < 5%) while minimal important difference was only reported for the BAT. Some studies reported the percentage of all patients diagnosed with BTP and/or background pain. However, on their own, the meaningfulness of these scores is hard to interpret. More usefully, Webber and colleagues (38) reported that total BAT scores were higher in those with inadequately controlled BTP (both self-rated and clinician-rated) and in those for whom changes were made to pain medication. Similar findings were reported for the Dutch version of the BAT.

Feasibility of the tools was mainly rated by the reviewers since no studies asked patients or professionals about tool feasibility. No tools were rated as requiring a high degree of patient or clinician comprehensibility or ability and none appeared overly long, time-consuming, or difficult to administer or score.

Although eight studies (39, 41, 43, 46-50) evaluated at least one psychometric property of a BTP assessment tool, there was a wide variety in the choice of property that was evaluated, making comparisons between tools challenging. To make recommendations for the most appropriate assessment tool, the COSMIN guidelines recommends categorising tools into three categories:

1) Those with sufficient content validity and at least low-quality evidence for sufficient internal consistency;

2) Tools with high quality evidence for an insufficient measurement property;

3) Tools not in 1) or 2)

Group 1 – recommended tools

Tools in group 1 can be recommended for use and results from the tool can be trusted according to the COSMIN criteria.

The BAT

The BAT was the only tool to meet criteria for the first category. Five measurement properties of the BAT were evaluated by Webber and colleagues in a study involving participants aged 27-89 years (38, 47). The study was published as a PhD thesis (38) and, subsequently, as a peer-reviewed journal article (47). Sufficient evidence for content validity came from a development study but this was of low quality. The authors did not state that they assessed structural validity. However, they conducted an exploratory factor analysis to assess unidimensionality, which, according to COSMIN (33), can be used as sufficient evidence for structural validity (moderate quality). There was also sufficient evidence for internal consistency (high quality); reliability (low quality); construct validity (moderate quality) and responsiveness (high quality). Other measurement properties were not evaluated.

The aim of the BAT is to characterise the nature of the patient's BTP in the previous week. This includes location, temporal characteristics, severity, distress, and interference; and documenting what exacerbates and alleviates the pain as well as the type, effectiveness, and side-effects of the patient's medication. While thorough, this 14-item questionnaire is shorter than the 22-item APBAT and can be used in both clinical and research settings. However, unlike the BPQ, BPQC, QUDEI, EPDS, and IQ-BTP, the BAT is not designed to diagnose BTP but presumes that the presence of BTP has already been established.

Group 2 – tools not recommended for use

Tools in the second group are not recommended for use by COSMIN. No tools were in this category. However, both the BPI and the McGill Pain Questionnaire have been used to assess BTP even though these were not designed to do this. A generic pain tool such as these may fail to distinguish BTP from other types of pain, which could affect management. Thus, we do not recommend these tools for assessing BTP.

Group 3 – tools requiring further assessment

Tools in this group have potential for being recommended but require further assessment.

Webber's Breakthrough Cancer Pain Algorithm

This algorithm is designed to assess for the presence of BTP in cancer using three closed questions but not to characterise the pain. BTP is diagnosed when a patient has mild (but not moderate or severe) background pain with short episodes of more severe pain. Three psychometric properties of Webber's algorithm have been assessed by Webber and colleagues (38, 39). Evidence for content validity was inconsistent and of low quality since it was not clear how items were chosen. Though the quality of the methods was high, there was not sufficient evidence for criterion validity. Evidence for known groups validity was doubtful and of low quality.

The Davies Algorithm (2009 and 2011 versions)

The Davies algorithm uses three closed question to assess the presence of BTP in cancer patients**.** Similarly to Webber's algorithm, patients are diagnosed with BTP if they have no or mild background pain with transient exacerbations of pain. Although 14 studies were found using the Davies algorithm to diagnose BTP (14 using the 2009 version, 2 using the 2011 version), we found no development studies or studies evaluating measurement properties thus its reliability and validity are unknown.

The APBAT

The APBAT is a 22-item questionnaire used to characterise BTP in cancer patients in research settings. Sufficient evidence for content validity was found in one study (46). However, the quality of this evidence was low since it was unclear whether all items were tested with participants in their final form and patients were not asked about the comprehensiveness of items.

The Italian APBAT

Sperlinga and colleagues (48) developed an Italian version of the APBAT but content validity was indeterminate (with low quality) and no other measurement properties of either version of the tool have been evaluated.

The Dutch BAT

A Dutch version of the BAT has recently been developed by Oldenmenger and colleagues (49). Content validity of the Dutch BAT was indeterminate and of low quality. There was indeterminate evidence for both structural validity and internal consistency, both with high quality of evidence. There was sufficient evidence for reliability, construct validity and responsiveness, with low, moderate, and very low quality, respectively.

The BAT-K

A Korean version of the BAT was developed by Shin and colleagues in 2017 (50). Evidence of content validity was indeterminate and of low quality. Evidence of structural validity and responsiveness of the BAT-K were both indeterminate and of moderate quality. There was sufficient evidence for internal consistency and reliability, with high and low quality, respectively.

The BPQ

The BPQ was developed to diagnose and characterise pain and has been used with patients with cancer or other conditions. BTP was defined as mild-moderate baseline pain with temporary flares of severe or excruciating pain. With 26 items, this is one of the longer tools though items have changed over time. No development studies or studies evaluated the BPQ's measurement properties were found.

The BPQC

The BPQC was the only tool found that was designed for use in children. It aims to diagnose and characterise BTP in children with conditions including cancer. Children with background pain severity of between 0-4 on a 0-10 rating scale (where 0 = none) and 'sudden strong pain somewhere on you without doing anything special' are diagnosed with BTP according to the tool. However, it does not have a sufficient development or content validity study and no studies were found that evaluated any of the BTCP's measurement properties.

The EPDS

The EPDS is a 14-item questionnaire that aims to characterise BTP. It was designed for use in clinical settings for patients with cancer or other conditions. No development studies or studies evaluating any measurement properties were found.

The INES DIO Mobile App

The INES DIO is a Spanish language mobile app developed by Boceta and colleagues (45) for clinicians to manage patients' BTP. It includes the Davies algorithm to diagnose BTP followed by questions to characterise the pain (the exact questions are not provided). We found no development studies or studies evaluating the app's measurement properties.

The IQ-BTP

The IQ-BTP is an 11-item questionnaire that categorises patients with any condition into those with no BTP or high, intermediate, or low likelihood for BTP. Potential BTP is further characterised depending on whether it is predictable, of known cause, localised and/or has a neuropathic component. Content validity of the IQ-BTP was inconsistent and of low quality since, though items were rated as relevant and comprehensive, the wording and response options were rated as insufficient. Evidence for structural

validity was indeterminate with moderate quality. There was sufficient high-quality evidence for both internal consistency and construct validity.

The Pain Guard Mobile App

The Pain Guard is a Chinese language mobile app designed for cancer patients to manage their pain after discharge from hospital. The app includes a diary to record the presence and characteristics of daily cancer pain and breakthrough cancer pain. The quality of the development study was rated as inadequate as patients were only asked to rate their satisfaction with the app but were not asked about comprehension or comprehensiveness of items. No studies were found which have evaluated any of the app's measurement properties.

The QUDEI

The QUDEI is the Italian version of the BPQ and has been used to assess pain in patients with cancer and other conditions. There was sufficient evidence that this tool was reliable, but quality of the evidence was low. No QUDEI development or content validity studies were found.

DISCUSSION

Diagnosing, assessing, and managing BTP is a significant clinical challenge for patients, their caregivers, and healthcare professionals. To our knowledge, this is the first systematic review of BTP tools for infants, children, young people, and adults that includes an assessment of the tools' measurement properties.

We found 81 studies that used a numerical rating scale only; 24 that used a visual analogue scale only and 12 that used a generic pain assessment tool (the BPI or McGill Pain Questionnaire) to measure, diagnose or assess BTP. However, we do not recommend any of these methods alone since they may not adequately distinguish BTP from other types of pain, which could detrimentally affect management and treatment.

Eleven named tools were found that were designed to diagnose or describe BTP, three of which were translations. Of these tools, we found no development studies or studies evaluating measurement properties of the Davies algorithm, BPQ, BPQC, the EPDS or the INES DIO mobile app and therefore do not recommend them for assessing BTP until evaluations of measurement properties, particularly content validity, have been conducted.

For the remaining tools, we were unable to conduct a meta-analysis or summary of findings since only one study per tool was found that either developed the tool or assessed one or more of its measurement properties. The lack of studies limits the recommendations we can make regarding the most appropriate tool to use for different populations and situations.

According to COSMIN (33), content validity (the extent that a tool's content reflects the construct it aims to measure) is the most important measurement property of a patient-or clinician-reported outcome measure. It should be measured by asking patients and professionals about the relevance, comprehensiveness, and comprehensibility of a tool's items. Eight tools had a development study and one (the Italian version of the APBAT) had a content validity study (distinguished from a development study since content validity was assessed after the final version of the tool was established). Although the construct, target population and context for use was described in almost all development studies, only seven (44-50) conducted a cognitive interview and none of these adequately asked patients or professionals about comprehensibility or comprehensiveness of the tool. As such, no development study was of adequate quality or higher. Evidence for content validity of the Italian APBAT was inconsistent and of doubtful quality.

Two tools, Webber's Breakthrough Cancer Pain Algorithm and Davies' Algorithm, were algorithms designed to diagnose but not characterise BTP. However, sensitivity of Webber's algorithm to diagnose BTP, compared to a clinician's diagnosis, was not high suggesting some patients may go undiagnosed and untreated if only this algorithm was used. No properties of the Davies' Algorithm have been evaluated thus its sensitivity and specificity are unknown. As such, we do not recommend either algorithm on its

own to diagnose BTP. Moreover, while algorithms may improve assessment, tools that help to characterise or describe BTP are needed to determine the aetiology and pathophysiology of the pain and to monitor the effectiveness of treatments (26). While the IQ-BTP and the QUDEI aim to both diagnose and characterise BTP, neither have sufficient evidence for content validity. However, there was high quality evidence for internal consistency of the IQ-BTP, thus a content validity study could be useful to clarify whether this tool can be recommended.

The majority of the named BTP tools included controlled background pain as a prerequisite for BTP. This was defined as controlled pain rated ≤4 on a 0-10 NRS (APBAT, BPQC) or pain described as mild (Davies algorithm, INES DIO Mobile App, IQ-BTP) or mild or moderate (BPQ, QUDEI). However, a recent commentary (51) highlighted that patients may have high baseline pain intensity with episodes of lower intensity BTP since the background pain and BTP may be caused by different mechanisms. As such, tools that eliminate a BTP diagnosis due to high background pain intensity may lead to underdiagnosis (52).

Recommendations:

The BAT was the only tool with sufficient content validity and at least low-quality evidence for sufficient internal consistency. As such, it is the only tool we recommend for characterising BTP in adults with cancer. However, more research on the psychometric properties of the BAT is needed. Reliability of the BAT was rated as doubtful while criterion validity of the BAT has not yet been assessed. The BAT is a self-report tool that requires users to write down their answers, which could exclude patients with motor or visual limitations if they are not given support to complete it. Additionally, the feasibility of the BAT was not assessed. The 14-item tool may seem too long to be clinically useful, especially for patients with complex conditions or comorbidities.

It is also unclear, whether this tool is appropriate for patients with other conditions and for children. Indeed, the BAT asks participants to characterise BTP experienced in the last week. This length of time may not be suitable for paediatric assessments or for patients with non-cancer conditions, where situations may change more rapidly with less predictability. Since this tool only describes the nature of patients' BTP, there is a clear need for a validated, reliable tool that can both diagnose and characterise BTP.

No feasibility studies were conducted for any BTP tools and only one tool (the BAT) gathered and incorporated user-feedback in its development. It is essential that future studies assess the acceptability and feasibility of BTP tools for patients and/or caregivers since overly long or complex tools may fail to be utilised in clinical practice.

Tools designed for adults may not be appropriate for use in paediatrics due to differences in disease manifestation and development. Tools with body maps (the ABPAT, the BAT, the EPDS), for example, do not include child body maps, while questions in tools designed for adults may not be worded appropriately for children and young people. We found only one tool, the BPQC, which was developed for use in children. It uses child-friendly language and asks for children to recall pain over the last two days rather than over a week, yet no psychometric properties of this tool have been evaluated. Moreover, the BPQC was designed for children aged 7 years and older to complete. There is a need for a tool that caregivers can use to assess pain in younger children or those who are not able to self-report due to impairments in cognitive or verbal abilities, both of which are more common in children experiencing BTP due to non-cancer diagnoses. In these children, pain may be difficult to separate from other symptoms or agitation, thus a more bespoke BTP tool is likely needed.

Limitations:

Systematic comparison of the validity of BTP tools is limited due to the lack of a universally agreed definition of BTP. However, we were still able to assess content validity (the most important property of an outcome measure) (53) following the COSMIN guidelines by assessing whether patients and professionals were asked about the relevance, comprehensiveness and comprehensibility of the tool and its items.

While the kappa value for risk of bias ratings in Table 3a and 3b was high, only a moderate kappa value was found for Table 3c. This was due to reviewers' differences in interpreting the scoring system in the

COSMIN manual since, for some items, the definition ascribed to each rating level and the example given for that rating appeared inconsistent. Nonetheless, after discussion, sometimes with a third reviewer, all disagreements were resolved.

We found five English language articles that developed new BTP tools (the INES DIO Mobile App and the Pain Guard Mobile App) or versions of existing BTP tools (the Italian APBAT, the Dutch BAT and the Korean BAT) in different languages and included them in this review. However, since only English language studies were included, it is possible that other language versions of these tools have been developed but were not identified in our review. The authors of all identified BTP assessment tools were contacted to ask if any other studies had been done assessing measurement properties or adapting the tool, thus minimising the risk of this.

Conclusions:

This systematic review found two tools designed to diagnose BTP (Webber's Breakthrough Cancer Pain Algorithm and the Davies Algorithm), two designed to characterise the nature of the BTP (the ABPAT and the BAT) and seven that aim to both diagnose and characterise BTP (the BPQ, the BPQC, the QUDEI, the EPDS, the IQ-BTP, the Pain Guard Mobil App, and the INES-DIO Mobile App). As noted by the FDA (54), for most patient- or clinician-reported outcome measures, there is no single gold standard criterion to assess the concept to be measured. This is true of breakthrough pain assessment tools, however, to make comparisons between BTP tools, a universally agreed definition of BTP is needed.

Only the BAT met COSMIN standards for recommendation for use, yet it presumes that the presence of BTP has already been diagnosed. There is a clear need for a validated tool that can diagnose BTP. Moreover, the BAT is designed to characterise BTP in adults with cancer only. There is a lack of non-cancer specific tools for assessing or characterising BTP, despite BTP being common in other conditions and in patients approaching end-of-life. There is a need for further validation of the BAT in other populations and for tools that diagnose BTP in adults and diagnose and characterise BTP in children.

Author contributions: CL conceived the idea, KG, SH, DES and CL planned and designed the study protocol, search strategy, data extraction and quality assessment and wrote the first draft; JB, AKA, SJ, DR, LF, CM, MJ, IW, RH and EH provided critical insights. All authors have approved and contributed to the final written manuscript.

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Table 1. Inclusion and exclusion criteria for Search 1 of the systematic review of breakthrough pain measures and their psychometric properties

	Inclusion	Exclusion
Population	BTP assessed in infants, children or adults of any age with any diagnosis and at any stage in life	
Location	Worldwide	
Publication type	All studies and PhD theses	Articles written in any language other than English, Masters theses, conference abstracts, reviews
Range of years	From the inception of each database until November 2020	
Assessment	Search 1: Any assessment instrument or measure (e.g. questionnaire, inventory, self-report, caregiver-report) used to assess BTP (e.g. duration, intensity, frequency) Search 2: Any studies that have developed, or evaluated one or more measurement properties of, an assessment, instrument or measure identified in Search 1	
Definition	All definitions of BTP will be included. Included measurement properties were: construct validity, content validity, structural validity, internal consistency, reliability, measurement error, cross-cultural validity, criterion validity and responsiveness	

Table 2. Characteristics of included studies assessing measurement properties of breakthrough pain assessment tools in the systematic review of breakthrough pain measures and their psychometric properties

Breakthrough pain (BTP) assessment	Study evaluating measurement properties of BTP assessment tool	Country	Language	Patient population				Response rate	Setting
				N (% female)	Age (range) years	Disease/ condition	Inclusion criteria		
Webber's Breakthrough Cancer Pain Algorithm (1, 2)	Webber (2013) (1), Webber et al., (2015) (2) [same study]	UK	English	135 (44)	Median 62 (33-96)	Cancer	1) pain related to cancer or cancer treatment 2) around the clock analgesia prescribed for the previous week 3) age>18 years	91.8%	Tertiary referral cancer centre, a hospital and a hospice
The Davies Algorithm (2009) (3)	N/A (no published studies assessing measurement properties)								
The Davies Algorithm (2011) (4)	N/A (no published studies assessing measurement properties)								
The Alberta Breakthrough Pain Assessment Tool for Cancer Patients (ABPAT) (5)	Hagen et al., (2008) (5)	Canada	English	9 (56)	Not stated	Cancer	1) age >18 years 2) pain due to cancer/cancer treatment 3) controlled baseline pain 4) BTP	56% national experts 73% international experts Patients: not stated	Experts: online survey Patients: tertiary hospital centre
Italian version of The Alberta Breakthrough Pain Assessment Tool for Cancer Patients (ABPAT) (6)	Sperlinga et al., (2015) (6)	Italy	Italian	249 (48)	Mean 68.7 (33-78)	Cancer	1) age >18 years 2) cancer 3) treatment with major opioids 4) controlled background pain 5) documented BTP	96%	Oncology and palliative care centres
The Breakthrough Pain Assessment Tool (BAT) (1)	Webber (2013) (1), Webber et al., (2014) (7) (same study)	UK	English	100 completed assessment 1 (46); 66% completed assessment 1 & 2; 81% completed assessment 1 & 3	Median 61 (27-89)	Cancer	1) age >18 years 2) cancer-related pain 3) cancer-related BTP 4) regular analgesia during previous week	66% completed assessment 1 & 2; 81% completed assessment 1 & 3	Tertiary referral cancer centre, a hospital and a hospice
Dutch version of the Breakthrough Pain Assessment Tool (8)	Oldenmenger et al., (2019) (8)	The Netherlands	Dutch	170 (44)	Median 61 (30-89)	Cancer	1) age >18 years 2) pain due to cancer 3) regular analgesia in previous week 4) BTP according to a specialist 5) use of 1 or more doses of rescue medication for BTP	100% completed assessment 1; 93% completed assessment 2; 90% completed assessment 3	3 hospitals, 1 hospice, 2 medical centres, 1 cancer institute
Korean Version of the Breakthrough Pain Assessment Tool (K-BAT) (9)	Shin et al., (2017) (9)	Korea	Korean	120 (46)	Median 61 (24-88)	Cancer	1) adult-onset cancer 2) cancer-related BTcP during the previous week	Not stated	Pain management clinic
The Breakthrough Pain Questionnaire (BPQ) (10)	N/A (no published studies assessing measurement properties)								
Breakthrough Pain Questionnaire for Children (BTPC) (11)	N/A (no published studies assessing measurement properties)								

The Episodic Pain Documentation Sheet (EPDS) (12)	N/A (no published studies assessing measurement properties)								
The Italian Questionnaire for BTP (IQ-BTP) (13)	Samolsky Dekel et al., (2016)(13)	Italy	Italian	120 (67)	Mean 63.7 (24-95)	Chronic pain (cancer or non cancer)	1) age >18 years 2) cancer/non-cancer chronic pain treated with strong opioids in the past week	Not stated	Hospital
INES DIO mobile app (14)	N/A (no published studies assessing measurement properties)								
The Pain Guard mobile app (2019) (15)	Yang et al., (2019) (15)	China	Chinese	Intervention (Pain Guard) group: 31 (45) Control group: 27 (22)	Intervention group: Mean 51.10 (SD 8.98) Control group: 53.96 (SD 8.58)	Cancer	1) Read Chinese and use mobile phone 2) aged 18 – 75 years 3) cancer pain in previous month	Not stated	In the community
The Questionnaire for Intense Episodic Pain (QUEDI) (16)	Caraceni et al., (2012) (16)	Italy	Italian	229 (48)	Mean 61 (SD 3)	Cancer	1) age >18 years 2) cancer-related chronic pain	95%	Palliative care centres

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Table 3a. Quality of the development of breakthrough pain assessment tools included in the systematic review of breakthrough pain measures and their psychometric properties

Assessment Tool[a]	**Design**							**Cognitive interview (CI) study[c]**				**Total prom development**
	General design requirements					Concept elicitation[b]	Total PROM design	General design requirements	Comprehensibility	Comprehensiveness	Total CI study	
	Clear construct	Clear origin of construct	Clear target population for which the tool was developed[d]	Clear context of use	Tool developed in sample representing the target population			CI study performed in sample representing the target population				
Webber algorithm (1, 2)	VG	VG	VG	VG	VG	I	I					I
ABPAT (3)	VG	VG	VG	VG	D	D	D	D	D	D	D	D
Italian ABPAT (4)	VG	VG	VG	VG	VG	N/A	A	VG	D	D	D	D
BAT (1, 5)	VG	VG	VG	VG	VG	A	A	A	I	D	I	I
Dutch BAT (6)	VG	VG	VG	VG	A	N/A	A	A	D	D	D	D
BAT-K (7)	VG	VG	VG	VG	VG	N/A	A	A	D	D	D	D
IQ-BTP (8)	VG	D	VG	VG	A	N/A	A	I				I
Pain Guard Mobile App (9)	I	D	VG	VG	VG	D	D	VG	I	D	I	I

VG = very good; A = adequate; D = doubtful; I = inadequate; NA = not applicable

[a] Tools without a development study were not included

[b] When the assessment tool was not developed in a sample representing the target population, the concept elicitation was not further rated

[c] Empty cells indicate that a CI study (or part of it) was not performed

[d] The target population age group was not stated in any article but based on COSMIN criteria all articles were rated as VG assuming the tool was used for all ages

Table 3b. Quality of studies on measurement properties included in the systematic review of breakthrough pain measures and their psychometric properties

Assessment Tool[a,b]	Content validity					Structural validity	Internal consistency	Cross-cultural validity	Reliability	Measurement error	Criterion validity	Construct validity		Responsiveness			
	Asking patients			Asking experts													
	Relevance	Comprehensiveness	Comprehensibility	Relevance	Comprehensiveness							Convergent validity	Known groups validity	Comparison with gold standard	Comparison with other instruments	Comparison between subgroups	Comparison before and after intervention
Webber algorithm (1, 2)											VG		D				
APBAT (3)																	
Italian APBAT(4)	D	D	D														
BAT (5)						A	VG		D			VG	D			I	VG
Dutch BAT (6)						VG	VG		D			VG	D			I	
BAT-K (7)						A	VG		D			A					
IQ-BPT (8)						A						VG					
Pain Guard Mobile App (9)																	
QUDEI (10)									D		I						

VG = very good; A = adequate; D = doubtful; I = inadequate; NA = not applicable
[a] Tools without any studies that assessed measurement properties were not included
[b] Empty cells indicate that this measurement property has not been assessed

Table 3c. Quality of the evidence for measurement properties of the breakthrough pain assessment tools included in the systematic review of breakthrough pain measures and their psychometric properties

Measurement property[a,b]	Webber algorithm (1, 2)		ABPAT (3)		Italian ABPAT (4)		BAT (1, 5)		Dutch BAT (6)		BAT-K (7)		IQ-BTP (8)		Pain Guard Mobile App (9)		QUDEI (10)	
	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence	Overall rating	Quality of evidence
Content validity[3]	±	very low	+	low	?	low	+	low	?	low	?	low	±	low	±	very low		
Relevance	+	very low	+	low	?	low	+	moderate	+	very low	+	very low	±	very low	+	very low		
Comprehensiveness	-	very low	+	low	+	low	+	very low	+	low	+	low	+	very low	?	low		
Comprehensibility	+	very low	+	very low	?	low	+	very low	?	very low	?	very low	-	very low	?	Very low		
Structural validity							+	moderate	?	high	?	moderate	?	moderate				
Internal consistency							+	high	?	high	+	high	+	high				
Cross-cultural validity																		
Measurement invariance																		
Reliability							+	low	+	low	+	low					+	low
Measurement error																		
Criterion validity	-	high																
Construct validity	?	low					+	moderate	+	moderate	?	moderate	+	high				
Responsiveness							+	high	+	very low								

+ = sufficient; - = insufficient; ? = indeterminate; ± = inconsistent results
[a] Tools without any studies that assessed measurement properties were not included
[b] Empty cells indicate that this measurement property has not been assessed
[c] Content validity was based on a development and/or content validity study

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Table 4. Interpretability of tools designed to measure, diagnose or characterise breakthrough pain included in the systematic review of breakthrough pain measures and their psychometric properties

Breakthrough pain assessment tool	Distribution of scores in the study population	Percentage of missing data	Floor and ceiling effects	Scores and change scores available for relevant (sub)groups	Minimal important change (MIC) or minimal important difference (MID)	Information on response shift
Webber's Breakthrough Cancer Pain Algorithm (1, 2)	N/A binary (does/does not have BTP)	Not reported	N/A (binary outcome)	Sensitivity of the algorithm to diagnose BTP: Percentage diagnosed with BTP via the algorithm: Overall sensitivity: 0.54 Sensitivity for different subgroups: Hospital patients: 0.61 Hospice patients: 0.36 Under 65 years: 0.63 65 and over: 0.44 Eastern Cooperative Oncology Group (ECOG) performance status 0-2: 0.66 ECOG performance status 3-4: 0.41 Pain with neuropathic features: 0.52 Nociceptive pain: 0.59 Inpatients: 0.53 Outpatients: 0.58 (Data taken from Webber, 2013 [PhD thesis]	N/A	Not reported
The Davies Algorithm [2009 version] (3)	N/A binary (does/does not have BTP)	Not reported	N/A (binary outcome)	None available	N/A	Not reported
The Davies Algorithm [2011 version] (4)	N/A binary (does/does not have BTP)	Not reported	N/A (binary outcome)	Percentage diagnosed with BTP via the algorithm: 100%	N/A	Not reported
The Alberta Breakthrough Pain Assessment Tool for Cancer Patients (ABPAT) (5)	N/A (goal is to characterise the patient's BTP)	Not reported	N/A (goal is to characterise the patient's breakthrough pain)	None available	N/A	Not reported
Italian version of The Alberta Breakthrough Pain Assessment Tool for Cancer Patients (ABPAT) (6)	N/A (goal is to characterise the patient's BTP)	Not reported	N/A (goal is to characterise the patient's breakthrough pain)	None available	N/A	Not reported
The Breakthrough Pain Assessment Tool (BAT) (1, 7)	N/A (goal is to characterise the patient's BTP)	0.8% (excluding missing data due to question not being applicable to participant)	N/A (goal is to characterise the patient's breakthrough pain)	**Patients who rated their BTP as adequately controlled:** Total BAT scores: 43.15 Severity subscale: 30.03 Treatment subscale: 13.12 **Patients who rated their BTP as inadequately controlled:** Total BAT scores: 54.62 Severity subscale: 39.26 Treatment subscale: 15.82 **Patients rated by clinician as having adequately controlled BTP:** Total BAT scores: 41.54 Severity subscale: 29.5 Treatment subscale: 12.04 **Patients rated by clinician as having inadequately controlled BTP:** Total BAT scores: 49.25 Severity subscale: 34.68 Treatment subscale: 14.77	**Patient's impression of change (better/not better) MID scores:** Mean BAT scores: 12.48 Severity subscale: 9 Treatment subscale: 3.72 Frequency: 0.93 Duration: 1.65 Worst BTP intensity: 1.75 Typical NTP intensity: 1.45 Normal life: 1.88 Distress: 1.72 **Clinician's impression of change (better/not better) MID scores:** Mean BAT scores: 12.88 Severity subscale: 10.27 Treatment subscale: 3.72 Frequency: 1.83 Duration: 1.02 Worst BTP intensity: 2.25 Typical NTP intensity: 1.77 Normal life: 2.08 Distress: 1.82	Not reported

				Patients that agreed with statement 'I don't need changes to painkillers' Total BAT scores: 42.67 Severity subscale: 29.98 Treatment subscale: 4.74 **Patients that agreed with statement 'I need changes to painkillers'** Total BAT scores: 53 Severity subscale: 37.73 Treatment subscale: 6.19 **Patients for whom clinicians did not make changes to painkillers** Total BAT scores: 42.83 Severity subscale: 30.10 Treatment subscale: 12.72 **Patients for whom clinicians made changes to painkillers** Total BAT scores: 48.83 Severity subscale: 34.51 Treatment subscale: 14.52 (Data taken from Webber, 2013 [PhD thesis]	MID not calculated for effectiveness, meaningful effect and side-effects as the change in score was not statistically significant **Difference in scores over time categorized by whether pain medications were changed at follow-up MID scores:** Total BAT score difference: 20.78 Severity subscale: 14.77 Treatment subscale: 6.28 Worst BTP intensity: 2.34 Typical NTP intensity: 1.82 Effectiveness: 2 Normal life: 2.93 Distress: 3.08 Duration: 1.93 Frequency:1.79 Meaningful effect: 0.81 Side-effects: 2	
Korean version of the BAT (8)	N/A (goal is to characterise the patient's BTP)	4.6%	N/A (goal is to characterise the patient's breakthrough pain)	None available	N/A	Not reported
Dutch version of the BAT (9)	N/A (goal is to characterise the patient's BTP)	Not reported	N/A (goal is to characterise the patient's breakthrough pain)	Scores on 7/9 items were significantly higher in patients who rated their BTP as inadequately controlled versus adequately controlled ($p < 0.005$) Scores on 8/9 items were significantly higher in patients whose BTP was rated by clinicians as inadequately controlled versus adequately controlled ($p < 0.005$) (higher scores indicate more severe BTP). No overall group comparisons were reported.	N/A	Not reported
The Breakthrough Pain Questionnaire (BPQ) (10)	N/A binary (does / does not have BTP) plus questions on BTP characteristics	Not reported	N/A (binary outcome)	None available	N/A	Not reported
Breakthrough Pain Questionnaire for Children (BPQC) (11)	N/A the assessment categorises children into 3 groups: 1. Children with uncontrolled background pain, 2) children with controlled background pain and no BTP, 3) children with controlled background pain and BTP	Not reported	N/A (category outcome + description of BTP)	Children with uncontrolled background pain: 0% Children with controlled background pain and no BTP: 43% Children with controlled background pain and BTP: 57%	N/A	Not reported
The Episodic Pain Documentation Sheet (EPDS) (12)	N/A (goal is to characterise the patient's episodic pain)	Not reported	N/A (binary outcome)	None available	N/A	Not reported
The INES-DIO mobile phone app (13)	Unknown	Not reported	Unknown	None available	N/A	Not reported
The Italian Questionnaire for BTP (IQ-BTP) (14)	N/A the assessment characterises people into 1) No BTP, 2) High/low/intermediate likelihood for BTP (plus characteristics)	None	N/A (category outcome + description of BTP)	Potential BTP: 36.7%	N/A	Not reported
The Pain Guard mobile phone app (15)	N/A (goal is to record incidences and characteristics of BTP and medication)	Not reported	N/A (goal is to record incidences and	Median number of BTP episodes recorded on the app over 4 weeks: 3	N/A	Not reported

			characteristics of BTP and medication)			
The Questionnaire for Intense Episodic Pain (QUDEI) (16)	N/A binary (does/does not have BTP)	Not reported	N/A (binary outcome)	Percentage diagnosed with BTP: 66%	N/A	Not reported

Table 5. Feasibility of tools designed to measure, diagnose or characterise breakthrough pain

Feasibility aspects	**Webber's Breakthrough Cancer Pain Algorithm (1, 2)**	**The Davies Algorithm [2009 version] (3)**	**The Davies Algorithm [2011 version] (4)**	**The Alberta Breakthrough Pain Assessment Tool for Cancer Patients (ABPAT) (5)**	**The Breakthrough Pain Assessment Tool (BAT) (1, 7)**	**The Breakthrough Pain Questionnaire (BPQ) (10)**	**Breakthrough Pain Questionnaire for Children (BPQC) (11)**	**The Episodic Pain Documentation Sheet (EPDS) (12)**	**The Italian Questionnaire for BTP (IQ-BTP) (14)**	**The Questionnaire for Intense Episodic Pain (QUDEI) (16)**
Patient's comprehensibility	*Low*	*Low*	*Low*	Moderate	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*
Clinician's comprehensibility	*Low*	*Low*	*Low*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*
Ease of administration	*Easy*	*Easy*	*Easy*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*
Length of the instrument	*Short*	*Short*	*Short*	*Medium*	*Medium*	*Medium*	*Medium*	*Medium*	*Medium*	*Medium*
Completion time	*Not stated*	*Not stated*	*Not stated*	*Not stated*	5-10 minutes	*Not stated*	*Not stated*	*Not stated*	5 minutes	10 minutes
Patient's required mental and physical ability level	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*	*Moderate*
Ease of standardisation	*N/A binary (does / does not have BTP*	*N/A binary (does / does not have BTP*	*N/A binary (does / does not have BTP*	*N/A (goal is to characterise the patient's BTP)*	*N/A (goal is to characterise the patient's BTP)*	*N/A binary (does / does not have BTP) plus questions on BTP characteristics*	*N/A the assessment categorises children into 3 groups*	*N/A (goal is to characterise the patient's BTP)*	*N/A the assessment categorises patients*	*N/A binary (does / does not have BTP*
Ease of score calculation	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*
Copyright	*Not stated*	*Not stated*	*Not stated*	*Not stated*	*Not stated*	*Not stated*	*Not stated*	*Not stated*	*Not stated*	*Not stated*
Cost of an instrument	*Free*	*Free*	*Free*	*Free*	*Free*	*Free*	*Free*	*Free*	*Free*	*Free*
Required equipment	*None*	*None*	*None*	*None*	*None*	*None*	*None*	*None*	*None*	*None*
Availability in different settings	*None*	*None*	*None*	*Italian version available*	*Korean version available*	*None*	*None*	*None*	*None*	*None*
Regulatory agency's requirement for approval	*None*	*None*	*None*	*None*	*None*	*None*	*None*	*None*	*None*	*None*
If clinicians and/or patients were not asked about feasibility aspects of a breakthrough pain tool, the reviewers rated this (in italics) The feasibility of tools translated into languages other than English are not rated										

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2. Webber K, Davies AN, Cowie MR. Accuracy of a diagnostic algorithm to diagnose breakthrough cancer pain as compared with clinical assessment. J Pain Symptom Manage 2015;50:495-500.
3. Davies A, Dickman A, Reid C, Stevens AM, Zeppetella G. The management of cancer-related breakthrough pain: recommendations of a task group of the Science Committee of the Association for Palliative Medicine of Great Britain and Ireland. Eur J Pain 2009;13:331-338.
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5. Hagen NA, Stiles C, Nekolaichuk C, et al. The Alberta Breakthrough Pain Assessment Tool for cancer patients: a validation study using a delphi process and patient think-aloud interviews. J Pain Symptom Manage 2008;35:136-152.
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10. Portenoy RK, Hagen NA. Breakthrough pain: definition, prevalence and characteristics. Pain 1990;41:273-281.
11. Friedrichsdorf SJ, Finney D, Bergin M, Stevens M, Collins JJ. Breakthrough pain in children with cancer. J Pain Symptom Manage 2007;34:209-216.
12. Zeppetella G, Ribeiro MD. Episodic pain in patients with advanced cancer. Am J Hosp Palliat Care 2002;19:267-76.
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14. Samolsky Dekel BG, Remondini F, Gori A, et al. Development, validation and psychometric properties of a diagnostic/prognostic tool for breakthrough pain in mixed chronic-pain patients. Clin Neurol Neurosurg 2016;141:23-29.
15. Yang J, Weng LZ, Chen ZK, et al. Development and testing of a mobile app for pain management among cancer patients discharged from hospital treatment: randomized controlled trial. JMIR Mhealth Uhealth 2019;7.
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Figure 1

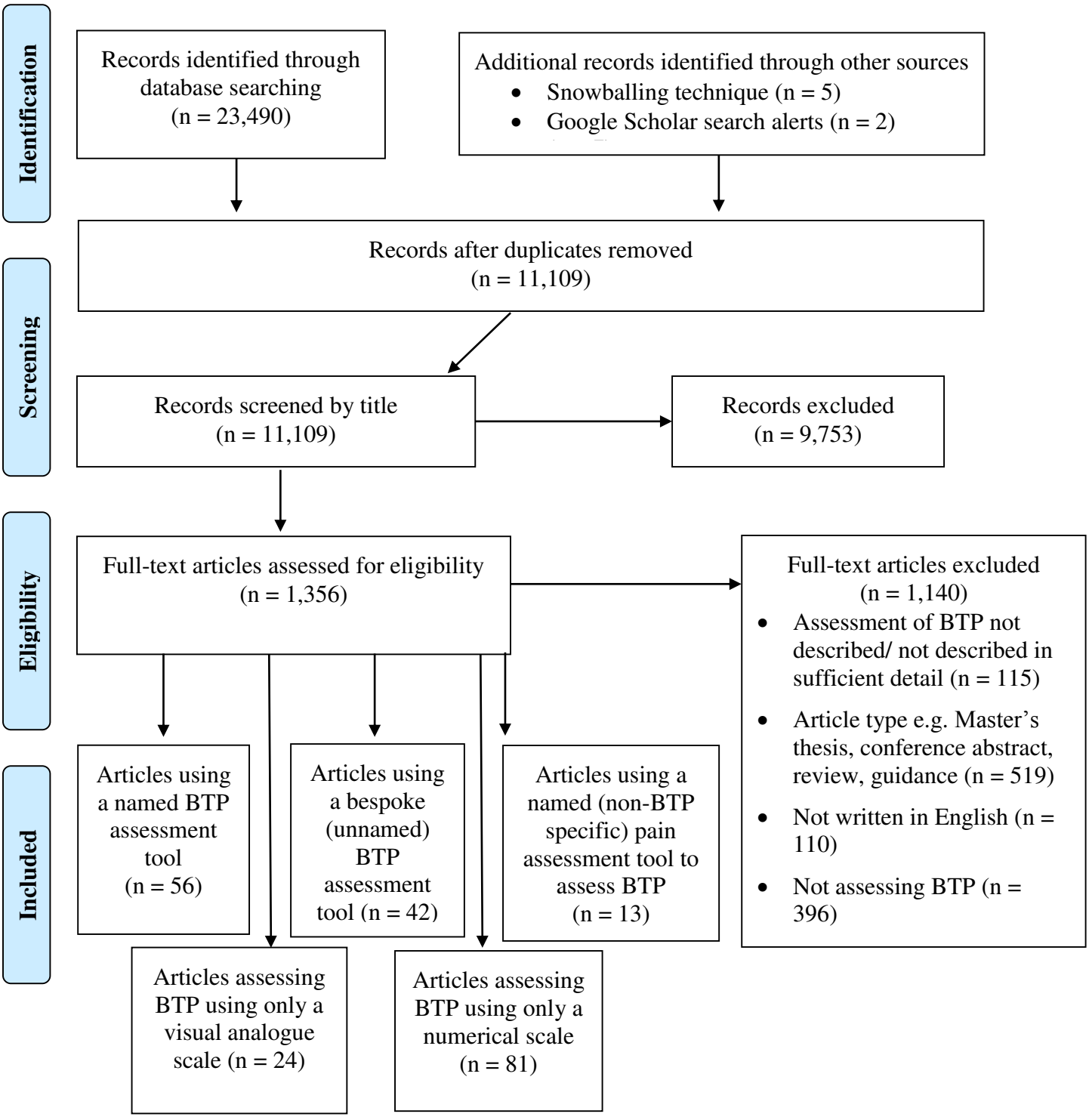

Figure 1. Flow of records for inclusion in search 1 of the systematic review of breakthrough pain measures and their psychometric properties

Figure 2

Click here to access/download;Figure(s);Figure 2 BTP Prisma flow diagram Search 2.docx

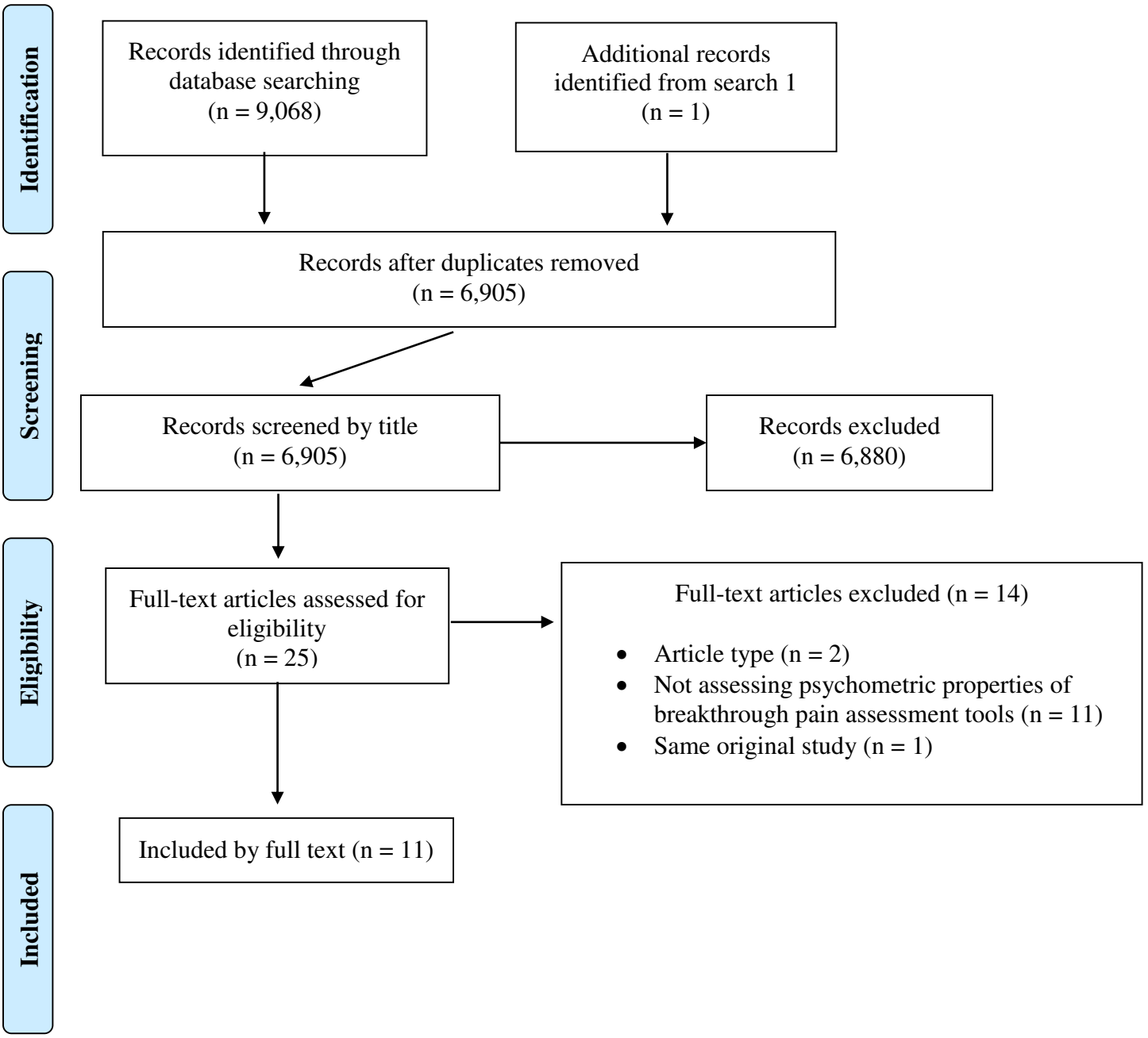

Figure 2. Flow of records for inclusion in search 2 of the systematic review of breakthrough pain measures and their psychometric properties

Supplementary File 1: A systematic review of measures of breakthrough pain and their psychometric properties: Search strategy

SEARCH 1

Prospero

1. MeSH DESCRIPTOR Breakthrough Pain EXPLODE ALL TREES

2. breakthrough pain or break through pain or break-through pain or incident pain or incidental pain or episodic pain or transient pain or transitory pain or spontaneous pain or BTP or pain flare

3. 1 or 2

Cochrane Library

ID Search Hits

Block 1:

#1 ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient or transitory or spontaneous) near/4 (pain)):ti,ab,kw

#2 "break through" near/4 pain:ti,ab,kw

#3 MeSH descriptor: [Breakthrough Pain] explode all trees

#4 BTP or "pain flare*":ti,ab,kw

#5 #1 OR #2 or #3 or #4

Block 2:

#6 (apprais* OR report* OR rated OR rating* OR assess* OR index OR indices OR instrument* OR measure* OR questionnaire* OR profile* OR scale* OR score* OR status OR survey* OR construct* OR development*):ti,ab,kw

#7 MeSH descriptor: [Patient Reported Outcome Measures] explode all trees

#8 MeSH descriptor: [Surveys and Questionnaires] explode all trees

#9 MeSH descriptor: [Outcome Assessment (Health Care)] explode all trees

#10 MeSH descriptor: [Pain Measurement] explode all trees

#11 #6 or #7 or #8 or #9 or #10

Block 1 + 2:

#12 #5 and #11

Embase Classic + Embase via OVID

Block 1:

1. ((breakthrough or break through or incident or incidental or episodic or transient or transitory or spontaneous) adj4 pain).ab,ti,kw
2. (BTP or pain flare*).ab,ti,kw.
3. breakthrough pain.sh.
4. 1 or 2 or 3

Block 2:

2. (apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*).ti,ab,kw.

3. exp Patient Reported Outcome Measures/

4. exp "Surveys and Questionnaires"/

5. exp Outcome assessment health care/

6. exp pain measurement/

7. 2 or 3 or 4 or 5 or 6

Block 1 + Bock 2:

8. 1 and 7

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R)

Block 1:

1. ((breakthrough or break through or incident or incidental or episodic or transient or transitory or spontaneous) adj4 pain).ab,ti,kw
2. (BTP or pain flare*).ab,ti,kw.
3. breakthrough pain.sh.
4. 1 or 2 or 3

Block 2:

2. (apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*).ti,ab,kw.

3. exp Patient Reported Outcome Measures/

4. exp "Surveys and Questionnaires"/

5. exp Outcome assessment health care/

6. exp pain measurement/

7. 2 or 3 or 4 or 5 or 6

Block 1 + Bock 2:

8. 1 and 7

CINAHL

Block 1 + 2:

S7 S1 AND S6

S6 S2 OR S3 OR S4 OR S5

Block 2:

S5 MH pain measurement

S4 MH outcome assessment

S3 MH Surveys and Questionnaires

S2 TI ((apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*)) OR AB ((apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*)) OR KW ((apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*))

Block 1:

S1 (AB ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient OR transitory OR spontaneous) N4 pain) OR TI ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient OR transitory OR spontaneous) N4 pain) OR KW ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient OR transitory OR spontaneous) N4 pain)) OR (AB (BTP OR ‘‘pain flare*” OR "break through pain") OR KW (BTP OR ‘‘pain flare*” OR "break through pain") OR TI (BTP OR ‘‘pain flare*” or "break through pain")) OR MH "breakthrough pain"

PsychINFO

Block 1 + 2:

S5 S1 AND S4

Block 2:

S4 S2 OR S3

S3 MA surveys and questionnaires OR MA Patient Reported Outcome Measures OR MA outcome assessment (health care) OR MA pain measurement

S2 TI ((apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*)) OR AB ((apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*)) OR KW ((apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*))

Block 1:

S1 (AB ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient OR transitory OR spontaneous) N4 pain) OR TI ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient OR transitory OR spontaneous) N4 pain) OR KW ((breakthrough OR break-through OR incident OR incidental OR episodic OR transient OR transitory OR spontaneous) N4 pain)) OR (AB (BTP OR ‘‘pain flare*” OR "break through pain") OR KW (BTP OR ‘‘pain flare*” OR "break through pain") OR TI (BTP OR ‘‘pain flare*” or "break through pain")) OR MH "breakthrough pain"

Web of Science

Block 1 + 2:

3 #2 AND #1

Block 2:

2 (TI =(apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*) OR TS=(apprais* or report* or rated or rating* or assess* or index or indices or instrument* or measure* or questionnaire* or profile* or scale* or score* or status or survey* or construct* or development*)

Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=All years

Block 1:

1 (TI=(((breakthrough OR break-through OR "break through" OR incident OR incidental OR episodic OR transient or transitory OR spontaneous) NEAR/4 (pain))) OR TS=(((breakthrough OR break-through OR "break through" OR incident OR incidental OR episodic OR transient or transitory OR spontaneous) NEAR/4 (pain))) OR TS=(BTP or "pain flare*") OR TI=(BTP or "pain flare*")) AND LANGUAGE: (English)

Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=All years

Google Scholar

1. allintitle: ((“breakthrough pain” OR “break-through pain” OR "break through pain" OR "BTP") (Appraisal OR report OR rated OR rating OR assessment OR index OR indices OR instrument OR measure OR questionnaire OR profile))
2. allintitle: ((“breakthrough pain” OR “break-through pain” OR "break through pain" OR "BTP") (scale OR score OR status OR survey OR construct OR development))
3. allintitle: ((“incident pain” OR “incidental pain” OR “episodic pain” OR “transient pain” OR “transitory pain” OR “spontaneous pain” OR "pain flare") (Appraisal OR report OR rated OR rating OR assessment OR index OR indices OR instrument OR measure OR questionnaire OR profile))
4. allintitle: ((“incident pain” OR “incidental pain” OR “episodic pain” OR “transient pain” OR “transitory pain” OR “spontaneous pain” OR "pain flare") (scale OR score OR status OR survey OR construct OR development))

The ProQuest Dissertations & Theses Database

ab(((breakthrough OR break-through OR "break through" OR incident OR incidental OR episodic OR transient OR transitory or spontaneous) NEAR/4 (pain))) OR ti(((breakthrough OR break-through OR "break through" OR incident OR incidental OR episodic OR transient OR transitory or spontaneous) NEAR/4 (pain))) OR mainsubject(((breakthrough OR break-through OR "break through" OR incident

OR incidental OR episodic OR transient OR transitory OR spontaneous) NEAR/4 (pain))) OR ab(BTP OR "pain flare") OR ti(BTP OR "pain flare")

Evidence Search

breakthrough pain OR break through pain OR BTP OR incident pain OR incidental pain OR episodic pain OR transient pain OR transitory pain OR pain flare OR spontaneous pain

OpenGrey

(breakthrough pain OR break through pain OR break-through pain OR BTP OR incident pain OR incidental pain OR episodic pain OR transient pain OR transitory pain OR pain flare OR spontaneous pain) AND (apprais* OR report* OR rated OR rating* OR assess* OR index OR indices OR instrument* OR measure* OR questionnaire* OR profile* OR scale* OR score* OR status OR survey* OR construct* OR development*) lang:"en"

Supplementary File 2: A systematic review of measures of breakthrough pain and their psychometric properties: Search strategy

Search 2 (part 1)

Search 2-Block 1) Terms to identify the BTP assessments found in search 1

Search 2-Block 2) Measurement properties of these assessments

Embase Classic + Embase via OVID

Searches	
1	(Alberta Breakthrough Pain or ABPAT or Breakthrough Pain Questionnaire or BPQ or Breakthrough Pain Assessment or The Questionnaire for Intense Episodic Pain or QUDEI or The Episodic Pain Documentation Sheet or The Italian Questionnaire for BTP or The Italian Questionnaire for Breakthrough Pain or IQ-BTP or Pain Guard).ab,ti,kw.
2	((BAT or Mhealth or App or application or INES) adj5 (breakthrough pain or BTP)).ab,ti,kw.
3	((Davies or Portenoy) adj5 (assessment* or approach or diagnosis or definition or algorithm* or criteria or criterion or principle* or method* or formula*)).ab,ti,kw.
4	(APM adj5 (assessment* or approach or diagnosis or definition or algorithm* or criteria or criterion or principle* or method* or formula*)).ab,ti,kw.
5	(Association of Palliative Medicine of Great Britain and Ireland) .ab,ti,kw.
6	1 or 2 or 3 or 4 or 5
7	exp intermethod comparison/ or exp data collection method/ or exp validation study/ or exp feasibility study/ or exp pilot study/ or exp psychometry/ or exp reproducibility/
8	(reproducib* or audit or psychometr* or clinimetr* or clinometr*).ab,ti.
9	exp observer variation/
10	exp discriminant analysis/ or exp validity/
11	((reliab* or unreliab* or homogene* or outcome assessment* or valid* or feasibility or pilot or coefficient or internal consistency).ab,ti.

12	(Cronbach* and alpha*).ab,ti.
13	(item correlation or item correlations or item selection or item selections or item reduction or item reductions or agreement or precision or imprecision or precise values or test-retest).ab,ti.
14	((test and retest) or (reliab* and (test or retest)) or stability or interrater or inter rater or intrarater or intra rater or intertester or inter tester or intratester or intra tester).ab,ti.
15	(interobserver or inter observer or intraobserver or intraobserver or intertechnician or inter technician or intratechnician or intratechnician or interexaminer or inter examiner or intraexaminer or intraexaminer or interassay or inter assay or intraassay or intra assay or interindividual or inter individual or intraindividual or intra individual or interparticipant or inter participant or intraparticipant or intraparticipant or kappa or kappas or coefficient of variation or repeatab* or ((replicab* or repeated) and (measure* or findings or result* or test*)) or generaliza* or generalisa* or concordance or (intraclass and correlation*) or discriminative or known group or factor*).ab,ti.
16	(dimensionality or subscale* or multitrait scaling analysis or multitrait scaling analyses or item discriminant or interscale correlation* or (error* and (measure* or correlat* or evaluat* or accuracy or accurate or precision or mean)) or individual variability or interval variability or rate variability or variability analysis or (variability (and value*)) or (uncertainty and (measurement or measuring)) or ((minimal* OR clinical* OR small OR meaningful) and (real OR important OR significant OR detectable) and (change OR difference)) or standard error of measurement or sensitiv* or responsive* or (limit and detection) or minimal detectable concentration or interpretab* or ceiling effect or floor effect or item response model or irt or rasch or differential item functioning or dif or computer adaptive testing or item bank or cross-cultural equivalence).ab,ti.
17	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
18	6 and 17

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) 1946 to 16 October2019

1	(Alberta Breakthrough Pain or ABPAT or Breakthrough Pain Questionnaire or BPQ or Breakthrough Pain Assessment or The Questionnaire for Intense Episodic Pain or QUDEI or The Episodic Pain Documentation Sheet or The Italian Questionnaire for BTP or The Italian Questionnaire for Breakthrough Pain or IQ-BTP or Pain Guard).ab,ti,kw.
2	((BAT or Mhealth or App or application or INES) adj5 (breakthrough pain or BTP)).ab,ti,kw.
3	((Davies or Portenoy) adj5 (assessment* or approach or diagnosis or definition or algorithm* or criteria or criterion or principle* or method* or formula*)).ab,ti,kw.
4	(APM adj5 (assessment* or approach or diagnosis or definition or algorithm* or criteria or criterion or principle* or method* or formula*)).ab,ti,kw.
5	((Association of Palliative Medicine of Great Britain and Ireland).ab,ti,kw
6	1 or 2 or 3 or 4 or 5
7	(instrumentation or methods).fs.
8	(Validation Studies or Comparative Study).pt.
9	exp Psychometrics/
10	psychometr*.ti,ab.
11	(clinimetr* or clinometr*).tw.
12	exp "Outcome Assessment (Health Care)"/
13	outcome assessment.ti,ab.
14	outcome measure*.tw.
15	exp Observer Variation/
16	observer variation.ti,ab.
17	exp Health Status Indicators/
18	exp "Reproducibility of Results"/
19	reproducib*.ti,ab.
20	exp Discriminant Analysis/
21	(reliab* or unreliab* or valid* or feasibility or pilot coefficient or homogeneity or homogeneous or internal consistency).ti,ab.
22	(cronbach* and (alpha or alphas)).ti,ab.
23	(item and (correlation* or selection* or reduction*)).ti,ab.

24	(agreement or precision or imprecision or precise values or test retest).ti,ab.
25	(test and retest).ti,ab.
26	(reliab* and (test or retest)).ti,ab.
27	(stability or interrater or inter-rater or intrarater or intra rater or intertester or inter tester or intratester or intra tester or interobserver or inter observer or intraobserver or intra observer or intertechnician or inter technician or intratechnician or intra technician or interexaminer or inter examiner or intraexaminer or intra examiner or interassay or inter assay or intraassay or intra assay or interindividual or inter individual or intraindividual or intra individual or interparticipant or inter participant or intraparticipant or intra participant or kappa* or repeatab*).ti,ab.
28	((replicab* or repeated) and (measure or measures or findings or result or results or test or tests)).ti,ab.
29	(generaliza* or generalisa* or concordance).ti,ab.
30	(intraclass and correlation*).ti,ab.
31	(discriminative or known group or factor* or dimension* or subscale*).ti,ab.
32	(multitrait and scaling and (analysis or analyses)).ti,ab.
33	(item discriminant or interscale correlation* or error or errors or individual variability).ti,ab.
34	(variability and (analysis or values)).ti,ab.
35	(uncertainty and (measurement or measuring)).ti,ab.
36	(standard error of measurement or sensitiv* or responsive*).ti,ab.
37	((minimal or minimally or clinical or clinically) and (important or significant or detectable) and (change or difference)).ti,ab.
38	(small* and (real or detectable) and (change or difference)).ti,ab.
39	(interval variability or meaningful change or ceiling effect or floor effect or Item response model or IRT or Rasch or Differential item functioning or DIF or computer adaptive testing or item bank or cross-cultural equivalence).ti,ab.
40	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39
41	6 and 40

CINAHL via EBSCO

Search Terms	Search Options

S8 S6 AND S7

S7 S1 OR S2 OR S3 OR S4 OR S5

S6 TI psychometr* OR TI observer variation OR TI reproducib* OR TI reliab* OR TI unreliab* OR TI valid* OR feasibility OR pilot OR TI coefficient OR TI homogeneity OR TI homogeneous OR TI "internal consistency" OR AB psychometr* OR AB observer variation OR AB reproducib* OR AB reliab* OR AB unreliab* OR AB valid* OR feasibility OR pilot OR AB coefficient OR AB homogeneity OR AB homogeneous OR AB "internal consistency" OR (TI cronbach* OR AB cronbach* AND (TI alpha OR AB alpha OR TI alphas OR AB alphas)) OR (TI item OR AB item AND (TI correlation* OR AB correlation* OR TI selection* OR AB selection* OR TI reduction* OR AB reduction*)) OR TI agreement OR TI precision OR TI imprecision OR TI "precise values" OR TI test-retest OR AB agreement OR AB precision OR AB imprecision OR AB "precise values" OR AB test-retest OR (TI test OR AB test AND TI retest OR AB retest) OR (TI reliab* OR AB reliab* AND (TI test OR AB test OR TI retest or AB retest)) OR TI stability OR TI interrater OR TI interrater OR TI intrarater OR TI intra-rater OR TI intertester OR TI inter-tester OR TI intratester OR TI intra-tester OR TI interobserver OR TI inter-observer OR TI intraobserver OR TI intra-observer OR TI intertechnician OR TI inter-technician OR TI intratechnician OR TI intra-technician OR TI interexaminer OR TI inter-examiner OR TI intraexaminer OR TI intra-examiner OR TI interassay OR TI inter-assay OR TI intraassay OR TI intra-assay OR TI interindividual OR TI inter-individual OR TI intraindividual OR TI intra-individual OR TI interparticipant OR TI inter-participant OR TI intraparticipant OR TI intra-participant OR TI kappa OR TI kappa's OR TI kappas OR TI repeatab* OR AB stability OR AB interrater OR AB inter-rater OR AB intrarater OR AB intra-rater OR AB intertester OR AB inter-tester OR AB intratester OR AB intra-tester OR AB interobserver OR AB inter-observer OR AB intraobserver OR AB intra-observer OR AB intertechnician OR AB inter-technician OR AB intratechnician OR AB intra-technician OR AB interexaminer OR AB inter-examiner OR AB intraexaminer OR AB intra-examiner OR AB interassay OR AB inter-assay OR AB intraassay OR AB intra-assay OR AB interindividual OR AB inter-individual OR AB intraindividual OR AB intra-individual OR AB interparticipant OR AB inter-participant OR AB intraparticipant OR AB intra-participant OR AB kappa OR AB kappa's OR AB kappas OR AB repeatab* OR ((TI replicab* OR AB replicab* OR TI repeated OR AB repeated) AND (TI measure OR AB measure OR TI measures OR AB measures OR TI findings OR AB findings OR TI result OR AB result OR TI results OR AB results OR TI test OR AB test OR TI tests OR AB tests)) OR TI generaliza* OR TI generalisa* OR TI concordance OR AB generaliza* OR AB generalisa* OR AB concordance OR (TI intraclass OR AB intraclass AND TI correlation* or AB correlation*) OR TI discriminative OR TI "known group" OR TI factor* OR TI dimension* OR TI subscale* OR AB discriminative OR AB "known group" OR AB dimension* OR AB subscale* OR (TI multitrait OR AB multitrait AND TI scaling OR AB scaling AND (TI analysis OR AB analysis OR TI analyses OR AB analyses)) OR TI item discriminant OR TI interscale correlation* OR TI error OR TI errors OR TI "individual variability" OR AB item discriminant OR AB interscale correlation* OR AB error OR AB errors OR AB "individual variability" OR (TI variability OR AB variability AND (TI analysis OR AB analysis OR TI values OR AB values)) OR (TI uncertainty OR AB uncertainty AND (TI measurement OR AB measurement OR TI measuring OR AB measuring)) OR TI "standard error of measurement" OR TI sensitiv* OR TI responsive* OR AB "standard error of measurement" OR AB sensitiv* OR AB responsive* OR ((TI minimal OR TI minimally OR TI clinical OR TI clinically OR AB minimal OR AB minimally OR AB clinical OR AB clinically) AND (TI important OR TI significant OR TI detectable OR AB important OR AB significant OR AB detectable) AND (TI change OR AB change OR TI difference OR AB difference)) OR (TI small* OR AB small* AND (TI real OR AB real OR TI detectable OR AB detectable) AND (TI change OR AB change OR TI difference OR AB difference)) OR TI meaningful change OR TI "ceiling effect" OR TI "floor effect" OR TI "Item response model" OR TI IRT OR TI Rasch OR TI "Differential item functioning" OR TI DIF OR TI "computer adaptive testing" OR TI "item bank" OR TI "cross-cultural equivalence" OR TI outcome assessment OR AB

meaningful change OR AB “ceiling effect” OR AB “floor effect” OR AB “Item response model” OR AB IRT OR AB Rasch OR AB “Differential item functioning” OR AB DIF OR AB “computer adaptive testing” OR AB “item bank” OR AB “cross-cultural equivalence” OR AB outcome assessment OR TI “interval variability” OR AB “interval variability”

S5 "Association of Palliative Medicine of Great Britain and Ireland"

S4 TI (APM N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR AB (APM N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))

S3 TI (Davies N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR AB (Davies N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR TI (Portenoy N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR AB (Portenoy N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))

S2 TI (((Mhealth or App or application) N5 (breakthrough pain or BTP)) OR AB (((Mhealth or App or application) N5 (breakthrough pain or BTP))

S1 TI ((Alberta Breakthrough Pain OR ABPAT OR Breakthrough Pain Questionnaire OR BPQ OR Breakthrough Pain Assessment or BAT OR The Questionnaire for Intense Episodic Pain OR QUDEI OR The Episodic Pain Documentation Sheet OR The Italian Questionnaire for BTP OR The Italian Questionnaire for Breakthrough Pain OR IQ-BTP OR INES OR Pain Guard)) OR AB ((Alberta Breakthrough Pain OR ABPAT OR Breakthrough Pain Questionnaire OR BPQ OR Breakthrough Pain Assessment or BAT OR The Questionnaire for Intense Episodic Pain OR QUDEI OR The Episodic Pain Documentation Sheet OR The Italian Questionnaire for BTP OR The Italian Questionnaire for Breakthrough Pain OR IQ-BTP OR INES OR Pain Guard))

PsychINFO via EBSCO

S8 S6 AND S7

S7 S1 OR S2 OR S3 OR S4 OR S5

S6 cl("Psychometrics & Statistics & Methodology" OR "Research Methods & Experimental Design") OR (psychometr* OR clinimetr* OR clinometr* OR "outcome assessment" OR "outcome measure*" OR "observer variation" OR reproducib* OR reliab* OR unreliab* OR valid* OR feasibility OR pilot OR coefficient OR homogeneity OR homogeneous OR "internal consistency" OR agreement OR precision OR imprecision OR "precise values" OR test-retest OR reliab* OR stability OR interrater OR inter-rater OR intrarater OR intra-rater OR intertester OR inter-tester OR intratester OR intra-tester OR interobserver OR inter-observer OR intraobserver OR intra-observer OR intertechnician OR inter-technician OR intratechnician OR intra-technician OR interexaminer OR inter-examiner OR intraexaminer OR intra-examiner OR interassay OR inter-assay OR intraassay OR intra-assay OR interindividual OR inter-individual OR intraindividual OR intra-individual OR interparticipant OR inter-participant OR intraparticipant OR intra-participant OR kappa OR kappa's OR kappas OR repeatab* OR generaliza* OR generalisa* OR concordance OR discriminative OR "known group" OR "factor*" OR dimension* OR subscale* OR "item discriminant" OR "interscale correlation*" OR error* OR "individual variability" OR "standard error of measurement" OR sensitiv* OR responsive* OR "meaningful change" OR "ceiling effect" OR "floor effect" OR "Item response model" OR IRT OR Rasch OR "Differential item functioning" OR DIF OR "computer adaptive testing" OR "item bank" OR "cross-cultural equivalence") OR ("cronbach* alpha*" OR "replicab* measure*" OR "replicab* finding*" OR "replicab* result*" OR "replicab* test*" OR "repeated measure*" OR "repeated finding*" OR "repeated result*" OR "repeated test*" OR "item correlation*" OR "item selection*" OR "item reduction*" OR "Test retest" OR "intraclass correlation*" OR "multitrait scaling analys*" OR "uncertainty measur*" OR "variability analys*" OR "variability value*" OR "minimal* important change" OR "minimal* important difference" OR "minimal* significant change" OR "minimal* significant difference" OR "minimal* detectable change" OR "minimal* detectable difference" OR "clinical* important change" OR "clinical* important difference" OR "clinical* significant change" OR "clinical* significant difference" OR "clinical* detectable change" OR "clinical* detectable difference" OR "small* real change" OR "small* real difference" OR "small* detectable change" OR "small* detectable difference") OR "interval variability" OR (SU.EXACT.EXPLODE("Measurement") OR SU.EXACT.EXPLODE("Error Analysis") OR SU.EXACT.EXPLODE("Test Construction") OR SU.EXACT.EXPLODE("Interrater Reliability") OR SU.EXACT.EXPLODE("Content Analysis") OR SU.EXACT.EXPLODE("Error of Measurement") OR SU.EXACT.EXPLODE("Factor Structure") OR SU.EXACT.EXPLODE("Testing Methods") OR SU.EXACT.EXPLODE("Statistical Reliability") OR SU.EXACT.EXPLODE("Consistency (Measurement)") OR SU.EXACT.EXPLODE("Computer Assisted Testing") OR SU.EXACT.EXPLODE("Factor Analysis") OR SU.EXACT.EXPLODE("Prediction") OR SU.EXACT.EXPLODE("Statistical Validity") OR SU.EXACT.EXPLODE("Prediction Errors"))

S5 "Association of Palliative Medicine of Great Britain and Ireland"

S4 TI (APM N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR AB (APM N5

(assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))

S3 TI (Davies N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR AB (Davies N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR TI (Portenoy N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR AB (Portenoy N5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))

S2 TI (((Mhealth or App or application) N5 (breakthrough pain or BTP)) OR AB (((Mhealth or App or application) N5 (breakthrough pain or BTP))

S1 TI ((Alberta Breakthrough Pain OR ABPAT OR Breakthrough Pain Questionnaire OR BPQ OR Breakthrough Pain Assessment or BAT OR The Questionnaire for Intense Episodic Pain OR QUDEI OR The Episodic Pain Documentation Sheet OR The Italian Questionnaire for BTP OR The Italian Questionnaire for Breakthrough Pain OR IQ-BTP OR INES OR Pain Guard)) OR AB ((Alberta Breakthrough Pain OR ABPAT OR Breakthrough Pain Questionnaire OR BPQ OR Breakthrough Pain Assessment or BAT OR The Questionnaire for Intense Episodic Pain OR QUDEI OR The Episodic Pain Documentation Sheet OR The Italian Questionnaire for BTP OR The Italian Questionnaire for Breakthrough Pain OR IQ-BTP OR INES OR Pain Guard))

Web of Science

# 9 620 (#8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Abstract of Published Item OR Book Chapter OR Review)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 8 4 (TI=(Portenoy NEAR/5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR TS=(Portenoy NEAR/5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 7 244 (TI=(Davies NEAR/5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR TS=(Davies NEAR/5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 6 156 ((TS=((“Alberta Breakthrough Pain” OR ABPAT OR “Breakthrough Pain Questionnaire” OR BPQ OR “Breakthrough Pain Assessment” OR “The Questionnaire for Intense Episodic Pain” OR QUDEI OR “The Episodic Pain Documentation Sheet” OR “The Italian Questionnaire for BTP” OR “The Italian Questionnaire for Breakthrough Pain” OR IQ-BTP OR “Pain Guard”)))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 5 247 (TI=(APM NEAR/5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR TS=(APM NEAR/5 (assessment* or approach or diagnosis or definition or algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 4 11 (TI=((Mhealth or App or application) NEAR/5 ("breakthrough pain" or BTP)) OR TS=((Mhealth or App or application) NEAR/5 ("breakthrough pain" or BTP))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 3 0 ((TI= ((BTP or “Breakthrough Pain”) NEAR/5 INES)) OR (TS= ((BTP or “Breakthrough Pain”) NEAR/5 INES))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 2 3 ((TI= ((BTP or “Breakthrough Pain”) NEAR/5 BAT)) OR (TS= ((BTP or “Breakthrough Pain”) NEAR/5 BAT))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

# 1 14 ((TI=(("Alberta Breakthrough Pain" OR ABPAT OR "Breakthrough Pain Questionnaire" OR BPQ OR "Breakthrough Pain Assessment" OR "The Questionnaire for Intense Episodic Pain" OR QUDEI OR "The Episodic Pain Documentation Sheet" OR "The Italian Questionnaire for BTP" OR "The Italian Questionnaire for Breakthrough Pain" OR IQ-BTP OR "Pain Guard")))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

The ProQuest Dissertations & Theses Database

1. ti("Alberta Breakthrough Pain" OR ABPAT OR "Breakthrough Pain Questionnaire" OR BPQ OR "Breakthrough Pain Assessment" OR "The Questionnaire for Intense Episodic Pain" OR QUDEI OR "The Episodic Pain Documentation Sheet" OR "The Italian Questionnaire for BTP" OR "The Italian Questionnaire for Breakthrough Pain" OR IQ-BTP OR "Pain Guard") OR ab("Alberta Breakthrough Pain" OR ABPAT OR "Breakthrough Pain Questionnaire" OR BPQ OR "Breakthrough Pain Assessment" OR "The Questionnaire for Intense Episodic Pain" OR QUDEI OR "The Episodic Pain Documentation Sheet" OR "The Italian Questionnaire for BTP" OR "The Italian Questionnaire for Breakthrough Pain" OR IQ-BTP OR "Pain Guard")
2. ti(((BTP OR "Breakthrough Pain") NEAR/5 BAT)) OR ab(((BTP OR "Breakthrough Pain") NEAR/5 BAT)) OR ti((BTP OR "Breakthrough Pain") NEAR/5 INES) OR ti((BTP OR "Breakthrough Pain") NEAR/5 INES) OR ti(((BTP OR "Breakthrough Pain") NEAR/5 (Mhealth OR App OR Application))) OR ab(((BTP OR "Breakthrough Pain") NEAR/5 (Mhealth OR App OR Application))) OR ti((Davies) NEAR/5 (assessment* OR approach OR diagnosis OR definition OR algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR ti((Davies) NEAR/5 (assessment* OR approach OR diagnosis OR definition OR algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR ti((APM) NEAR/5 (assessment* OR approach OR diagnosis OR definition OR algorithm* OR criteria OR criterion OR principle* OR method* OR formula*)) OR ti((APM) NEAR/5 (assessment* OR approach OR diagnosis OR definition OR algorithm* OR criteria OR criterion OR principle* OR method* OR formula*))"Association of Palliative Medicine of Great Britain and Ireland"
3. 1 OR 2

Google Scholar

1. allintitle: ((“Alberta Breakthrough Pain” OR ABPAT OR "Breakthrough Pain Questionnaire” OR BPQ))
2. allintitle: ((“Breakthrough Pain Assessment” OR “The Questionnaire for Intense Episodic Pain” OR QUDEI))
3. allintitle: ((“The Episodic Pain Documentation Sheet” OR “The Italian Questionnaire for BTP” OR “The Italian Questionnaire for Breakthrough Pain”))
4. allintitle: ((“IQ-BTP” OR “Pain Guard” OR “BTP App” OR “Breakthrough pain App” OR "MHealth app" OR "Mhealth application" OR “Davies algorithm OR “APM algorithm”))

Evidence Search

1. “Alberta Breakthrough Pain” OR ABPAT OR “Breakthrough Pain Questionnaire” OR BPQ OR “Breakthrough Pain Assessment” or BAT OR “The Questionnaire for Intense Episodic Pain” OR QUDEI OR “The Episodic Pain Documentation Sheet” OR “The Italian Questionnaire for BTP” OR “The Italian Questionnaire for Breakthrough Pain” OR “IQ-BTP”
2. INES OR “Pain Guard” OR “BTP App” OR “Breakthrough pain App” OR "MHealth app" OR "Mhealth application"
3. “Davies algorithm”
4. ”Association of Palliative Medicine of Great Britain and Ireland”
5. “APM algorithm”

All results filters by Primary research only

OpenGrey

“Alberta Breakthrough Pain” OR ABPAT OR” Breakthrough Pain Questionnaire” OR BPQ OR “Breakthrough Pain Assessment” or BAT OR “The Questionnaire for Intense Episodic Pain” OR QUDEI OR “The Episodic Pain Documentation Sheet” OR “The Italian Questionnaire for BTP” OR “The Italian Questionnaire for Breakthrough Pain” OR “IQ-BTP” OR “Pain Guard” OR “BTP App” OR “Breakthrough pain App” OR "MHealth app" OR "Mhealth application" OR “Davies algorithm” OR “Association of Palliative Medicine of Great Britain and Ireland” OR “APM algorithm”

Search 2.2

Search 2.2-Block 1) Terms to identify the generic pain assessments tools used to assess BTP found in search 1 (The Brief Pain Inventory and the McGill Pain Questionnaire)

Search 2.2-Block 2) Measurement properties of these assessments

Embase Classic + Embase via OVID

Searches	
1	(Brief Pain Inventory or BPI or SFPBI or SF-PBI or McGill Pain Questionnaire or McGill Melzack Pain Questionnaire or McGill Questionnaire or McGill-Melzack Pain Questionnaire or MPQ or SFMPQ or SF-MPQ).ab,ti,kw.
2	exp intermethod comparison/ or exp data collection method/ or exp validation study/ or exp feasibility study/ or exp pilot study/ or exp psychometry/ or exp reproducibility/
3	(reproducib* or audit or psychometr* or clinimetr* or clinometr*).ab,ti.
4	exp observer variation/
5	exp discriminant analysis/ or exp validity/
6	((reliab* or unreliab* or homogene* or outcome assessment* or valid* or feasibility or pilot or coefficient or internal consistency).ab,ti.
7	(Cronbach* and alpha*).ab,ti.
8	(item correlation or item correlations or item selection or item selections or item reduction or item reductions or agreement or precision or imprecision or precise values or test-retest).ab,ti.
9	((test and retest) or (reliab* and (test or retest)) or stability or interrater or inter rater or intrarater or intra rater or intertester or inter tester or intratester or intra tester).ab,ti.
10	(interobserver or inter observer or intraobserver or intraobserver or intertechnician or inter technician or intratechnician or intratechnician or interexaminer or inter examiner or intraexaminer or intraexaminer or interassay or inter assay or intraassay or intra assay or interindividual or inter individual or intraindividual or intra individual or interparticipant or inter participant or intraparticipant or intraparticipant or kappa or kappas or coefficient of variation or repeatab* or ((replicab* or repeated) and (measure* or findings or result* or test*)) or generaliza* or generalisa* or concordance or (intraclass and correlation*) or discriminative or known group or factor*).ab,ti.

11	(dimensionality or subscale* or multitrait scaling analysis or multitrait scaling analyses or item discriminant or interscale correlation* or (error* and (measure* or correlat* or evaluat* or accuracy or accurate or precision or mean)) or individual variability or interval variability or rate variability or variability analysis or (variability (and value*)) or (uncertainty and (measurement or measuring)) or ((minimal* OR clinical* OR small OR meaningful) and (real OR important OR significant OR detectable) and (change OR difference)) or standard error of measurement or sensitiv* or responsive* or (limit and detection) or minimal detectable concentration or interpretab* or ceiling effect or floor effect or item response model or irt or rasch or differential item functioning or dif or computer adaptive testing or item bank or cross-cultural equivalence).ab,ti.
12	2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13	1 and 12

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) 1946 to 16 October2019

1	(Brief Pain Inventory or BPI or SFPBI or SF-PBI or McGill Pain Questionnaire or McGill Questionnaire or McGill Melzack Pain Questionnaire or McGill-Melzack Pain Questionnaire or MPQ or SFMPQ or SF-MPQ).ab,ti,kw.
2	(instrumentation or methods).fs.
3	(Validation Studies or Comparative Study).pt.
4	exp Psychometrics/
5	psychometr*.ti,ab.
6	(clinimetr* or clinometr*).tw.
7	exp "Outcome Assessment (Health Care)"/
8	outcome assessment.ti,ab.
9	outcome measure*.tw.
10	exp Observer Variation/
11	observer variation.ti,ab.
12	exp Health Status Indicators/
13	exp "Reproducibility of Results"/

14	reproducib*.ti,ab.
15	exp Discriminant Analysis/
16	(reliab* or unreliab* or valid* or feasibility or pilot coefficient or homogeneity or homogeneous or internal consistency).ti,ab.
17	(cronbach* and (alpha or alphas)).ti,ab.
18	(item and (correlation* or selection* or reduction*)).ti,ab.
19	(agreement or precision or imprecision or precise values or test retest).ti,ab.
20	(test and retest).ti,ab.
21	(reliab* and (test or retest)).ti,ab.
22	(stability or interrater or inter-rater or intrarater or intra rater or intertester or inter tester or intratester or intra tester or interobserver or inter observer or intraobserver or intra observer or intertechnician or inter technician or intratechnician or intra technician or interexaminer or inter examiner or intraexaminer or intra examiner or interassay or inter assay or intraassay or intra assay or interindividual or inter individual or intraindividual or intra individual or interparticipant or inter participant or intraparticipant or intra participant or kappa* or repeatab*).ti,ab.
23	((replicab* or repeated) and (measure or measures or findings or result or results or test or tests)).ti,ab.
24	(generaliza* or generalisa* or concordance).ti,ab.
25	(intraclass and correlation*).ti,ab.
26	(discriminative or known group or factor* or dimension* or subscale*).ti,ab.
27	(multitrait and scaling and (analysis or analyses)).ti,ab.
28	(item discriminant or interscale correlation* or error or errors or individual variability).ti,ab.
29	(variability and (analysis or values)).ti,ab.
30	(uncertainty and (measurement or measuring)).ti,ab.
31	(standard error of measurement or sensitiv* or responsive*).ti,ab.
32	((minimal or minimally or clinical or clinically) and (important or significant or detectable) and (change or difference)).ti,ab.
33	(small* and (real or detectable) and (change or difference)).ti,ab.
34	(interval variability or meaningful change or ceiling effect or floor effect or Item response model or IRT or Rasch or Differential item functioning or DIF or computer adaptive testing or item bank or cross-cultural equivalence).ti,ab.
35	2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34

36	1 and 35

CINAHL via EBSCO

Search Terms	Search Options
S3	S1 AND S2
S2	TI psychometr* OR TI observer variation OR TI reproducib* OR TI reliab* OR TI unreliab* OR TI valid* OR feasibility OR pilot OR TI coefficient OR TI homogeneity OR TI homogeneous OR TI "internal consistency" OR AB psychometr* OR AB observer variation OR AB reproducib* OR AB reliab* OR AB unreliab* OR AB valid* OR feasibility OR pilot OR AB coefficient OR AB homogeneity OR AB homogeneous OR AB "internal consistency" OR (TI cronbach* OR AB cronbach* AND (TI alpha OR AB alpha OR TI alphas OR AB alphas)) OR (TI item OR AB item AND (TI correlation* OR AB correlation* OR TI selection* OR AB selection* OR TI reduction* OR AB reduction*)) OR TI agreement OR TI precision OR TI imprecision OR TI "precise values" OR TI test-retest OR AB agreement OR AB precision OR AB imprecision OR AB "precise values" OR AB test-retest OR (TI test OR AB test AND TI retest OR AB retest) OR (TI reliab* OR AB reliab* AND (TI test OR AB test OR TI retest or AB retest)) OR TI stability OR TI interrater OR TI interrater OR TI intrarater OR TI intra-rater OR TI intertester OR TI inter-tester OR TI intratester OR TI intra-tester OR TI interobserver OR TI inter-observer OR TI intraobserver OR TI intra-observer OR TI intertechnician OR TI inter-technician OR TI intratechnician OR TI intra-technician OR TI interexaminer OR TI inter-examiner OR TI intraexaminer OR TI intra-examiner OR TI interassay OR TI inter-assay OR TI intraassay OR TI intra-assay OR TI interindividual OR TI inter-individual OR TI intraindividual OR TI intra-individual OR TI interparticipant OR TI inter-participant OR TI intraparticipant OR TI intra-participant OR TI kappa OR TI kappa's OR TI kappas OR TI repeatab* OR AB stability OR AB interrater OR AB inter-rater OR AB intrarater OR AB intra-rater OR AB intertester OR AB inter-tester OR AB intratester OR AB intra-tester OR AB interobserver OR AB inter-observer OR AB intraobserver OR AB intra-observer OR AB intertechnician OR AB inter-technician OR AB intratechnician OR AB intra-technician OR AB interexaminer OR AB inter-examiner OR AB intraexaminer OR AB intra-examiner OR AB interassay OR AB inter-assay OR AB intraassay OR AB intra-assay OR AB interindividual OR AB inter-individual OR AB intraindividual OR AB intra-individual OR AB interparticipant OR AB inter-participant OR AB intraparticipant OR AB intra-participant OR AB kappa OR AB kappa's OR AB kappas OR AB repeatab* OR ((TI replicab* OR AB replicab* OR TI repeated OR AB repeated) AND (TI measure OR AB measure OR TI measures OR AB measures OR TI findings OR AB findings OR TI result OR AB result OR TI results OR AB results OR TI test OR AB test OR TI tests OR AB tests)) OR TI generaliza* OR TI generalisa* OR TI concordance OR AB generaliza* OR AB generalisa* OR AB concordance OR (TI intraclass OR AB intraclass AND TI correlation* or AB correlation*) OR TI discriminative OR TI "known group" OR TI factor* OR TI dimension* OR TI subscale* OR AB discriminative OR AB "known group" OR AB dimension* OR AB subscale* OR (TI multitrait OR AB multitrait AND TI scaling OR AB scaling AND (TI analysis OR AB analysis OR TI analyses OR AB analyses)) OR TI item discriminant OR TI interscale correlation* OR TI error OR TI errors OR TI "individual variability" OR AB item discriminant OR AB interscale correlation* OR AB error OR AB errors OR AB "individual variability" OR (TI variability OR AB variability AND (TI analysis OR AB analysis OR TI

values OR AB values)) OR (TI uncertainty OR AB uncertainty AND (TI measurement OR AB measurement OR TI measuring OR AB measuring)) OR TI “standard error of measurement” OR TI sensitiv* OR TI responsive* OR AB “standard error of measurement” OR AB sensitiv* OR AB responsive* OR ((TI minimal OR TI minimally OR TI clinical OR TI clinically OR AB minimal OR AB minimally OR AB clinical OR AB clinically) AND (TI important OR TI significant OR TI detectable OR AB important OR AB significant OR AB detectable) AND (TI change OR AB change OR TI difference OR AB difference)) OR (TI small* OR AB small* AND (TI real OR AB real OR TI detectable OR AB detectable) AND (TI change OR AB change OR TI difference OR AB difference)) OR TI meaningful change OR TI “ceiling effect” OR TI “floor effect” OR TI “Item response model” OR TI IRT OR TI Rasch OR TI “Differential item functioning” OR TI DIF OR TI “computer adaptive testing” OR TI “item bank” OR TI “cross-cultural equivalence” OR TI outcome assessment OR AB meaningful change OR AB “ceiling effect” OR AB “floor effect” OR AB “Item response model” OR AB IRT OR AB Rasch OR AB “Differential item functioning” OR AB DIF OR AB “computer adaptive testing” OR AB “item bank” OR AB “cross-cultural equivalence” OR AB outcome assessment OR TI “interval variability” OR AB “interval variability”

S1 TI ((Brief Pain Inventory or BPI or SFPBI or SF-PBI or McGill Pain Questionnaire or McGill Questionnaire or McGill Melzack Pain Questionnaire or McGill-Melzack Pain Questionnaire or MPQ or SFMPQ or SF-MPQ)) OR AB ((Brief Pain Inventory or BPI or SFPBI or SF-PBI or McGill Pain Questionnaire or McGill Questionnaire or McGill Melzack Pain Questionnaire or McGill-Melzack Pain Questionnaire or MPQ or SFMPQ or SF-MPQ))

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S3 S1 AND S2

S2 cl(“Psychometrics & Statistics & Methodology” OR “Research Methods & Experimental Design”) OR (psychometr* OR clinimetr* OR clinometr* OR “outcome assessment” OR “outcome measure*” OR ”observer variation” OR reproducib* OR reliab* OR unreliab* OR valid* OR feasibility OR pilot OR coefficient OR homogeneity OR homogeneous OR “internal consistency” OR agreement OR precision OR imprecision OR “precise values” OR test-retest OR reliab* OR stability OR interrater OR inter-rater OR intrarater OR intra-rater OR intertester OR inter-tester OR intratester OR intra-tester OR interobserver OR inter-observer OR intraobserver OR intra-observer OR intertechnician OR inter-technician OR intratechnician OR intra-technician OR interexaminer OR inter-examiner OR intraexaminer OR intra-examiner OR interassay OR inter-assay OR intraassay OR intra-assay OR interindividual OR inter-individual OR intraindividual OR intra-individual OR interparticipant OR inter-participant OR intraparticipant OR intra-participant OR kappa OR kappa’s OR kappas OR repeatab* OR generaliza* OR generalisa* OR concordance OR discriminative OR “known group” OR “factor*” OR dimension* OR subscale* OR “item discriminant” OR “interscale correlation*” OR error* OR “individual variability” OR “standard error of measurement” OR sensitiv* OR responsive* OR “meaningful change” OR “ceiling effect” OR “floor effect” OR “Item response model” OR IRT OR Rasch OR “Differential item functioning” OR DIF OR “computer adaptive testing” OR “item bank” OR “cross-cultural equivalence”) OR (“cronbach* alpha*” OR

"replicab* measure*" OR "replicab* finding*" OR "replicab* result*"
OR "replicab* test*" OR "repeated measure*" OR "repeated finding*" OR
"repeated result*" OR "repeated test*" OR "item correlation*" OR "item selection*"
OR "item reduction*" OR "Test retest" OR "intraclass correlation*" OR "multitrait
scaling analys*" OR "uncertainty measur*" OR "variability analys*" OR "variability
value*" OR "minimal* important change" OR "minimal* important difference" OR
"minimal* significant change" OR "minimal* significant difference" OR
"minimal* detectable change" OR "minimal* detectable difference" OR
"clinical* important change" OR "clinical* important difference" OR
"clinical* significant change" OR "clinical* significant difference" OR
"clinical* detectable change" OR "clinical* detectable difference" OR "small* real
change" OR "small* real difference" OR "small* detectable change" OR "small*
detectable difference") OR "interval variability"
OR (SU.EXACT.EXPLODE("Measurement") OR SU.EXACT.EXPLODE("Error Analysis")
OR SU.EXACT.EXPLODE("Test Construction")
OR SU.EXACT.EXPLODE("Interrater Reliability")
OR SU.EXACT.EXPLODE("Content Analysis") OR SU.EXACT.EXPLODE("Error
of Measurement") OR SU.EXACT.EXPLODE("Factor Structure")
OR SU.EXACT.EXPLODE("Testing Methods")
OR SU.EXACT.EXPLODE("Statistical Reliability") OR SU.EXACT.EXPLODE("Consistency
(Measurement)") OR SU.EXACT.EXPLODE("Computer Assisted Testing")
OR SU.EXACT.EXPLODE("Factor Analysis") OR SU.EXACT.EXPLODE("Prediction")
OR SU.EXACT.EXPLODE("Statistical Validity")
OR SU.EXACT.EXPLODE("Prediction Errors"))

S1 TI ((Brief Pain Inventory or BPI or SFPBI or SF-PBI or McGill Pain Questionnaire or McGill Questionnaire or McGill Melzack Pain Questionnaire or McGill-Melzack Pain Questionnaire or MPQ or SFMPQ or SF-MPQ)) OR AB ((Brief Pain Inventory or BPI or SFPBI or SF-PBI or McGill Pain Questionnaire or McGill Melzack Pain Questionnaire or McGill Questionnaire or McGill-Melzack Pain Questionnaire or MPQ or SFMPQ or SF-MPQ))

Web of Science

# 1 (TI=((("Brief Pain Inventory" or SFPBI or SF-PBI or "McGill Pain Questionnaire" or "McGill Questionnaire" or "McGill Melzack Pain Questionnaire" or "McGill-Melzack Pain Questionnaire" or MPQ or SFMPQ or SF-MPQ))) AND LANGUAGE: (English)
Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years

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6. allintitle: (("McGill Pain Questionnaire" OR "McGill Questionnaire" OR "McGill Melzack Pain Questionnaire" OR "McGill-Melzack Pain Questionnaire"))
7. allintitle: ((MPQ OR SFMPQ OR SF-MPQ))

Evidence Search

1. ("Brief Pain Inventory" or BPI or SFPBI or SF-PBI or "McGill Pain Questionnaire" or "McGill Questionnaire" or "McGill Melzack Pain Questionnaire" or "McGill-Melzack Pain Questionnaire" or MPQ or SFMPQ or SF-MPQ)

All results filters by Primary research only

OpenGrey

1. "Brief Pain Inventory" or BPI
2. McGill AND Pain

Supplementary File 3. Characteristics of tools used to diagnose, measure or describe breakthrough pain identified from Search 1 of the systematic review of breakthrough pain measures and their psychometric properties

Name of Assessment Tool (or article if no name given)	Definition of breakthrough pain (BTP)	Assessment type	Number and type of items (or assessment description if items not described)	Range of scores/Scoring	Target population	Mode of administration	Recall Period	Intended context	Original Language	Number of articles using tool to assess BTP (including original)
Webber's Breakthrough Cancer Pain Algorithm (1, 2) *[no official name given]*	Controlled background pain + short-lived episodes of more severe pain	Algorithm	1 closed question to assess presence/absence of background pain; 1 closed question to assess severity of background pain; 1 closed question to assess presence/absence of BTP Total: N = 3	Binary (patient has/ does not have background pain; patient has/ does not have BTP)	Cancer patients (age not stated)	Self-report	Background pain: past week BTP: past week	Clinical	English	1 (3)
The Davies Algorithm [2009 version] (4, 5) [*also referred to as the Association of Palliative Medicine of Great Britain and Ireland (APM) algorithm for assessing breakthrough cancer pain]*	Controlled background pain + transient exacerbations of pain	Algorithm	1 closed question to assess presence/absence of background pain; 1 closed question to assess control of background pain; 1 closed question to assess presence/absence of BTP Total: N = 3	Binary (patient has/ does not have background pain; patient has/ does not have BTP)	Cancer patients (age not stated)	Self-report or interview-based with healthcare professional	Background pain: past week BTP: past week	Not stated	English	14 (4, 6-15)
The Davies Algorithm [2011 version] (16)	Controlled background pain + transient exacerbations of pain	Algorithm	3 closed question to assess presence/absence of background pain; 1 closed question to assess control of background pain; 1 closed question to assess presence/absence of BTP Total: N = 5	Binary (patient has/ does not have background pain; patient has/ does not have BTP)	Cancer patients (age not stated)	Self-report or interview-based with healthcare professional	Background pain: past week BTP: past week	Not stated	English	2 (5, 16)
The Alberta Breakthrough Pain Assessment Tool for Cancer Patients (ABPAT) (17)	Controlled background pain + a brief flare-up of pain	Questionnaire	1 open question to describe background pain; 3 open questions to describe the 3 most bothersome BTPs; 1 open question to list BTP medications; 15 closed questions to assess BTP characteristics: same or different to background pain, temporal nature; intensity; location (mark pain on body outline); quality; causes; predictability; pain relief; medication satisfaction; 2 closed questions for clinicians to assess BTP aetiology and inferred pathophysiology Total: N = 22	No overall score. Aim is to characterise the BTP	Cancer patients (age not stated)	Interview-based with healthcare professional	Background pain: not specified BTP: not specified except for question on frequency: past 24 hours	Research	English	11 (17-25) [2 with the short form of the Italian ABPAT (18, 25), 1 with simplified version of the ABPAT (26)]

The Breakthrough Pain Assessment Tool (BAT) (1, 3)	Controlled background pain + short-lived episodes of more severe pain	Questionnaire	10 closed questions to assess BTP: location (mark on body outline), temporal characteristics, severity, distress, interference, medication effectiveness and side-effects; 4 open questions to assess BTP cause, what helps the pain, medication type and effectiveness Total: N = 14	No overall score. Aim is to characterise the BTP	Cancer patients (age not stated)	Interview-based	Background pain: not assessed BTP: Previous week	Clinical	English	5 (3, 27-30)
The Breakthrough Pain Questionnaire (BPQ) (31)	Controlled background pain + temporary flares of severe or excruciating pain lasting ≤ 12 hours	Questionnaire	8-10 questions to assess background pain: presence/ absence, controllability, severity, location, number of episodes; quality (all closed questions), what reduces the pain;, what exacerbates the pain (open questions) 16 questions to assess BTP: presence/ absence, number of episodes, location, quality, severity, temporal nature, cause, predictability (all closed questions); cause; what reduces the pain (open questions) Total: N = 26 *(items have been changed over time)*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics	Not stated	Interview-based	Background pain: past week BTP: not specified except for question assessing one kind of severe flare up of BTP: past 24 hours	Not stated	English	14 (31-44) (3 used a modified version) (34, 37, 44)
Breakthrough Pain Questionnaire for Children (45)	Controlled background pain + episodes of severe pain	Questionnaire	3 questions to assess background pain: location (show where pain is), temporal nature (closed question); severity (via VAS or Faces scale); 11 questions to assess BTP: severity (via VAS or Faces scale), temporal nature and quality (closed questions), what helps (open question) Total: N = 14	Categorises participants (1. uncontrolled background pain, 2. controlled background pain and no BTP, 3. controlled background pain and BTP) + description of BTP characteristics	Children (diagnoses not stated)	Interview-based	Background pain: today or yesterday; BTP: not specified except for question assessing sudden strong pain: today or yesterday	Not stated	English	2 (45, 46)
The Episodic Pain Documentation Sheet (47)	Not defined	Questionnaire	2 closed question to assess presence/ absence of background pain and analgesia; 11 closed questions to assess episodic pain: temporal characteristics, precipitating events, predictability, pathophysiology and aetiology 1 question to assess episodic pain location (mark on body outline) Total: N = 14	Categorises participants (1. no background pain, 2. controlled background pain, 3. uncontrolled background pain) + description of BTP characteristics	Not stated	Interview-based	Background pain: not specified BTP: not specified but questions ask about daily and weekly frequency of pain	Clinical	English	1 (47)
INES DIO mobile app (48)	Controlled background pain + brief exacerbations of severe pain	App containing algorithm + questionnaire	First 3 questions are the Davis Algorithm, then questions to assess pain characteristics: quality, temporal characteristics, if background pain is controlled, pain region and radiation, BTP duration, BTP intensity (via a NRS or the Categorical Scale), provocative factors, palliative factors *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of background pain and BTP characteristics	Used with adults with cancer	Interview-based with healthcare professional	Background pain: not specified BTP: not specified but patients were asked to record frequency of pain flares per day	Clinical	Spanish	1
The Italian Questionnaire for BTP (IQ-BTP) (49)	Controlled background pain with an intensity of ≤4 on a 1-10 NRS + pain flares with an intensity of NRS≥6 lasting 30-60 minutes	Questionnaire	2 closed question to assess presence/ absence of background pain and analgesia; 9 closed questions to assess BTP: severity, temporal characteristics, location, predictability, cause, quality	Categorises participants (1. Potential BTP, 2. BTP, 3. No BTP) +	Not stated	Self-report	Background pain: past 3-7 days BTP: past 24 hours	Clinical or research	Italian	2 (49, 50) (used same sample of patients)

			Total: N = 11	description of BTP characteristics						
The Pain Guard mobile app) (51)	A pain severity score of ≤ 4/10	App containing questionnaire	1 closed question to assess presence/ absence of BTP via a NRS; assessed BTP characteristics: location (mark pain on body outline), time of episode; nature; 3 open questions to assess medication used: name, dose, times taken *Exact questions and question type not all stated*	Binary (patient has/ does not have BTP) + description of BTP characteristics and pain medication	Used with adults with cancer	Self-report	Pain in past 24 hours and currently (not clear if this is background pain and/or BTP)	Clinical	Chinese	1
The Questionnaire for Intense Episodic Pain (QUDEI) (52)	Analgesics regularly administered in the previous 3 days for pain + ≥ 1 episode of more intense pain	Questionnaire	*Not clear but the QEDEI is 'the Italian version of the Breakthrough Pain Questionnaire'(53) so assume same format*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of background pain and BTP characteristics	Not stated	Interview-based	Background pain: past 24 hours BTP: past 24 hours	Clinical	English	2 (52, 53)
The Brief Pain Inventory (BPI) (54, 55)	N/A (questionnaire not designed to assess BTP specifically, but has been used for this in other studies)	Questionnaire	6 questions on patient demographics; 5 closed questions to assess presence of pain and treatment in last week; 1 question on pain location (mark on body outline); 4 questions to assess pain severity at worst, at best, on average and now (all via NRS); 2 open questions on what relieves pain and increases pain; 2 closed questions on pain relief with medications; 3 closed questions on beliefs about pain origin, 1 question on description of pain (choose descriptor words); 6 closed questions on pain interference with activities (via NRS); 10 questions on pain medications (9 closed, 1 open)	No overall score. Aim is to characterise the pain	Not stated	Self-report	Most questions: previous week, also questions on current and average pain (not designed to assess BTP)	Clinical	English	12 (56-66) [2 used same sample of patients (59, 64); 3 used only 1 section of the BPI (56, 61, 63)]
The McGill Pain Questionnaire (67)	N/A (questionnaire not designed to assess BTP specifically, but has been used for this in other studies)	Questionnaire	Questions for clinicians: 1 open question on diagnosis, 3 open questions on analgesics (type, dose, time given), 1 closed question on intelligence level (NRS) Questions for patients: Pain location (mark on body outline); description of pain (choose descriptor words); how does pain change with time (choose descriptor word); 2 open questions on what relieves and increases pain; 5 questions on strength of pain now, at worst, at best, when had worst toothache, worst, headache, worst stomach ache (all via NRS)	Severity of pain on a NRS (1-5) and description of pain quality	Any	Interview-based with healthcare professional	Current pain (not designed to assess BTP)	Clinical	English	1 (68) [using only the present pain intensity scale]

Azhar et al., (2019) (69)	Brief episodes of intense pain	Questionnaire	Questionnaire consisting of questions about the patient's experience of BTP during the last week *Exact questions and question type not stated*	Not stated - description of patients' experiences of BTP	Used with adults with cancer	Self-report	Background pain: not specified BTP: past week, and day before follow-up assessment	Not stated	English	1
Baek et al., (2016) (70)	Pain with a high intensity, short time interval between onset and peak intensity, short duration, potential recurrence over 24 hours and non-responsiveness to background pain relief	Questionnaire	Questions on BTP prevalence, frequency and treatment *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Self-report	Background pain: not specified but recorded average pain intensity in past 24 hours and satisfaction with pain medication in past week BTP: not specified	Not stated	Korean	1
Bhatnagar et al., (2010) (71)	Intermittent acute pain flares despite regular analgesics	Questionnaire-diary	Questionnaire diary to report BTP episodes and characteristics: intensity (via a NRS), temporal features, site, pain type, precipitating factors, predictability *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Self-report	Diary completed over a 1-week period documenting every episode of pain	Not stated	Not stated (conducted in India)	1
Bushehri et al., (2016) (72)	A 2-point increase from background pain on a 0–10 NRS scale with pain score or a 25% increase in analgesics + no decrease in pain with analgesic intake returning to background level within 10 days	Patient diary	1 question to assess BTP intensity via a NRS; 1 question to assess analgesic intake via a NRS Total: N = 2	Binary (patient has/ does not have BTP)	Used with adults with cancer	Self-report or interview-based with healthcare professional	A pain and analgesic use diary daily was completed for 10 days following the day of radiation	Not stated	English	1
Caraceni et al., (2004) (66)	Relatively well controlled background pain + a transitory pain flare	Questionnaire	1 question to assess type of pain syndrome; 1 question to assess presence/absence of BTP; Questions about pain duration, treatment and pathophysiology (exact questions not stated) Also included the short-form of the BPI *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of pain characteristics, interference and treatment	Used with adults with cancer	Interview-based with healthcare professionals + self-report (BPI)	Background pain and BTP: not specified except for pain intensity: currently and in past 24 hours	Not stated	English, Spanish, Filipino, Italian	1
Caraceni, & Portenoy (1999) (73)	Background pain + a pain flare episode	1 question	1 closed question to assess presence/ absence of BTP Total: N = 1	Binary (patient has/ does not have BTP)	Used with adults with cancer	Interview-based with researcher	BPT: not specified	Not stated	Not stated but the survey was conducted in Australia, Canada, Chile, Colombia, Denmark, Finland, France, Germany, Greece, Holland, India, Israel, Italy, Mexico, Norway, New Zealand, Panama, Philippines,	1

									Portugal, China, Russia Spain, USA Thailand	
Davies et al., (2011) (16)	Controlled background pain + a transient exacerbation of pain	Questionnaire	4 Sections: Section 1 Davies algorithm (3 closed questions); Section 2: questions on BTP characteristics including interference assessed with a NRS (other questions not described); Section 3: questions about current treatment; Section 4: questions about features for a new treatment and alternative routes of administration *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics; treatment; views on new treatment	Used with adults with cancer	Self-report	Section 1 of questionnaire: Background pain: past week BPI: Past week Other sections: not specified	Not stated	Danish, German, Swedish, English	1
Ferrell et al., (1999) (74)	Controlled background pain + transitory episodes of moderate to severe pain	Data were derived from homecare medical records and patient interviews	*Not stated*	*Not stated*	Used with adults with cancer	Self-report and interview-based with healthcare professional	Not specified	Not stated	English	1
Fine & Busch (1998) (75)	Background pain of mild or moderate intensity + a transitory increase in pain to an intensity of 'severe' or 'excruciating'	Questionnaires – 1 for patients, 1 for caregivers	Assessed pain intensity and pain relief (both via a NRS), other questions not described *Exact questions and question type not stated*	Binary (patient has/ does not have BTP)	Used with adults in hospices and their caregivers (no diagnosis restrictions)	Interview-based with healthcare professional	Background pain: past 24 hours BTP: past 24 hours	Not stated	English	1
Gatti, et al., (2014) (76)	Rapid, transitory exacerbations of pain lasting 30-40 minutes , irrespective of background pain control	Questionnaire	Assessed BTP frequency, intensity and duration *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Not stated	Background pain: the week before enrolment; BTP pain: not specified	Not stated	Italian	1
Gatti, et al., (2013) (77)	Not described	Structured interview and clinical study form	Assessed duration of pain condition; presence/ absence of BTP; number of episodes; severity (via a NRS) *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics	Used with adults (no diagnosis restrictions)	Interview-based with healthcare professional	Background pain: not specified BTP: past week	Not stated	Italian	1
Gomez-Batiste et al., (2002) (78)	Relatively well-controlled background pain + a transitory increase of pain of higher than moderate intensity	Interview	Assessed BTP temporal characteristics, severity and type *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Interview-based with researcher	Background pain: not specified BTP: past 24 hours	Not stated	Spanish	1
Hird et al., (2009) (79)	'Pain flare' is a temporary worsening of pain in the treated bony metastatic site after palliative radiotherapy	Questionnaire	5 open questions to assess patients' thoughts during pain flare, interference, management, meaning of the pain flair, if radiation was worthwhile Total: N = 5	No overall score. Aim is to find out more about the patient's experiences of the pain flare	Used with adults with cancer	Interview-based	Pain dairy completed daily for 10 days following radiotherapy	Not stated	English	1

Holtan et al., (2007) (80)	Generally controlled background pain + brief episodes of intense pain	Questionnaire	1 closed question to assess presence/absence of BTP; 1 closed question to assess number of episodes Total: N = 2	Binary (patient has/does not have BTP) + number of episodes	Used with adults with cancer	Interview-based with researcher	Pain assessed over previous 24 hours and currently (not clear if this is background pain and/or BTP)	Not stated	Norwegian	1
Knudsen et al., (2011) (81)	Not stated	Interview	1 closed question to assess presence/absence of BTP Total: N = 1	Binary (patient has/does not have BTP)	Used with adults with cancer	Interview-based with healthcare professional	Pain intensity and location: past 24 hours (not clear if this is background pain and/or BTP)	Not stated	Not stated – multicentre, international study	1
Koh et al., (2018) (82)	A sudden increase in chronic pain	Questionnaire	Not stated	Not stated	Used with adults with cancer	Self-report	Pain intensity and BTP experience: prior to and 1 week after educational intervention	Not stated	Korean	1
Laird, et al., (2011) (83)	Adequately controlled background pain + a transitory exacerbation of pain (increase in severity from background pain by 2+ points on a 0-10 NRS)	Questionnaire	1 question to assess severity of background pain via a NRS; 6 closed questions to assess BTP characteristics: number of episodes, severity (via a NRS), temporal characteristics, predictability Total: N = 7	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics	Used with adults with cancer	Self-report	Background pain: last 24 hours BTP: last 24 hours	Not stated	English	1
Ljuca et al., (2010) (84)	Not defined	BTP characteristics were monitored	Assessed frequency, intensity and temporal characteristics of BTP *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Unclear	BTP: every day for 10 days	Not stated	Not stated	1
Magnani, et al., (2018) (14)	Adequately controlled background pain with a stable opioid regimen + transient pain exacerbations	Questionnaire	Davis algorithm used to assess presence of BTP, presence of background pain, opioid regimen; assessed BTP temporal characteristics, predictability and intensity *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics	Used with adults with cancer	Interview-based with healthcare professional	Background pain: not specified BTP: Last week	Not stated	Italian	1
Mercadante, Porzio et al., (2013) (85) Mercadante, Aielli et al., (2015) (86)	Background pain of acceptable intensity + clearly distinguishable pain exacerbations	Retrospective analysis	Davis algorithm used to assess presence of BTP, BTP intensity assessed via a NRS *Exact questions and question type not stated*	Binary (patient has/ does not have BTP)	Used with adults with cancer	Retrospective analysis by researcher	Background pain: past week BTP: past week	Research	Italian	1
Mercadante et al., (2009) (87)	Controlled background pain + a transitory pain flare of at least moderate intensity	Interview	Assessed the presence/ absence of BTP; BTP intensity, temporal characteristics, effects of movement and limitations *Exact questions and question type not stated*	Binary (patient has/ does not have BTP) + description of BTP characteristics	Used with adults with cancer	Interview-based with healthcare professional	Background pain: past 24 hours BTP: past 24 hours	Not stated	Italian	1

Mercadante, Guccione et al., (2013) (88)	Background pain + distinguishable peaks of pain	Interview	Assessed the presence/ absence of BTP *Exact questions and question type not stated*	Not stated	Used with adults with cancer	Interview-based with researcher	Background pain: not specified BPT: not specified	Research	Italian	1
Mercadante et al., (2010) (89)	Controlled background pain + a transitory pain flare of at least moderate intensity	Interview	Assessed the presence/ absence of BTP; BTP intensity (via a NRS), temporal characteristics, effects of movement *Exact questions and question type not stated*	Binary (patient has/ does not have BTP) + description of BTP characteristics	Used with adults with cancer	Interview-based with researcher	Background pain: not specified BPT: not specified	Not stated	Italian	1
Mercadante et al., (2017) (90), Mercadante et al., (2018) (91), Mercadante, Adile et al., (2019) (92), Mercadante, Masedu et al., (2019) (93),	Controlled background pain + a transitory pain flare of at least moderate intensity	Not stated	Davis algorithm used to assess presence of BTP; assessed BTP temporal characteristics, intensity (via NRS), predictability, triggers, location, mechanism, relieving factors, interference with daily life, who made diagnosis, medications *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Not stated	Background pain: last week BTP: presence/absence: last week; other characteristics: not specifically stated except for average intensity: past 24 hours	Not stated	Italian	1
Mercadante, Lazzari et al., (2015) (94)	Background pain of intensity ≤4/10 on a NRS + distinguishable pain peaks (≤ 4/ day)	Web-based clinical report form	2 closed questions to assess presence/ absence of background pain; 2 closed questions to assess presence/ absence of BTP; questions to assess BTP temporal characteristics; intensity (via NRS), predictability, medications *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics	Used with adults with cancer	Not stated	Not specified, but used retrospective analysis of medical charts	Not stated	Italian	1
Okoroha et al., (2016) (95)	Pain uncontrolled by prescribed pain medications	Pain diary	Not stated	Binary (patient has/ does not have BTP)	Used with adults after ligament reconstruction	Self-report	Pain diary completed every 4 hours on day of surgery and 3 days post operatively. After surgery, nurses recorded VAS pain scores every hour	Not stated	English	1
Petzke et al., (1999) (96)	Background pain + distinguishable, transient pain exacerbations	Questionnaire	Assessed presence/ absence of background pain and BTP; background pain and BTP temporal characteristics, quality, location (mark on body outline) *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Interview-based with healthcare professional	Background pain: last 24 hours BTP: last 24 hours	Not stated	German	1
Rivera et al., (2014) (41)	Controlled background pain + transient pain exacerbations	Pain diary	Portenoy algorithm used to diagnose BTP; assessed BTP intensity (via a VRS) and temporal characteristics *Exact questions and question type not stated*	Binary (patient has/ does not have BTP) + description of BTP characteristics	Used with adults with cancer	Self-report	Pain diary assessing pain throughout the day on day 3,7,15 and 30 after treatment (not clear if this is background pain and/or BTP)	Not stated	Spanish	1

Rodriguez et al., (2018) (97)	Controlled background pain + transient pain exacerbations	Questionnaire	Davies algorithm used to diagnose presence of background pain and BTP; assessed BTP temporal characteristics, location, intensity, effect of activity, predictability and type *Exact questions and question type not stated*	Binary (patient has/ does not have background pain; patient has/ does not have BTP) + description of BTP characteristics	Used with elderly adults treated with opioids	Interview-based with researcher	Background pain: last week BTP: presence/absence: last week; other characteristics: not specifically stated	Not stated	Spanish	1
Sng et al., (2018) (98)	Pain or pressure requiring one or more doses of unscheduled supplemental epidural medication	Survey	Assessed presence/ absence of BTP; causes of BTP; highest pain score *Exact questions and question type not stated*	Binary (patient has/ does not have BTP) + description of BTP characteristics	Used with women in labour	Interview-based with researcher	Current pain	Not stated	English	1
Sng et al., (2015) (99)	Pain or pressure requiring one or more doses of unscheduled supplemental epidural medication	Survey	Assessed presence/ absence of BTP	Binary (patient has/ does not have BTP)	Used with women in labour	Interview-based with researcher	Current pain	Not stated	English	1
Suri et al., (2018) (100)	A period of increased pain lasting 2 or more hours	Questionnaire	Assessed presence/ absence of BTP; duration of time elapsed since BTP flare-up onset	Binary (patient has/ does not have BTP)	Used with adults with lower back pain	Self-report	Background pain: not specified Pain flare: current flare lasting at least 2 hours	Not stated	English	1
Suri et al., (2011) (101)	A period of increased pain lasting 2 or more hours	Questionnaire	Assessed presence/ absence of BTP; duration of time elapsed since BTP flare-up onset	Binary (patient has/ does not have BTP)	Used with adults with lower back pain	Self-report	Background pain: not specified Pain flare: current flare lasting at least 2 hours	Not stated	English	1
Tagami et al., (2018) (102)	Controlled background cancer pain + episodic severe pain flares	Questionnaire	Assessed temporal characteristics of BTP and effectiveness of rescue medication *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Interview-based	Background pain: last 24 hours BTP: not specified	Not stated	Japanese	1
Taylor et al., (2007) (103)	Controlled background pain of moderate or less intensity + transitory pain increases	Questionnaire	Closed questions to assess effect on BTP on quality of life; satisfaction of BTP medication; side-effects of BTP medication *Number of questions not stated*	No overall score. Aim is to escribe patient's experiences' of BTP and BTP medications	Used with adults (non-cancer)	Self-report	Not clearly specified but possibly 3 days prior to screening	Not stated	English	1

Valeberg et al., (2008) (104)	Usual pain + brief episodes of increased pain	Questionnaire	Closed question to assess presence/ absence of BTP Total: N = 1	Binary (patient has/ does not have BTP)	Used with adults with cancer	Interview-based with researcher	Used BPI (most questions: previous week; also questions on current and average pain) BTP: not specifically stated	Not stated	Norwegian	1
Westhoff, et al., (2014) (105)	Controlled background pain + a two-point increase in pain score on an 11-point rating scale, compared to background, without a decrease in analgesics, or a 25% increase in analgesic intake without a decrease in pain score. Score and analgesic intake return to background levels after the episode	Questionnaire	Assessed presence/ absence of BTP; change in analgesic intake; pain severity via a NRS *Exact questions and question type not stated*	Binary (patient has/ does not have BTP)	Used with adults with cancer	Self-report	Used BPI (most questions: previous week; also questions on current and average pain) completed daily for 15 days, beginning at start of radiotherapy, and on day 29	Not stated	Dutch	1
Zeppetella, (2008) (106)	Controlled background pain + transient pain exacerbations	Diary card	Assessed BTP characteristics: location, severity, temporal characteristics, relationship to fixed analgesic dose, precipitants, predictability, palliative factors *Exact questions and question type not stated*	No overall score. Aim is to characterise the BTP	Used with adults with cancer	Self-report	Background pain: not specified BTP: last 24 hours	Not stated	English	1
Key BTP: breakthrough pain; Controlled background pain: controlled with pain medication; NRS: numerical rating scale; VAS: visual analogue scale; VRS: verbal rating scale										

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