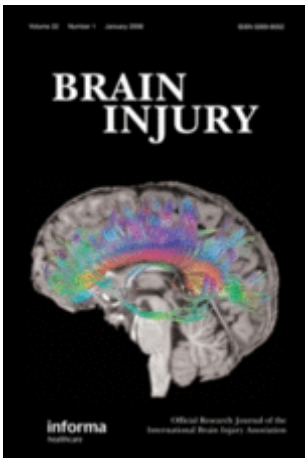


# Assessing aggression following Acquired Brain Injury (ABI): A systematic review of assessment measures.



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| Journal: | *Brain Injury* |
| Manuscript ID | TBIN-2019-0044.R1 |
| Manuscript Type: | Review |
| Keywords: | Acquired Brain Injury (ABI), aggression, Systematic Review, assessment, Reliability, Validity |
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# Assessing aggression following Acquired Brain Injury (ABI):

# A systematic review of assessment measures

**Re-submission date:** 20th May 2019

**Word count excluding title page, abstract, disclosures and references** = 4907

**Abstract**

**Objective:** To conduct a systematic review to identify and examine the reliability and validity of standardised measures used to assess aggression in people with ABI.

**Data sources:** Systematic searches of PsychInfo, Medline, Embase, PubMed and CINAHL databases along with hand searching of grey literature and review articles.

**Study selection:** Studies were included if the sample had an ABI, and the measure included assessment of aggression.

**Data extraction:** Sample and measure characteristics and psychometric properties were extracted. Measure quality was assessed using the COSMIN checklist.

**Data synthesis:** Of 5,100 abstracts screened, 78 were reviewed in full against the inclusion and exclusion criteria, and 25 articles met the criteria for analysis. Included articles assessed the psychometric properties of 17 different measures of aggression in adults with ABI. Quality of evidence was often low. Four measures (MBPC-1990R, NFI, SASNOS and KSMS) demonstrated positive evidence of at least one psychometric property with good quality evidence.

**Conclusions:** Although a large number of general measures were available, there are few measures that only assess post-ABI aggression, and many are not well-validated. Future research should assess the psychometric properties of these measures.

**Keywords:** Acquired Brain Injury (ABI), aggression, systematic review, assessment, reliability, validity

## Introduction

Aggression can be problematic in people with an Acquired Brain Injury (ABI) in inpatient (1, 2, 3, 4), residential (5), and community settings (6, 7, 8). Although it is noted that the majority of people with an ABI do not display aggression (3, 4), when it occurs it can be challenging and upsetting to carers (9), interfere with rehabilitation through challenges in managing behaviours and limiting access to therapy (10), and result in admission to locked settings. Appropriate, valid, and reliable measures of aggression are important as they help determine an individual's placement where behaviours can be appropriately managed, inform relevant treatment, and contribute to monitoring progress over time including changes following treatment.

"Aggression" in this review uses a definition provided in previous research (11) which includes verbal aggression, physical aggression towards others, and aggression towards objects or self. Aggression in people with ABI is typically measured using three methods: behavioural observation, patient self-report, and informant-report, these are described in Table 1.

[Table 1 about here]

To be clinically useful, assessment measures of aggression must demonstrate adequate psychometric properties. Reliability of a measure refers to whether two different raters would achieve the same outcome (inter-rater) or whether the measure would achieve the same outcome on two occasions (test-retest). Reliability is particularly relevant for observational measures which would be completed by different observers at different times. Validity refers to the ability of a measure to accurately measure the construct it was designed to measure. Several types of validity are relevant to measures of aggression which include; the relatedness amongst items in a measure (internal consistency), whether the content of the measure accurately reflects the construct measured (content validity), the dimensions of the construct

measured (structural validity), the construct compared to other known measures of the construct (construct validity), and whether the measure can detect change when change has occurred (responsiveness). Adequate validity ensures that the measure can assess the type of aggression or behaviour that is intended to measure in people with ABI and setting that it was designed to be used. To the author's knowledge, there are no previous systematic reviews that assess the reliability and validity of measures of aggression in adults with ABI.

**Aims of the systematic review**

The primary aims of this systematic review were to: (1) identify all measures used to assess aggression in people with ABI, to (2) assess the reliability and validity of these measures, and (3) to understand the characteristics of the sample each measure has been validated.

## Methods

### Protocol and registration

The reporting of this review has been in line with Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (15). The PRISMA guidelines are followed in order to improve on the reporting of systematic reviews (see Supplementary Table 1). The protocol for this review was registered on Prospero Database of Systematic Reviews on 04/12/17, registration number CRD42017083116.

### Sources and search strategy

Five electronic databases were searched to obtain measures of aggression in people with an ABI. Database searches took place on 02/06/18. The following databases were selected; PsychINFO (1906 – May week 4 2018), Medline (1946 – May week 4 2018), Embase (1980 – 2018 week 23), PubMed (1965 - June 2018) and CINAHL (1982 – 2018).

Search terms were identified according to the PICO criteria; Population (brain injury), Intervention/exposure (assessment measures) and Outcome (aggression). Scoping searches were used within the databases to identify variants in key words to identify relevant literature. A number of terms were selected to describe brain injury, aggression and assessment measures, using Boolean terms to combine terms with "AND" and "OR" with the use of asterisks to include variants of spelling. The following search criterion was used to search the five databases;

Brain injury terms: "Brain injury OR brain damage OR head injury OR head trauma OR neurorehabilitation"

AND

Aggression terms: "aggressi* OR anger OR impulsiv* OR irritability OR hostil* OR violen*"

AND

Assessment measure terms: "questionnaire OR indicators OR rating scale OR measurement OR psychometric OR factor structure OR factor analysis OR valid* OR reliab* OR inventory OR inventories OR assess*"

No limits were set about the date of publication in the initial search. Articles from each database were combined using Endnote software and duplicates removed.

In addition to these database searches, terms describing brain injury, assessment measures, and aggression were searched through Google Scholar to identify literature which may not be identified through database searches. A shortened version of the search criteria was used including the terms; "brain injury" and "aggression" and "assessment or questionnaire or rating scale or outcome". A limit was set for this search to reviewing titles and abstracts for the first 1000 articles, a method which has been used in previous systematic reviews (16). Grey

literature was also searched using the term "brain injury" and "aggression" through the British Library e-thesis online service (EThOS) and Open Grey online search, and through the Bielefeld Academic Search Engine (BASE) using the shortened search criteria.

Articles were screened through title and abstract using specific inclusion and exclusion criteria.

Inclusion criteria/exclusion criteria

Included studies needed to include assessment of the psychometric properties of measures of aggression in adults (people aged 18 or over) with ABI as their main aim. Adolescents or children were not included due to the substantial literature base on child and adolescent brain injury which was beyond the scope of this review. The definition of ABI was inclusive of Traumatic Brain Injury (TBI) (e.g. physical trauma due to accidents or assaults), as well as any other acquired forms of injury or damage to the brain (e.g. stroke, brain tumour, infection, hypoxia or substance abuse including alcohol-related damage).

The study had to describe an assessment measure, we considered "assessment measure" to include psychometric scales, questionnaire measures, rating scales, and observational measures. Aggression needed to be a component of the assessment. The definition of aggression included one or more of the following; verbal aggression (e.g. threats), physical aggression towards other people (e.g. hitting others), and aggression towards objects (e.g. smashing objects) or self (e.g. banging own head). Studies were included where aggression was either the main concept being measured or aggression was explicitly described as a factor where multiple factors are measured, using multiple items. Studies were excluded if aggression was only reflected in one item or single question within the assessment measure. Measures were excluded if they only assessed violence towards self or self-harm, sexual violence, or intimate partner violence (IPV). These were considered as separate types of aggression each with their own substantial literature base which was outside of the scope of this review.

Only studies and measures in the English language were included.

Data extraction

Initial searches were completed by XX. Screening against inclusion and exclusion criteria of full texts were performed by both researchers (XX and XX) separately and rated "include", "exclude" or "uncertain". Independent ratings were shared and uncertainties or different ratings discussed to come to an agreed rating. Initial agreement was obtained in 59.2% of papers, with uncertainties on 28.9% of papers and different ratings on 11.8%. A total of 31 papers were discussed and a rating agreed. Researchers were able to come to an agreement about all papers without involving a third reviewer. Where other review articles or systematic reviews were identified, these were hand searched by XX for further relevant references.

A final list of included studies was produced and data extracted using a standardised pro-forma adapted for the purposes of this review from a form used by other systematic reviews and meta-analyses (17). The form was piloted with a small sample of articles and then modified to extract the following information: sample size, sample characteristics (age, gender, country, and setting), aggression measure characteristics (name of measure, type of measure e.g. observational, patient self-report or informant-report), number of items, name(s) of sub-scale(s), and definition of aggression), details of psychometric properties measured, and statistical values. A narrative synthesis of data was then completed which involved reviewing and detailing the extracted data in narrative form.

Quality assessment

The COSMIN (Consensus-based Standards for the Selection of Health Measurement Instruments) methodology for systematic reviews of Patient Reported Outcome Measures (PROM) (18) was followed for quality assessment. The COSMIN methodology can also be

used for other types of outcome measures or applications, such as clinician reported, or performance-based measures. It is recommended for such purposes that methodology be adapted appropriately e.g. changing the term "patient" to "clinician", and considering the relevance of certain types of validity when other types of instruments are used, e.g. assessing the internal structure and relatedness amongst items may not be relevant in certain observational measures. A previous systematic review (19) used the Downs and Black checklist (20) and the QUADAS (21) for methodological quality assessment of studies. These tools were designed for use in healthcare intervention studies and studies of diagnostic accuracy. In this review the COSMIN methodology was selected as a recently updated tool which is designed specifically for use in studies assessing outcome measure properties (e.g. reliability and validity). As well as assessing the methodological quality of studies, the COSMIN also assesses the psychometric measurement properties of an outcome measure.

The COSMIN Risk of Bias Checklist assesses the methodological quality of studies on measurement properties of outcome measures providing an overall quality of evidence score of "very low", "low", "moderate", or "high". The interpretation of each quality score as described in the COSMIN methodology is detailed in Table 2. The COSMIN Risk of Bias Checklist assesses standards for PROM development, content validity, structural validity, internal consistency, cross-cultural validity/measurement invariance, reliability, measurement error, criterion validity, hypothesis testing for construct validity, and responsiveness. For each measurement property, a checklist of standards referring to design requirements and preferred statistical methods are assessed, and pooled where multiple studies asses the same property to come to an overall quality of evidence rating. Studies (or pooled studies) are evaluated according to; risk of bias, unexplained inconsistencies in pooled results, sample size, and indirectness (performed in relevant population and context). A measurement property begins

at a "high" grading, and is subsequently downgraded one or two levels (e.g. high to moderate, or high to low) based on a set criteria when there are concerns in any of the above areas.

[Table 2 about here]

The COSMIN checklist also provides a result quality score, which categorises the result or pooled results of the psychometric property as "sufficient", "indeterminate" or "insufficient" using set criteria of values. Each psychometric property has a set requirement for what result value would be considered "sufficient" (these are described at the bottom of Table 5). When these values are not met, an "insufficient" rating is given, and where required values are unclear, or not reported, an "indeterminate" rating is given. Ratings were made by XX, with a second researcher XX assessing 10% of papers to check for consistency. A final percentage of 60.7% consistency in ratings were achieved, where results were inconsistent these were discussed and agreement made. A third reviewer was not required.

## Results

A total of 5,100 studies were identified through database searches, Google Scholar, and grey literature. Abstracts were reviewed against the inclusion criteria, a total of 78 of these were included to be reviewed in full. Hand-searching using systematic review articles did not add any additional references. The flow diagram of the search process is detailed in Figure 1.

[Figure 1 about here]

A total of 53 studies were excluded (see Supplementary Table 2). Twenty-two did not assess aggression by the inclusion criteria (e.g. assessed impulsivity or anger), 11 were review articles or books, 11 did not assess the validity of measures, four studies did not report on a brain injury

sample, two did not provide details of the aggression scale, two were published in different languages, and one was not an adult sample.

A final total of 25 studies were included in the review, totalling 17 measures of aggression. These measures and included studies are listed in Table 3. Further descriptive detail of included measures can be found in Supplementary Table 3.

[Table 3 about here]

Of the 17 measures included, four were considered to be specific measures of aggression only (ATTACKS, BARS, OAS-MNR and OAS-MNR-E), 11 measured multiple factors including aggression (BASTβ, CMBT, CCB, ILS, MBPC-199R, NFI, NPI, OBS, OBS-SR, SASNOS and KSMS), and two measured agitation and irritability with aggression as a factor (ABS and NTUIS). Measures assessing aggression as one factor among other symptoms varied between 14-76 items in length, assessing between five to 12 different factors, with four to 14 items within the aggression scales. Aggression in some scales (e.g. NFI) was a small component of the full scale. Some papers provided limited detail regarding measures, including not stating the number of aggression items (BASTβ and ILS).

In regard to type of measure of included studies, Table 3 shows five were behavioural observational measures (ABS, ATTACKS, BARS, OAS-MNR, OAS-MNR-E), three patient self-report (BASTβ, OBS-SR, KSMS), five informant report by staff only (CBMT, CCB, ILS, OBS, SASNOS), and one informant-report by carers (MBPC-1990R). Three measures (NTUIS, NFI, NPI) were suitable for both self and informant report. The SASNOS is also available in self-report version, however only the informant (staff) report was validated in included studies. Eight measures were designed or validated for use in inpatient settings, one for residential settings and eight for use in community or outpatient settings. The majority (12

measures) were designed or validated for use with people with ABI, with five validated for people with TBI only.

All studies that reported gender of the sample used both males and females to validate their measure, although gender balance in validation studies was skewed towards male samples. Four studies did not report gender of the sample (ABS, ATTACKS, ILS and OAS-MNR). Studies were conducted in a range of countries, with the majority of measures being validated in the UK (seven measures) and the USA (six measures). Other countries included Australia (two measures), Taiwan (one measure). One measure (NFI) was developed and used across 14 different countries.

Each measure assessed between one to six psychometric properties. The measures were assessed for various psychometric properties which included; content validity (four measures), structural validity (five measures), internal consistency (eight measures), reliability (11 measures), construct validity (12 measures), and responsiveness (four measures). Six studies described the development of a new aggression measure.

While the majority of scales were developed specifically for use with people with brain injury, five of these measures were initially developed for use in a different population (ATTACKS, CCB, MBPC-1990-R, NPI, and OAS-MNR). The ATTACKS scale was developed to record inpatient assaults, this scale demonstrated good inter-rater reliability (ICC for scales between 0.61-0.7) and correlated with scores of aggression severity on a Visual Analogue Scale (Spearman's $p = 0.70$) (47). The CCB was developed to assess aggressive behaviour in people with learning disabilities, tests of inter-rater reliability (Spearman's $r$ for scales between 0.682 – 0.702) and test retest reliability (Spearman's $r$ 0.531 – 0.689) indicated the measure is reliable of whether a behaviour occurred, although reliability decreased when assessing frequency, management difficulty and severity of a behaviour (48). The MBPC-1990R was developed for

use in patients with dementia. It has demonstrated good internal consistency (alpha from 0.67 to 0.95), test–retest reliability ($r$ = 0.77-0.88), and inter-rater reliability between two interviewers interviewing the same observer ($r$ = 0.78 – 0.88) although low inter-rater reliability was seen between two observers (0.43-0.53) indicating that the observers perceptions impacted on the reporting of behaviour frequency. Convergent and discriminant validity was confirmed through comparison of MBPC-1990R scores with other related measures (49, 50, 51). The NPI was developed for use in patients with dementia and has demonstrated good internal consistency (Chronbachs alpha 0.88), interrater reliability (93.6 – 100%) test retest reliability ($r$ = 0.79 – 0.86), and concurrent validity was demonstrated with positive correlations with related measures (52, 53). The original OAS was developed for use in psychiatric inpatient samples, and demonstrated good inter-rater reliability, (ICC between 0.72 – 1.0 (11).

Quality assessment summary of all measures

The COSMIN study quality table (Table 4) summarises the overall study quality (or pooled study quality) for each measure. Only one measures (NFI) achieved "high" quality of evidence in all areas of psychometric property assessed; The NFI assessed structural validity, internal consistency and construct validity. All other measures were assigned a "low" or "very low" rating for the quality of evidence in at least one area which was assessed.

[Table 4 about here]

Measures assessed for PROM development and content validity were frequently rated with "low" (e.g. CBMT, MBPC-1990R, OBS) or "very low" (e.g. BASTβ, OAS-MNR, SASNOS, KSMS) quality of evidence due to not involving the staff, carer, or patient in determining comprehensibility or comprehensiveness of the measure. Measures assessed for structural validity and internal consistency were often rated as "moderate" (e.g. ILS, NTUIS, SASNOS) or "high" (e.g. ABS, MBPC-1990R, NFI, NPI, KSMS) quality of evidence. Measures assessed

for reliability, construct validity and responsiveness were often rated "low" or "very low" due to statistical methods not being considered optimal by the checklist (e.g. BARS, ILS, OBS, OBS-SR), or a small sample size (e.g. ABS, ATTACKS, CBMT, CCB, NTUIS, NPI, OAS-MNR, OAS-MNR-E, SASNOS).

The COSMIN psychometric result quality table (Table 5) summarises the values and quality of each psychometric result (or pooled psychometric results) for each measure. Five measures were considered to have sufficient psychometric results for all areas measured; the BARS and OAS-MNR for reliability and construct validity, the NTUIS and MBPC-1990R for internal consistency and construct validity, and the OAS-MNR-E for reliability. All twelve other measures and areas of psychometric property had values which did not meet the threshold for a sufficient value or did not report the values required for the COSMIN criteria.

[Table 5 about here]

## Discussion

This systematic review identified 17 different validated measures of aggression in adults with ABI. Only four of the included measures assessed aggression alone, with the remaining 13 measures assessing a number of areas of behaviour and functioning, which included aggression. Measures varied from observational measures, informant-reports, and patient self-reports, and were validated across a range of different settings including inpatients units, and community settings. The majority of work was conducted in the UK and USA. Quality of measurement tools as judged by the COSMIN was often low with the MBPC-1990R, NFI, SASNOS and KSMS being most valid with high quality evidence and sufficient psychometric properties demonstrated in at least one area. Reasons for low quality included; small sample

sizes, lack of optimal statistical methods used, or not involving users in the development process.

There was some variation in how aggression was defined. Most measures included verbal aggression, physical aggression towards objects, and aggression towards other people, with 11 out of 19 measures (57.9%) also measuring self-directed aggression. This finding was unexpected as self-directed aggression is often overlooked in aggression literature, with only 36% of studies measuring aggression in inpatient settings including self-harm in their definition (54). This may be explained by a number of measures in this review basing their items on the criteria used in the Overt Aggression Scale (11) which includes self-directed aggression. Some measures were developed for specific types of aggression such as interpersonal physical aggression (ATTACKS) and verbal aggression (NTUIS). A smaller number of measures also assessed sexual aggression (e.g. unwanted touching) as a sub-scale as part of a broader measurement of aggression (BASTβ, CCB, ILS). The limited measures which included this would suggest that sexual behaviours may be seen as relating to aggression but are not typically classed as aggression when assessed using these measures, or when defining aggression in the literature (54). This was therefore not covered within the definition in this review.

Although there were a variety of measures, the majority of these assessed aggression as a component of a complex presentation of other symptoms and behaviours such as cognitive and emotional symptoms, rather than assessing aggression alone. A previous systematic review involving people with TBI reported similar findings (19). This reflects how aggression is only one of the many reported cognitive, behavioural, and emotional outcomes following ABI (55, 56). The limited number of measures available that were designed to assess aggression alone (e.g. ATTACKS, BARS, OAS-MNR and OAS-MNR-E) were all observational measures to be completed by staff. Whilst these require minimal completion time, observational measures are

not always appropriate. An aggression-specific measure is not available in self or informant-report, thus the few measures that are available are not suited to all uses. In patient or informant report, aggression is measured among other symptoms, and length of the measures can vary. In some cases aggression is only a small component of the full scale, which should be considered when selecting a measure.

In inpatient and residential settings, there was a trend for use of aggression measures completed by staff either through observation or through a questionnaire or checklist. Staff are available in these settings to observe and record incidents, thus this is a pragmatic method to assess a patient's level of aggression. This review found five observational measures of aggression for use in inpatient settings (ABS, Attacks, BARS, OAS-MNR, and OAS-MNR-E), and four staff-informant measures (CBMT, CCB, ILS, and SASNOS). The SASNOS is also available in self-report, however this version was not validated in the included studies. Inter-rater reliability has been evidenced as sufficient in these measures when assessed, indicating that different staff raters often make the same judgements. Observational measures can be criticised for underreporting of incidents by staff when occurring frequently (57). For example, a busy inpatient unit may struggle to document all observations of aggression, thus these could be used in conjunction with a staff-informant measure to capture overall aggression.

Within community settings we identified only one staff-informant measure (OBS). Staff presence is limited in community settings making staff-informant measures difficult to complete with fewer observation opportunities, instead aggression tended to be measured through self or carer-informant report. Carer-informant questionnaires can be completed by someone who knows the individual well and who can offer insight into the individual's behaviour. We identified one carer-informant questionnaire in this review (MBPC-1990R) and three with both carer and self-report versions (NTUIS, NFI and NPI). One of which included a measurement of the impact of the behaviour on the carer (MBPC-1990R). It is noted however

that this level of impact could potentially be a cause of bias, where behaviours may be rated as more problematic (14). Using this alongside other measures such as patient self-report could help reduce this bias.

Patient self-report questionnaires (BASTβ, OBS-SR, and KSMS) have the advantage of being able to assess the individuals own perception of aggression. We found that some have both carer and self-report versions (NTUIS, NFI and NPI), however when comparisons are made, varied and often low levels of inter-rater agreement have been found (42). The inter-rater agreement varied dependent on the individual's awareness levels, suggesting this is a form of bias in self-report measures. This finding isn't unexpected as patient self-report scales reflect patients' inner thoughts and feelings regarding their aggression, whereas an observer/informant measure reflects observable aggressive behaviours. Patients inner thoughts may not be known to an observer, and patients observable behaviours may not be accurately recorded by the patient themselves. This may be the case if lacking awareness or insight into their difficulties and behaviours, lacking memory, or if in denial of less desirable behaviours such as aggression. Other research has demonstrated a similar lack of concordance between self and others reports of aggression (6, 58). It may be more appropriate when selecting a self-report questionnaire, to consider use of an informant questionnaire where possible to obtain a more accurate reflection of an individual's aggression.

A previous systematic review published in 2014 (19) identified six measures of aggression for use in people with TBI. The current review expands on this with the addition of more recent measures for use in people with TBI (e.g. BASTβ), and additional measures suitable for use in people with ABI. Although the current review identified 17 measures, only one measure was included in both reviews (NFI). The current review used different inclusion and exclusion criteria, and a different definition for aggression. The current systematic review also excluded studies in which the aggression component of the measure comprised of an assessment of anger

rather than behavioural displays of aggression (verbal aggression or physical aggression). Indeed, for this reason one of the studies identified in the previous review was excluded (Psychosocial Outcome Risk Indicator; 59). Measures were also excluded where the definition of aggression was unclear, such as when a description was not provided detailing the factors or items, where it was not possible to determine if the inclusion criteria were met. For this reason four of the studies identified in the previous review were excluded (Katz Adjustment Scale; 60, Minesota Multiphasic Personality Inventory – 2; 61, Personality Assessment Inventory; 62, Ruff Neurobehavioural Inventory; 63).

*Strengths and limitations*

The current review used a wide search criteria with over 5,000 articles reviewed for inclusion. Hand searching of review articles and exploration of grey literature made it less likely for measures to have been missed. This review is, therefore, likely to reflect the current literature on validated assessment measures for aggression in people with ABI. We do, however, accept some limitations in the search specifically by not including Cochrane and Trials databases and not including separate search terms for reasons for acquired damage to the brain (e.g., stroke, brain tumour).

A specific definition of aggression was adhered to in this review. Several measures which assessed aggression with a single question amongst other factors were excluded using this criteria, as well as measures of factors loosely related to aggression such as anger. Measures of related concepts would therefore not be captured in this review.

A wide variety of assessment measures were identified, however this review highlights the limited research investigating psychometric properties of the current measures, with the majority being limited to one study validating the measure in people with ABI, with many psychometric properties not being assessed. This limits the ability to determine a tool's validity

in the ABI population as the included studies were often limited by small sample sizes, potential for bias, and lacked the required methodology or statistics for determining the psychometric property.

Research within this area is ongoing and would benefit from further validation of the current measures to enable clinicians to identify the more appropriate measures to use when assessing aggression. Authors of the current measures have identified further work such as confirming the factor structure of the BASTβ along with further validity testing (26) and ongoing projects revising and validating the SASNOS.

*Applying findings to clinical practice*

Due to the variety of constructs which are measured and the mixture in quality of evidence, it is not practical to recommend a specific tool for use across all settings. Instead, a clinician should consider the types of aggression and other behaviours that are relevant to assess and select a tool based on this. Some measures such as the MBPC-1990R, NFI, SASNOS and KSMS did demonstrate positive results for psychometric properties in areas where high quality evidence was used. These should be used with caution due to the limited number of studies and psychometric properties assessed. In an inpatient setting, a measure such as the OAS-MNR/OAS-MNR-E or the BARS may be useful for staff as a way of documenting and monitoring incidents of aggression as they occur. These measures have the advantage of having good evidence for reliability between raters. The ABS demonstrated good evidence of internal consistency which could be used where agitation and aggression are relevant to record.

For lengthier assessment of aggression and other areas of functioning, a number of measures with good internal consistency were identified. A self or informant report tool such as the NFI or the NPI could be of use, the NPI through its screening approach allows for a larger number of areas to be assessed in fewer questions. Shorter measures which assess multiple areas such

as the KSMS could be used as a self-report, or the NTUIS as a self or informant report where irritability and verbal aggression is relevant to record. The MBPC-1990R could be used for an informant to document the frequency and impact of a number of problem areas. The SASNOS had the highest number of psychometric properties assessed, achieving good evidence for internal consistency, reliability, and responsiveness. Although quality of evidence was rated low in some areas, this was due to a small sample size. Remaining areas within the COSMIN checklist were often rated as adequate, indicating the SASNOS may be a helpful tool for staff assessing aspects of neurobehavioural disability in inpatient settings. A self-report version of the SASNOS is also available, but is not yet validated. When selecting a specific type of measure, the limitations of the measure type should be considered. Most accurate information regarding aggression would be obtained by a combination of observational, self, and informant reports.

In conclusion, a wide variety of measures are available to assess aggression in adults with ABI with tools available for use in community and inpatient settings that capture a number of facets of aggression. This review highlights that although a number of measures exist, there is a lack of well- validated measures within this population which has been impacted by a small number of often low quality studies assessing limited aspects of validity. Some assessment measures demonstrate good evidence of some aspects of validity (e.g. MBPC-1990R, NFI, SASNOS and KSMS), although further research to validate these measures would be required.

## Disclosure of interest

The authors report no conflict of interest. The work was completed and written by the authors as part of a doctoral thesis. This project was not in receipt of funding.

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*Table 1. Description of different aggression measure types*

| Assessment of aggression | Typically completed by | Description | Advantages | Disadvantages |
|---|---|---|---|---|
| **Behavioural observation (E.g. OAS-MNR)** | An observer, typically a staff member. | Rating an incident of aggression after witnessing. | Captures objective detail of behaviours. | Not always possible to observe all behaviours and does not capture the persons perspective. |
| **Patient self-report questionnaire (E.g. KSMS )** | Person with an ABI. | Responses to questions or statements about aggression, usually on a Likert scale. | Captures the person's self- report of behaviours and feelings such as anger. Able to assess multiple areas of functioning. Can be completed when observation is not possible (e.g. community living). | Limited self-awareness or memory may impact accuracy of ratings (12, 13). |

| | | | | |
|---|---|---|---|---|
| **Informant-report questionnaire (E.g. SASNOS )** | Caregiver such as family member or partner, can also be completed by staff. | Responses to questions or statements about aggression, usually on a Likert scale. | Captures the informant's knowledge of the person's behaviour and feelings, also able to assess multiple areas of functioning. Can resolve biases of self-report. | Informants may be biased or may have limited knowledge about the individual's behaviours or feelings. Can be biased due to carer burden e.g. behaviours rated as more problematic due to personal involvement/ stressors (14). |

Table 2. COSMIN quality of evidence scores and their interpretation

| Quality of evidence | Interpretation |
|---|---|
| High | We are very confident that the true measurement property lies close to that of the estimate (pooled or summarised result) of the measurement property. |
| Moderate | We are moderately confident in the measurement property estimate: the true measurement property is likely to be close to the estimate of the measurement property, but there is a possibility that it is substantially different. |
| Low | Our confidence in the measurement property estimate is limited: the true measurement property may be substantially different from the estimate of the measurement property. |
| Very low | We have very little confidence in the measurement property estimate: the true measurement property is likely to be substantially different from the estimate of the measurement property. |

*Table 3. Study characteristics including measure description.*

| **Study and measure** | **Setting: Inpatient/community, country**<br>**Sample: ABI/TBI, gender, mean age (years), SD, range.** |
|---|---|
| **Agitated Behaviour Scale (ABS):** Observational measure of agitation. 14 items. Four aggression items. | |
| (22) | Setting: Inpatient, USA<br>Sample: TBI (*n*=35), 82.9% male, Mean age = 28.2. |
| (23) | Setting: Inpatient, USA<br>Sample: ABI (*n*=212), 73% male, Mean age = 31.2 (14.27), 13 – 72. |
| (24) | Setting: Inpatient, USA<br>Sample: TBI (*n*=45), Gender/age not stated. |
| **Attempted and Actual Assault Scale (Attacks):** Observational measure of interpersonal physical violence. Five scores regarding actual and intended severity of an assault. | |
| (25) | Setting: Inpatient, UK<br>Sample: ABI (*n*=25), Gender not specified, Mean age = 38.25 (15.55), 19-63. |
| **Behavioural assessment screening tool (BASTβ)**: Patient self-report of behavioural problems/emotional symptoms, coping strategies, and major life events. 67 items. Beta version with scale development not yet published. | |
| (26) | Setting: Community, USA<br>Sample: TBI (*n*=11), Group 1: 100% male, Group 2: 47% male, age 25 – 68. |
| **BIRT Aggression Rating Scale (BARS):** Observational measure of impulsive aggression. Records and categorises verbal and physical aggression, with three levels of severity. | |
| (27) | Setting: Inpatient, UK<br>Sample: ABI (*n*=309), 71% male, Mean age =42.0 (14.5), 17–74. |

| | |
|---|---|
| **Challenging Behaviour Management tool (CBMT):** Informant report (staff) of eight challenging behaviours. Four aggression items. | |
| (28) | Setting: Inpatient, UK<br>Sample: ABI (*n*=20), 60% male, Mean age = 51 (11), 23–67. |
| **Checklist of Challenging Behaviour (CCB):** Informant report (staff) of aggressive and challenging behaviour. 32 items. 14 aggression items. | |
| (29) | Setting: Inpatient, UK<br>Sample: ABI (*n*=22), 81.8% male, mean age = 39.74 (10.36), 20-57 |
| **Independent Living Scale (ILS):** Informant report (staff) of multiple areas of functioning e.g. activities of daily living and behaviour. 44 items. Number of aggression items not stated. | |
| (30) | Setting: Inpatient, USA<br>Sample: Post-acute TBI, details unclear |
| **Memory and Behavior Problems Checklist – 1990R (MBPC-1990R):** Informant report (carer) of 25 problem behaviours. Six aggression items. | |
| (31) | Setting: Community, UK<br>Sample: ABI (*n*=222), male = 72%, mean age = 46 (13.5), 18-72 |
| **National Taiwan University Irritability Scale (NTUIS):** Patient and informant (carer) report of emotional/behavioural expressions of irritability. 18 items. Nine aggression items. | |
| (32) | Setting: Community, Taiwan<br>Sample: TBI (*n* = 64), 47% male, Mean age = 35.11 (14.81) |
| **Neurobehavioural functioning inventory (NFI):** Patient or informant-report (carer) of a range of behaviours/symptoms. 66-76 items depending on version. Nine aggression items. | |
| (33) | Setting: Community, USA<br>Sample: TBI (*n*=520), 77% male, Age not specified |

| | |
|---|---|
| (34) | Setting: Setting unclear, 14 different countries<br><br>Sample: TBI (*n*=655), Male 74%, Mean age = 31.64 (13.80) |
| (35) | Setting: Setting unclear, USA<br><br>Sample: TBI (*n*=586), 76.8% male. Age not specified |
| (36) | Setting: Community, New Zealand<br><br>Sample: TBI (*n*=108), Male 73%, Age 20–87 |
| **Neuropsychiatric Inventory (NPI):** Patient and informant report (carer). 12 domains such as depression, anxiety irritability, and disinhibition, 7–9 items in each. Seven aggression items. | |
| (37) | Setting: Setting unclear, USA<br><br>Sample: TBI (*n*=51), 72% male, Mean age = 38.06 (19.08) |
| (38) | Setting: Community, USA<br><br>Sample: TBI (*n*=287), 61.8% male, Mean age=39.02 (12.71) |
| **Overt aggression Scale - Modified for Neurorehabilitation (OAS-MNR):** Observational measure of aggressive behaviour; type, severity, antecedents, and interventions used. | |
| (39) | Setting: Inpatient, UK<br><br>Sample: ABI (*n*=18), gender and age not stated |
| **Overt Aggression Scale - Modified for Neurorehabilitation – Extended (OAS-MNR-E):**<br><br>Modification of the OAS-MNR. Includes "where" section and "outcome/resolution" section. | |
| (40) | Setting: Inpatient, USA<br><br>Sample: ABI(*n*=34), male = 82.5%, Mean age=54(13), 33-80 |
| **Overt Behaviour Scale (OBS):** Informant report (staff) of severity and frequency of nine challenging behaviours. Four aggressive behaviour items. | |

| | |
|---|---|
| (41) | Setting: Community, Australia<br>Sample 1: ABI *n*=30, gender unknown, mean age = 31.5 (13.2)<br>Sample 2: ABI *n*=28, 85.7% male, age unknown |
| **Overt Behaviour Scale-Self Report (OBS-SR):** Patient self report measure of severity and frequency of nine challenging behaviours. Four aggressive behaviour items. | |
| (42) | Setting: Community, Australia<br>Sample 1: ABI *n*=37, 48.6% male, age = 51.7 (16).<br>Sample 2: ABI *n*=34, 72.7% male, age=38.2 (13.1) |
| **St Andrews- Swansea Neurobehavioural Outcome Scale (SASNOS):** Informant (staff) and self-report of neurobehavioural disability. 49 items. 12 aggression items. | |
| (43) | Setting: Inpatient, UK<br>Sample: ABI (*n*=95), 73.7% male, Mean age = 40.3 (11.3), 18-62 |
| (44) | Setting: Inpatient, UK<br>Sample: ABI (*n*=145), 71% male, age not stated |
| (45) | Setting: Inpatient, UK<br>Sample: ABI(*n*=50), 76.7% male, Mean age = 45.7 (13.7), 18 – 73 |
| **The sister Kenny Symptom management Scale (KSMS):** Patient self-report tool to examine perceived difficulty with managing symptoms. 34 items. Eight aggression items. | |
| (46) | Setting: Community, USA<br>Sample: Study 1: ABI (*n*=328), 58.5% male, mean age = 41 (11.91)<br>Study 2: ABI (*n*=336), 57.1% male, 53.9% male, age = 40.9 (11.52) |

**Notes:** "Inpatient" refers to patients with ABI residing in inpatient/residential neurobehavioural rehabilitation and treatment services where patients are cared for by staff.

"Community" refers to patients with ABI residing in own homes including receiving support through family/carers or accessing outpatient treatment services.

*Table 4. COSMIN quality assessment: Overall study quality*

| Measure | Development | Content Validity | Structural Validity | Internal consistency | Reliability | Hypothesis testing for construct validity | Responsiveness |
|---|---|---|---|---|---|---|---|
| ABS | | | High | Moderate | Low | Very low | |
| Attacks | | | | Low | | Low | |
| BASTβ | Very low | Moderate | | | | | |
| BARS | | | | | Moderate | Low | |
| CBMT | Low | Low | | | Very low | | |
| CCB | | | | | Very low | Low | |
| ILS | | | Moderate | | Very low | | |
| MBPC 1990R | | Low | | High | | High | |
| NTUIS | | | | Moderate | | Low | |
| NFI | | | High | High | | High | |
| NPI | | | High | Moderate | | | Low |
| OAS-MNR | Very low | | | | Very low | Low | |
| OASMNR-E | | | | | Low | | |
| OBS | Low | | | | Very low | Very low | Very low |
| OBS-SR | | | | | Low | Very low | |
| SASNOS | Very low | Low | Very low | Moderate | Low | Low | High |
| KSMS | Very low | | | High | Very low | Moderate | Moderate |

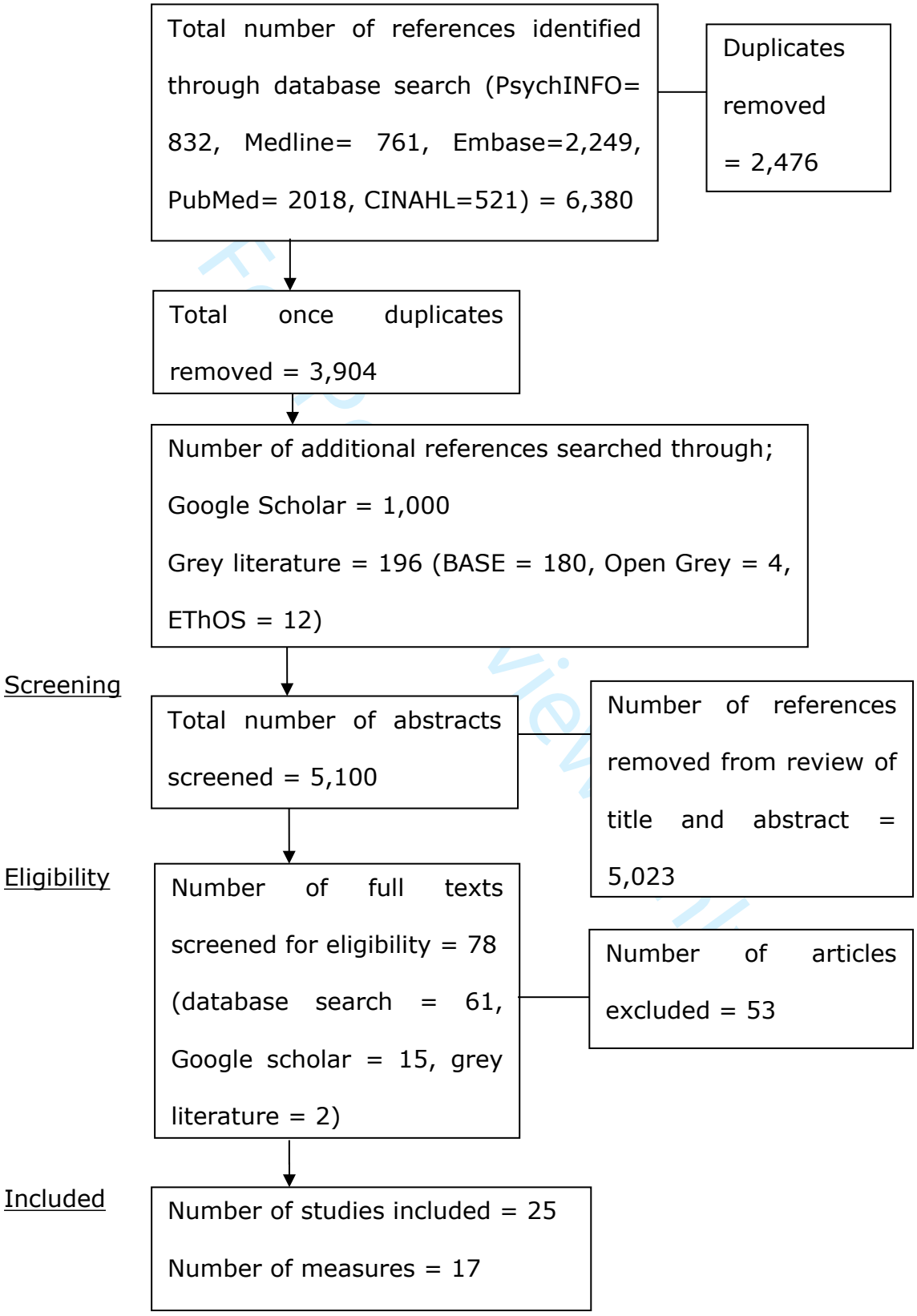
*Table 5: COSMIN quality assessment: Psychometric result quality*

| | **Structural Validity** | | **Internal consistency** | | **Reliability** | | **Hypothesis testing for construct validity** | | **Responsiveness** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **Result & quality** | | **Result & quality (Chronbachs alpha)** | | **Result & quality (ICC or Kappa)** | | **Result & quality (correlation coefficient)** | | **Result & quality** | |
| ABS | Rho value = 0.85 | - | a = 0.801 to 0.921 | + | No ICC or Kappa. | ? | (1) r = 0.424 - 0.787 | - | | |
| Attacks | | | a = 0.38. | - | | | (1) r = 0.50 (2) r = 0.39 | + | | |
| BASTβ | | | | | | | | | | |
| BARS | | | | | ICC = 0.92 | + | (3) r = 0.15. and 0.22 | + | | |
| CBMT | | | | | No ICC or Kappa. | ? | | | | |
| CCB | | | | | No ICC or Kappa. | ? | (1) r = 0.468 to 0.638 | + | | |
| ILS | KMO = 0.94, BTS p=0.00. $R^2$ =0.77 – >0.85 | ? | | | No ICC or Kappa. | ? | | | | |
| MBPC 1990R | | | a = 0.69 to 0.80 | + | | | (1) r = 0.70 to 0.78 (3) r =-0.02 (2)r=0.24 to 0.56 | + | | |
| NTUIS | | | a =0.92 | + | | | (1)r = 0.54, (3) r = 0.05 | + | | |
| NFI | CFI 0.86 to 0.93. RMSEA 0.08 to 0.12 | - | a = 0.79 to 0.95 | + | | | (1) r= -0.34 to 0.65. (2) r = -0.50 to 0.26 | - | | |
| NPI | CFI 0.977 to 0.991 infit outfit 0.84 to 1.5 | ? | a= 0.758 to 0.914 | + | | | | | d from -1.32 to -2.30. | ? |
| OAS-MNR | | | | | Kappa 0.742 to 1.0 | + | (1) r= 0.50 (2) r=0.39 | + | | |
| OASMNR-E | | | | | Kappa 0.772 to 0.977 | + | | | | |
| OBS | | | | | No ICC or Kappa. | ? | (1) r= 0.37 to 0.66 | - | No effect size | ? |
| OBS-SR | | | | | ICC 0.689 | - | (1)r= 0.37 to 0.61 | - | | |
| SASNOS | Infit/outfit values 0.7 to1.3 | ? | a= 0.62 to 0.93 | + | ICC 0.59 to 0.96. | + | (1) r= -0.3 to 0.71 (3) r=0.31 | - | Effect size 0.71 to 1.05 | + |
| KSMS | | | a= 0.77 to 0.92 | + | No ICC or Kappa. | ? | (1) r= -0.2 to 0.68. | - | d=0.34 to 0.81 | ? |

Result quality; + = sufficient, ? = indeterminate, required values not reported, and - = insufficient.

Required values;
Structural Validity: factor analysis: CFI >0.95, RMSEA <0.06 Rasch: Same as factor analysis, and residual correlations <0.2, and adequate graphs or item scalability >0.3, and infit/outfit mean squares ≥0.5 and ≤1.5 or Z-standardized values > -2 and <2
Internal Consistency: Chronbachs Alpha ≥0.70 for all subscales
Reliability: ICC or weighted kappa values ≥0.70, correlations not sufficient
Construct validity: correlations of >0.50 with measures which are expected to relate (1), and <0.30 for measures which are related but dissimilar (2), and <0.30 for unrelated measures (3).
Responsiveness: Area Under the Curve or effect sizes describing values which would constitute a good effect size

*Figure 1. CONSORT flow diagram detailing review process*



## Supplementary Table 1. PRISMA checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 3-4 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 4 & 6 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | 4 |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 5-7 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 4-6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 4-6 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6-7 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7-8 |

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| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 5 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | COSMIN 7-9 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | N/A |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 7-8 |
| Section/topic | # | Checklist item | Reported on page # |
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 8-9 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | N/A |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 9 (Fig 1) |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 9-12 (Table 3 and Supp Table 3) |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | 12-13 (Tables 4-5) |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 9-12 Table 3 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | N/A |

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| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | 11-13 (Tables 4-5) |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | N/A |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 13-20 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 17-18 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 18-20 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | N/A no funding |

**Supplementary table 2. Table of excluded papers (*n*=53) and reasons for exclusion**

| Author | Measure | Reason for exclusion |
|---|---|---|
| Alderman, Knight & Henman (2002) | OAS-MNR | Does not validate measure |
| Alderman, Bentley & Dawson (1999) | OAS-MNR | Does not validate measure |
| Alderman, Davis, Jones & McDonnel (1999) | OAS-MNR | Does not validate measure |
| Alderman, Major & Brooks (2018) | START | Items do not reflect aggression |
| Alderman, Knight, Stewart, & Gayton (2011) | OAS-MNR | Does not validate measure |
| Andrews, Kaye, Aitken, Parr, Bates & Murphy (2003) | ESDQ | Items do not reflect aggression: only one question in anger scale |
| Azouvi (2015) | Dysexecutive Questionnaire | Items do not reflect aggression – one question |
| Bateman, Teasdale, & Willmes (2009) | Self-rating European Brain Injury Questionnaire | Items do not reflect aggression: impulsivity not aggression |
| Belanger, Brown, Crowell, & Vanderploeg (2002) | Key Behaviors Change Inventory | Sample not brain injury |
| Beni, et al (2017) | The Geneva Scale of Socio-emotional Behavior Change | Measure not in English |

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| Bodenburg | Dysexecutive Questionnaire | Items do not reflect aggression – one question |
| Bogner & Corrignan (2009) | Ohio State University TBI identification method | Items do not reflect aggression: TBI screening method |
| Bohac, Malec & Moessner (1997) | Mayo-Portland Adaptability Inventory | Items do not reflect aggression – one question |
| Boosman et al (2016) | Motivation for Traumatic Brain Injury Rehabilitation Questionnaire | Items do not reflect aggression: Anger |
| Ca Silver, Cattran & Oddy (2014) | The BIRT Neuro-Behavioural Scales | Items do not reflect aggression |
| Cattran, Oddy & Wood (2011) | BIRT regulation of emotions questionnaire | Items do not reflect aggression: Emotion regulation |
| Cattran, Oddy, Wood & Moir (2011) | Five measures of non-cognitive neurobehavioural (NCNB) change | Items do not reflect aggression and not validated in this article |
| Chervinsky et al (1998) | Motivation for traumatic brain injury rehabilitation questionnaire | Items do not reflect aggression: Anger |
| Corrignan & Bogner (1995) | Agitated Behavior Scale | Review article |
| Corrigan, Smith-Knapp & Granger (1997) | Functional Independence Measure | Items do not reflect aggression |
| Cusimano, Holmes, Sawicki & | Review | Review article |

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| Topolovec-Vranic, (2014) | | |
| Diamond & Magaletta (2006) | Short-form Buss-Perry Aggression Questionnaire | Sample not brain injury |
| Egeland & Kovalic-Gran (2010) | Conners' Continuous Performance Test | Items do not reflect aggression |
| Gagnon (2016) | A French adaptation of the Overt Behaviour Scale | Measure not in English |
| Galski, Palatz, Bruno & Walker (1994) | Cognitive Behavioral Rating Scale | Validation not described in detail and not main purpose of study |
| Hall et al (2001) | Review | Review article |
| Heilbronner & Henry (2013) | Review | Review book |
| Horton & Tommons (1982) | Wiggins MMPI content scales | Items do not reflect aggression and does not validate measure |
| Johansson, Jamora, Ruff & Pack (2008) | Ruff Neurobehavioural Inventory anger scale | Aggression scale not described |
| Kolitz et al (2003) | Key Behaviors Change Inventory | Items do not reflect aggression: interpersonal difficulties |
| Kurtz & Blais (2007) | Personality Assessment Inventory | Review article |
| Leon-Carrion (1998) | Neurologically-related Changes in Personality Inventory | Sample not brain injury |

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| Malec (2000) | Mayo-Portland Adaptability Inventory | Items do not reflect aggression – one question |
| Malec, Kean, Altman & Swick (2012) | Mayo-Portland adaptability inventory | Items do not reflect aggression: one question in adjustment index |
| Malec & Hammond (2018) | Neuropsychiatric Inventory | Does not validate measure |
| Malloy & Grace (2005) | Review | Review article |
| Max et al (1998) | The Neuropsychiatric Rating Schedule | Child/adolescent sample |
| Meachen (2008) | Brief Symptom Inventory - 18 | Items do not reflect aggression |
| Monsalve et al (2012) | Neuropsychiatric Inventory | Does not validate measure |
| Mooney, Walmsley & McFarland (2006) | self-report Dysexecutive Questionnaire | Participants not brain injury and items do not reflect aggression- one question |
| Mosalve et al (2014) | Review article | Review article |
| Palev et al (2001) | MMPI-2 Content Scales | Items do not reflect aggression – unclear |
| Pender & Fleminger (1999) | Review | Review article |
| Rochat (2018) | UPPS model of impulsivity | Items do not reflect aggression - impulsivity |
| Shukla, Devi & Agrawal (2011) | Review | Review article |
| Suris et al (2004) | Review | Review article |
| Swan & Alderman (2004) | Neurobehavioural | Items do not reflect |

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| | Expectations Scale | aggression and does not validate measure |
| Tate (2013) | Review | Review article |
| Till, Christensen & Green (2009) | Personality Assessment Inventory | Aggression scale not described |
| Tulsky, Kisala, Holdnack, & Cohen (2016) | Traumatic Brain Injury-Quality-of-Life measurement system | Items do not reflect aggression - anger |
| Vallat-Azouvi et al (2018) | Brain Injury Complaint Questionnaire | Items do not reflect aggression – one question |
| Woessner & Caplan (1995) | Symptom Checklist-90-Revised | Items do not reflect aggression and does not validate measure |
| Yamasato (2007) | Questionnaire for Neurobehavioral Disability | Items do not reflect aggression |

*Supplementary Table 3. Description of all included aggression measures.*

| Measure | Description |
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| Agitated Behavior Scale (ABS) | Observational measure. A 14-item scale to monitor agitation in the acute phase of recovery from ABI. Statements which describe behaviours are rated following an observation period on a scale of 1-4 from "absent" to "present to an extreme degree". Includes agitation with aggression factor (four items). Aggression includes violence or threats towards people or property, physical or verbal abuse to self, explosive anger, and being uncooperative. |
| Attempted and Actual Assault Scale (Attacks) | Observational measure. A measure of interpersonal physical violence following witnessing an event. Five scores are produced regarding actual and intended severity of an assault, taking into account use of weapons, area targeted, number of times struck, commitment to achieving assault, and potential for injury. Measures aggression only: Interpersonal physical violence, the actual severity, and intended severity of an assault. |
| Behavioural assessment screening tool (BASTβ) | Patient self-report. A 67-item measure of behavioural problems/emotional symptoms, coping strategies and major life events. Statements are rated on a three-point scale from "never" to "frequently". The BAST is in Beta version with scale development not yet published. Aggression items include; anger and verbal aggression towards others (yelling and disagreements), physical fights with others, and inappropriate sexual comments. |
| BIRT Aggression Rating Scale | Observational measure. A rating scale used by staff witnessing aggression to record and categorise verbal and physical aggression, |

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| (BARS) | with three levels of severity. Designed for measuring impulsive aggression. Verbal aggression includes directed, non-directed, and threats of harm. Physical aggression can be destructive or non-destructive towards objects, self or other. |
| Challenging Behaviour Management tool (CBMT) | Informant-report (staff) measure. Records challenging behaviours, scored by staff over a specified time period using all available evidence. Eight behaviours are scored on intensity, management, predictability, frequency and duration from "mild" to "severe". Contains four aggression items: verbal aggression, physical aggression against people, physical aggression against objects, and against self. |
| Checklist of Challenging Behaviour (CCB) | Informant-report (staff). A 32-item scale rating aggressive and challenging behaviours on frequency, severity and management difficulty in the preceding three months. Items are rated on a five point scale (0-4). Contains 14 Aggression items include physical aggression towards others (e.g. biting, punching, throwing things), as well as unwanted sexual contact and self-injury. |
| Independent Living Scale (ILS) | Informant report (staff). A 44-item tool assessing multiple areas of functioning from observational data over a one week period. Includes activities of daily living, behaviour, and initiation. Each item is weighted for scoring on a 100 point scale. Includes a directed aggression factor (number not stated) which includes items such as; physical aggression, self-abuse, property abuse, angry language, and sexually aberrant behaviour. |
| Memory and Behavior Problems | Informant report (carer). A measure of 25 problem behaviours on frequency over the past week and how much each problem has upset |

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| Checklist – 1990R (MBPC-1990R) | the carer, on a five point scale from "not at all" to "extremely". Assesses Four factors; excessive, aggressive, cognitive, and passive/low mood. The aggression subscale (six items) includes items which reflect being suspicious, angry, striking out, behaviour dangerous to themselves, verbal aggression or threats, and uncooperative behaviour. |
| National Taiwan University Irritability Scale (NTUIS) | Patient and informant report (carer). An 18-item measure of emotional and behavioural expressions of irritability. Items are rated on a six point scale, scored for pre-injury and post injury. Measures annoyance and verbal aggression. Aggression (nine items) includes getting into arguments, disagreeing with others, and letting irritation show. |
| Neurobehavioural functioning inventory (NFI) | A self or informant-report (carer) tool assessing a range of behaviours and symptoms following TBI in six factors depression, somatic, memory/attention, communication, aggression, and motor symptoms. Items are rated on a four point scale from "never" to "always". Several versions of the NFI have been described, a 70-item version (study one), a 66-item version (study two) and the most recent 76-item version (studies three and four). The aggression items (nine items) include how often the individual hits or pushes others, makes inappropriate comments, screams or yells, threatens to hurt others, breaks or throws things, curses at others or self, argues, and is rude to others. |
| Neuropsychiatric Inventory (NPI) | Patient and informant report (carer). Evaluates a number of disturbances on severity, frequency and caregiver distress across 12 domains such as depression, anxiety irritability, and disinhibition. Each domain has a screening question followed by seven to nine questions |

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| | about difficulties. Agitation/aggression (seven items) includes slamming doors, kicking furniture, hurting or hitting others, shouting or cursing angrily. |
| Overt aggression Scale - Modified for Neurorehabilitation (OAS-MNR) | Observational measure. A scale rated following an aggressive behaviour. Records type of aggression (four types) and severity (range 1-4), antecedents observed (18 categories), and interventions used (14 interventions). Measures aggression only; verbal aggression and physical aggression against objects, self, and others. |
| Overt Aggression Scale - Modified for Neurorehabilitation – Extended (OAS-MNR-E) | Observational measure. A modification of the OAS-MNR to include a "where" section (13 locations) and an "outcome/resolution" section indicating how the incident ended. Measures aggression only; verbal and physical aggression against objects, self, and others. |
| Overt Behaviour Scale (OBS) | Informant report (staff). A measure of severity and frequency of nine challenging behaviours and the impact they have on others, rated on a five point scale. Measures four aggressive behaviours; Verbal aggression and physical aggression against objects, self, and others. |
| Overt Behaviour Scale-Self Report (OBS-SR) | Patient self report. As above, but language suited to self-report. |
| St Andrews-Swansea Neurobehavioural Outcome Scale | Informant (staff) and self-report. A 49-item measure to identify neurobehavioural disability, support received, goals, and measuring progress. Domains include; interpersonal behaviour, cognition, aggression, inhibition, and communication. Items are rated on a seven |

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| (SASNOS) | point scale from “never” to “always”. Aggression scale (12 items) includes; provocative behaviour (e.g. swearing), irritability (e.g. reacting angrily), and overt aggression (threatening others, physical aggression against others, or objects). |
| The sister Kenny Symptom management Scale (KSMS) | Patient self-report. A 34-item tool to examine patient’s perceived difficulty with managing symptoms in five areas; executive functions, language, recent memory, aggressive behaviour, and physical symptoms. Items are rated on a five point scale. The aggression scale (eight items) includes losing temper, arguing, yelling, being pushy or demanding, destroying things, and physically attacking someone. |