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The key role of base rates: systematic review and meta-analysis of the predictive value of four risk assessment instruments

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Summary

AIMS OF THE STUDY: Many countries have seen a decline in recidivism rates over the past decades. These base rates are pertinent information for assessing the recidivism risk of offenders. They provide a foundation for clinical assessment and an empirical basis for risk assessment instrument norms, which inform expected recidivism rates. The present study explored the extent to which base rates influence the validity of risk assessment instruments.

METHODS: We systematically reviewed the available evidence on the discrimination ability of four well-established risk assessment instruments used to estimate the probability of recidivism for general (Level of Service Inventory-Revised [LSI-R]), violent (Violence Risk Appraisal Guide [VRAG]), sexual (Static-99R), and intimate partner violent offences (Ontario Domestic Assault Risk Assessment [ODARA]). We conducted a bivariate logit-normal random effects meta-analysis of sensitivity and false positive rates and modelled the positive and negative predictive values. We used base rates as reported in (a) the construction samples of each risk assessment instrument and (b) recent official statistics and peer-reviewed articles for different offence categories and countries. To assess the risk of bias, we used the Joanna Briggs Institute Critical Appraisal Checklist for Diagnostic Test Accuracy Studies.

RESULTS: We screened 644 studies and subsequently analysed 102, of which 96 were included in the systematic review and 24 in the meta-analyses. Discrimination was comparable for all four instruments (median area under the curve = 0.68–0.71). The information needed to calculate summary statistics of sensitivity and false positive rate was often not reported, and a risk of bias may be present in up to half of the studies. The largest summary sensitivity and false positive rate were estimated for the ODARA, followed by the LSI-R, the VRAG, and the Static-99R. If base rates are low, positive predictive values tend to be relatively low, while negative predictive values are higher: positive predictive value = 0.032–0.133 and negative predictive value = 0.985–0.989 for sexual offences; positive predictive value = 188–0.281 and negative predictive value = 0.884–0.964 for intimate partner violence; positive predictive value = 0.218–0.241 and negative predictive value = 0.907–0.942 for violent offences; positive predictive value = 0.335–0.377 and negative predictive value = 0.809–0.810 for general offences.

CONCLUSIONS: When interpreting the results of individual risk assessments, it is not sufficient to provide the discrimination of the instrument; the risk statement must also address the positive predictive value and discuss its implications for the specific case. As recidivism rates are neither stable over time nor uniform across countries or samples, the primary interpretation of risk assessment instruments should rely on the percentile rank. Expected recidivism rates should be interpreted with caution. However, our results are drawn from a limited database, as studies not reporting sufficient information were excluded from analyses and it was only possible to identify current base rates for modelling positive and negative predictive values for certain countries. International standards for consistently collecting and reporting base rates are important to better identify crime trends. Future research on the validity of risk assessment instruments should follow rigorous reporting standards.

Introduction

Mental health and criminal justice professionals are often faced with the task of assessing the probability of future offences by an individual. These forensic risk assessments inform sentencing, treatment, and release decisions. There are more than 400 risk assessment instruments worldwide that support this process [1]. Their use is considered to be state of the art as these instruments are, on average, better

ABBREVIATIONS

AUC:	area under the curve
LSI-R:	Level of Service Inventory-Revised
ODARA:	Ontario Domestic Assault Risk Assessment
Static-99R:	sexual recidivism risk assessment instrument
VRAG:	Violence Risk Appraisal Guide

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at predicting criminal recidivism than clinical judgement alone [2–4].

Studies on the validity of risk assessment instruments focus on two aspects: discrimination and calibration. Discrimination is an instrument's ability to differentiate between recidivists and non-recidivists. In forensic settings, discrimination is most commonly measured using the area under the curve (AUC) in receiver operating characteristic curve analysis [5]. The AUC is an overall measure of discrimination, constructed by plotting pairs of sensitivity (sensitivity, or the true positive rate, is the proportion of recidivists who were correctly assessed as "high risk") and specificity (specificity, or the true negative rate, is the proportion of non-recidivists who were correctly assessed as "low risk") across all possible cut-off values. AUC values range from 0 to 1, where 1 indicates perfect discrimination and values below 0.5 indicate poorer discrimination than chance. By contrast, calibration assesses whether the expected recidivism rates in the norm tables of the risk assessment instruments correspond to the actual (observed) recidivism rates [5].

Although not an exact equivalent to calibration, positive and negative predictive values provide a more practical indication of the utility of risk assessments than AUC values, as they focus on the prospective prediction of adverse outcomes [5]. The positive predictive value reflects the proportion of individuals assessed as "high risk" who reoffended, and the negative predictive value the proportion of individuals assessed as "low risk" who did not reoffend. Positive and negative predictive value depend not only on the risk assessment instrument's discriminative ability but also on the base rate of the criterion. In forensic settings, base rates are typically the observed recidivism rates in a specific population over a defined period. A risk assessment instrument's performance is best when the base rate is 50% [6, 7]. As the base rate decreases, the risk assessment instrument's positive predictive value decreases and negative predictive value increases. In populations with very low base rates, the recidivism risk of individuals classified as high risk is over-estimated, whereas underestimation is more common in populations with very high base rates.

Base rates differ greatly depending on the offence and the characteristics of the sample [8, 9]. They also fluctuate over time and have shown a declining trend over the past decades [10–12].

Research objectives

Despite the clear implications for forensic practitioners and criminal justice decision-makers, the extent to which the predictive values of a risk assessment instrument vary according to current base rates has not yet been systematically explored. The present work intended to fill this gap. We aimed to:

1. Conduct a systematic review and meta-analysis of different aspects relating to the discrimination ability of four frequently used risk assessment instruments to predict recidivism for general, sexual, violent, and intimate partner violent offences.
2. Examine the positive and negative predictive values of the risk assessment instruments given current low and high base rates and discuss the implications for forensic practice.

Materials and methods

Reporting standards

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement to report the results of our study transparently and completely [13] (see appendix, supplementary material S1). A study protocol has not been prepared.

Eligibility criteria

In accordance with PRISMA, we followed the PFO (population, prognostic factor, and outcome) framework to specify inclusion and exclusion criteria, as designed for prognostic studies. Our meta-analysis included instruments used to assess general, violent, sexual, and intimate partner violent recidivism risks to cover the broad range of forensic risk assessment instruments. For each of these offence types, we selected one risk assessment instrument that is widely used in forensic practice and provides expected recidivism rates, and whose validity has been replicated in several countries [14–17]. The following four risk assessment instruments were selected:

- Level of Service Inventory-Revised (LSI-R) [18] for general recidivism
- Violence Risk Appraisal Guide (VRAG) [19] for violent recidivism
- Static-99R [20] for sexual recidivism
- Ontario Domestic Assault Risk Assessment (ODARA) [21] for intimate partner violent recidivism

We specified eligibility criteria regarding the study design and measures of validity. For the systematic review, studies were eligible if they reported AUCs, including corresponding measures (i.e., 95% confidence interval [95% CI] and/or standard error [SE]); for the meta-analysis, studies were eligible if they reported true/false positives and true/false negatives, sensitivity and specificity, or positive and negative predictive value (the full list of inclusion and exclusion criteria is provided in the appendix, supplementary material S2). The objective of each study was to identify high-risk offenders by utilising the relevant risk assessment instrument.

Information source and search strategy

We conducted a systematic search in PsycInfo (EBSCO interface; 1887 onwards) and PubMed (including MEDLINE, PMC, and Bookshelf; 1887 onwards). The search terms consisted of both the full name and acronym of each of the four risk assessment instruments combined with the terms "[accura* OR replicat* OR valid*]". The full search strings are provided in appendix, supplementary material S3. We restricted the search to peer-reviewed articles and dissertations. We identified additional sources by screening the reference lists of studies included in this systematic review as well as those in earlier reviews and meta-analyses [9, 14, 17, 20, 22–31]. The last search was carried out on March 30, 2023.

Selection process

We imported all identified records into EndNote [32], where duplicates were removed. Two reviewers (MW and an undergraduate student of psychology) screened all records (titles/abstracts) and reviewed the full text of the retrieved records to select eligible studies. Some studies were ineligible for inclusion for more than one reason. We describe the hierarchy of how we categorised reasons for the exclusion of full texts in appendix, supplementary material S4.

Data collection process

For each study, two independent reviewers (MW, NS, or MK) extracted data into a Microsoft Excel spreadsheet. Disagreements were resolved by discussion between the reviewers, AR, and JE, as well as by re-examination of the report. Sample data that were used in more than one published article were only included once. When deciding between multiple articles, we favoured studies with a higher level of comparability to the construction sample, larger sample sizes, those published in peer-reviewed journals, and original research rather than re-analyses of previously collected data. We did not contact study investigators to obtain missing data.

Study variables

For the outcome variable, we extracted base rates and data on measures of validity, including AUC values and their corresponding 95% CIs or standard errors; true positive, true negative, false positive, and false negative; sensitivity and specificity; and predictive values. Additionally, we extracted data on the study characteristics, including the authors, title, and geographic region (categorised into Australasia, Europe, North America, and mixed); sample characteristics, including the mean age, age range and standard deviation (SD), sample size, and type of index offence; and outcome characteristics, including the type of recidivism, legal status of recidivism, and length of follow-up (supplementary material S5 in the appendix).

Risk assessment instruments perform best under the conditions for which they were originally developed [9, 16, 33]. Therefore, we assessed the extent to which each study was comparable to the construction study in terms of offender age and sex, type of index offence, type and legal status of recidivism, and length of follow-up (supplementary material S6 in the appendix). We contacted the developers of each instrument to confirm whether we had correctly specified these comparators and made changes if needed. If a study did not provide enough information to assess comparability, we considered the respective characteristic as not met.

Some studies reported outcomes for subgroups and, therefore, had multiple extractable values. Based on pre-defined decision rules (supplementary material S7 in the appendix), we extracted only one value for each study variable.

Base rate scenarios

As base rates are not stable over time, we did not rely solely on those reported in the construction samples. To identify current base rates reported in North America, Western Europe, and Australia for different offence categories, we searched for national statistics and peer-reviewed publications on recidivism rates (search strategy in appendix, supplementary material S8). We chose statistics with the highest relevance for forensic practice. The inclusion criteria for base rates were total cohort studies, adult offenders, fixed follow-up period, start of time at risk since 2000, and index and recidivism offences of the same type. Concerning the legal status of recidivism, we considered convictions for sexual and violent offences, and police records or charges for intimate partner violent offences. To account for different base rate scenarios, we chose the lowest and highest base rates identified.

Risk of bias

To assess the risk of bias in the included studies, we applied the Joanna Briggs Institute Critical Appraisal Checklist for Diagnostic Test Accuracy Studies [34, 35]. The Joanna Briggs Institute checklist consists of 10 items that address study design, sampling, attrition, analytical procedure, and outcomes. The answer categories for each item are yes, no, unclear, and not applicable. Not all items of the Joanna Briggs Institute checklist were applicable to our included studies, because risk assessment instruments are not classic diagnostic tests. Eight items were applicable to the ODARA, Static-99R, and VRAG studies, and seven were applicable to the LSI-R studies. Even fewer Joanna Briggs Institute items were applicable for some individual studies due to logical interdependencies. We dummy-coded the answer categories as yes = 1 and no or unclear = 0. To assess the overall risk of bias, we first calculated the total number of items met for each study. Second, we divided this value by the number of items that were applicable to the study. Because the Joanna Briggs Institute checklist provides no scheme for evaluating studies as having a low or high risk of bias [34], we dichotomised the proportions of Joanna Briggs Institute items met as follows: If more than 50% of the applicable items were met, the study was classified as lower risk; otherwise, it was classified as higher risk. Two reviewers (of MW, NS, and MK) independently assessed the risk of bias for each included study. Disagreements were resolved by discussion and re-examination of the report.

Analytical strategy

We reported the characteristics of studies included in the systematic review and meta-analysis for each risk assessment instrument. We calculated the median, minimum, and maximum for sample size, age, length of follow-up, proportion of female offenders, and base rate. Furthermore, we summarised counts and percentages for geographic regions, type of index offence, type and legal status of recidivism, and studies with lower risk of bias.

Systematic review

For each risk assessment instrument, we calculated the median AUC and median lower and upper bounds of the 95% CIs. We also reported the smallest and largest AUC, including their corresponding 95% CIs. As an indicator of between-study differences in AUCs, we examined whether the 95% CIs of the smallest and largest AUCs overlapped.

If the studies provided standard errors for the AUCs, we calculated 95% CIs with AUC ± 1.96 × standard error.

Meta-analysis of sensitivity and false positive rates

A meta-analysis of test accuracy studies requires 2 × 2 contingency tables. If they were not reported in the primary study, we calculated true positive, true negative, false positive, and false negative based on sample size (n), base rate (in %), sensitivity (true positive rate), and specificity (true negative rate) [36] (supplementary material S9 in the appendix).

Furthermore, between-study heterogeneity of sensitivities and specificities must be low, otherwise pooling these statistics would be misleading [36–38]. For each risk assessment instrument, we tested the equality of sensitivity and specificity with chi-squared tests, and computed correlations between the measures with rho. We conducted bivariate logit-normal random effects meta-analysis of sensitivity and false positive rate (1−specificity) for each risk assessment instrument. We analysed the models using linear mixed model techniques with restricted maximum likelihood estimation [40]. Bivariate models are more precise than alternative methods in estimating sensitivities and specificities [38], mainly because they consider (negative) correlations between the two [40].

Modelling of positive and negative predictive value

Based on the results of the bivariate meta-analysis of sensitivity and false positive rate, we calculated the positive and negative predictive value for three different base rate scenarios (supplementary material S9). For each risk assessment instrument, we used the lowest and highest base rates identified in the search alongside the base rate reported for the construction sample.

Statistical analyses and graphing were conducted in R version 4.1.3 with the tidyverse, madan, and forestplot packages [36, 41, 42]. Data and code used for this study are available on the Open Science Framework (https://osf.io/jbgka/).

Results

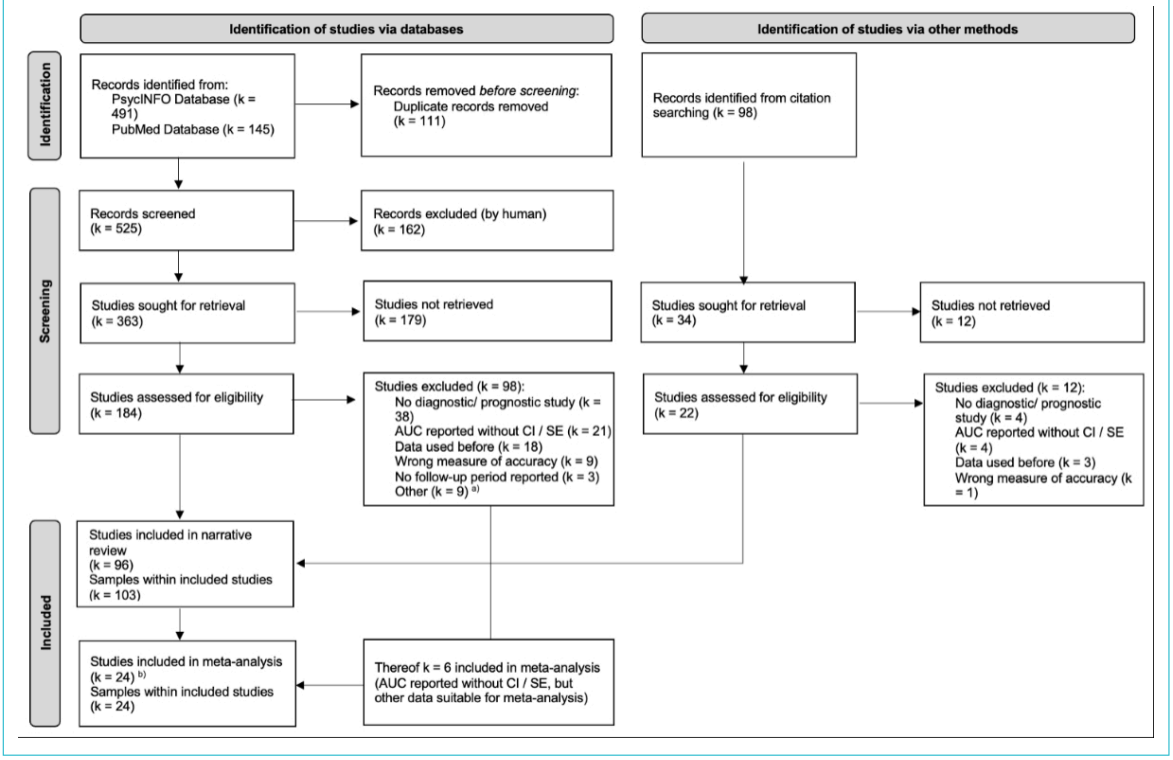
Study selection and eligible studies

After importing the search results into EndNote, 116 duplicates were removed. We screened 644 records, of which 543 were identified through scientific databases and 101 through reference lists. Overall, we reviewed 206 full texts (see figure 1).

Only 16 studies were comparable to the construction samples regarding offender age and sex, type of index offence, type and legal status of recidivism, and length of follow-up. Of these, six used the LSI-R, three the ODARA, six the Static-99R, and one the VRAG.

We included 102 studies (109 independent samples, n = 92,720), of which 96 (103 samples, n = 74,674) were included in the systematic review and 24 (24 samples, n = 23,398) were included in the meta-analyses. All studies included in the systematic review reported AUCs and corresponding 95% CIs or standard error as the measure of discrimination. The studies included in the meta-analysis were not an exact sub-sample of those included in the systematic review: Six studies did not report AUCs with corresponding 95% CIs or standard error, but rather sensitivity and specificity, and were therefore included in the meta-

Figure 1: PRISMA 2020 Flow Diagram [13]. a Wrong instrument (k = 2); Instrument modified (k = 2); No base rate reported (k = 2); No index offence (k = 2); No sample size reported (k = 1). b Thereof k = 6 not included in the narrative review (area under the curve [AUC] reported without CI [confidence interval] / SE [standard error]). All records were retrievable.



analysis. Full texts were most commonly excluded for having a non-diagnostic or non-prognostic study design (e.g., systematic review or meta-analysis), no reported measure of validity, or overlapping datasets (figure 1).

Study characteristics

The largest number of studies eligible for the systematic review focused on the Static-99R, followed by the VRAG. The LSI-R and ODARA were used in the smallest number of eligible studies. Such differences in the number of eligible studies were not as pronounced for the meta-analysis (table 1). The sample sizes of the eligible studies had large variations (table 1).

The median age of participants in all eligible studies was between 35 and 40 years. Most studies included predominantly male participants and were conducted in North America or Europe. In most studies, the risk assessment instruments were used to assess offenders with an index offence and predict the types of recidivism for which the instrument was developed. The LSI-R and VRAG studies had substantial variations in types of index offences and recidivism (table 1).

The most frequently used category for the legal status of recidivism was "charge, conviction, or criminal record", with two exceptions. In the meta-analysis, LSI-R studies used the category "arrest or incarceration" most frequently, and ODARA studies used the categories "charge, conviction, or criminal record" and "police report" equally often (table 1).

The median follow-up periods were largely comparable between instruments. The exceptions were LSI-R studies included in both the systematic review and meta-analysis and ODARA studies included in the meta-analysis, which reported shorter follow-up periods (table 1).

Evidence of the risk of bias assessed with the Joanna Briggs Institute checklist was mixed. For the systematic review, only half or less than half of the studies on the Static-99R, ODARA, or VRAG had a lower risk of bias. For

Table 1:
Characteristics of samples included in the systematic review and meta-analysis by risk assessment instrument.

Study characteristics		Systematic review (k = 103)				Meta-analysis (k = 24)			
		LSI-R[7]	Static-99R	ODARA	VRAG[7, 8]	LSI-R	Static-99R	ODARA	**VRAG**
Total number of samples		16	39	14	34	5	7	5	7
Median sample size count (min/max)		240.5 (56/9454)	399 (66/17,455)	147.5 (30/589)	126.5 (25/1353)	516 (112/17,410)	181 (100/650)	145 (30/589)	140 (52/495)
Countries, % (count)	Australasia[1]	0.0% (0)	17.9% (7)	7.1% (1)	–	40.0% (2)	14.3% (1)	20.0% (1)	–
	Europe[2]	43.8% (7)	15.4% (6)	21.4% (3)	50.0% (17)	20.0% (1)	42.9% (3)	20.0% (1)	100.0% (7)
	North America[3]	56.2% (9)	64.1% (25)	71.4% (10)	47.1% (16)	40.0% (2)	42.9% (3)	60.0% (3)	–
	Mixed[4]	–	2.6% (1)	–	–	–	–	–	–
Median age in years (min/max)		35 (27.7/39.5)	40.7 (23.5/55.8)	36.2 (28.6/40.5)	33.4 (24.7/41.2)	34.5 (17/35.6)	39.4 (37.5/47.2)	37.7 (32.2/40.5)	35.4 (32/42)
Median % females (min/max)		1.4 (0/100)	–	0 (0/100)	0 (0/100)	0 (0/50)	–	–	0 (0/10)
Type of index offence, % (count)	Intimate partner violence	–	–	0.0% (0)	–	–	–	0.0% (0)	–
	Violence (excl. sexual)	12.5% (2)	–	–	38.2% (13)	–	–	–	28.6% (2)
	Violence (incl. sexual)	6.2% (1)	0.0% (0)	–	11.8% (4)	–	0.0% (0)	–	0.0% (0)
	General	18.8% (3)	–	–	17.6% (6)	0.0% (0)	–	–	28.6% (2)
Type of recidivism, % (count)	Intimate partner violence	–	–	0.0% (0)	–	–	–	0.0% (0)	–
	Violence (excl. sexual)	6.2% (1)	–	0.0% (0)	23.5% (8)	–	–	0.0% (0)	57.1% (4)
	Violence (incl. sexual)	0.0% (0)	0.0% (0)	–	0.0% (0)	–	0.0% (0)	–	0.0% (0)
	General	18.8% (3)	0.0% (0)	–	73.5% (25)	0.0% (0)	–	–	–
Legal status recidivism, % (count)	Arrest or incarceration	18.8% (3)	30.8% (12)	0.0% (0)	2.9% (1)	60.0% (3)	14.3% (1)	20.0% (1)	–
	Charge, conviction, or criminal record	68.8% (11)	56.4% (22)	57.1% (8)	70.6% (24)	20.0% (1)	71.4% (5)	40.0% (2)	71.4% (5)
	Police report	6.2% (1)	–	28.6% (4)	2.9% (1)	–	–	40.0% (2)	–
	Other	6.2% (1)	12.8% (5)	14.3% (2)	20.6% (7)	–	14.3% (1)	–	28.6% (2)
Median length follow-up in years (min/max)		2 (0/19.7)	5 (0.1/16.4)	4.7 (0/11.6)	4.7 (0/49)	2 (0.5/5)	5 (0.2/16.4)	2.1 (0/11.6)	6 (0/10)
Median base rate in months (min/max)		38 (9/77)	8.5 (1.9/24.7)	23.1 (11.5/44)	27.5 (4.7/80)	23 (9.8/58)	9.9 (4/21)	20 (11.5/50)	18 (4.7/32.8)
Comparable contextual factors, % (count)[5]		25.0% (4)	15.4% (6)	21.4% (3)	–	60.0% (3)	28.6% (2)	–	–
Joanna Briggs Institute assessment: lower risk of bias[6], % (count)		87.5% (14)	43.6% (17)	50.0% (7)	41.2% (14)	100.0% (5)	71.4% (5)	40.0% (2)	71.4% (5)

k: independent samples; LSI-R: Level of Service Inventory-Revised; ODARA: Ontario Domestic Assault Risk Assessment; Static-99R: sexual recidivism risk assessment instrument; VRAG: Violence Risk Appraisal Guide;

[1] Australia, China, New Zealand, Singapore, and South Korea;

[2] Austria, Belgium, Germany, the Netherlands, Norway, Sweden, Switzerland, and the UK;

[3] Canada and the USA;

[4] Study population from more than one world region;

[5] Full comparability regarding offender age and sex, type of index offence, type and legal status of recidivism, and length of follow-up (cf. appendix, supplementary material S6);

[6] Joanna Briggs Institute checklist for diagnostic test accuracy studies, with lower risk of bias indicating an above median assessment score;

[7] One LSI-R and four VRAG studies did not provide information on the type of index offence;

[8] One VRAG study did not provide information on the legal status of recidivism.

the meta-analysis, two out of five studies on the ODARA had a lower risk of bias (table 1).

Systematic review

The 95% CIs of the median, smallest, and largest AUCs overlapped for the VRAG, ODARA, and LSI-R; thus, large between-study differences in AUCs were not present for these risk assessment instruments. However, for the Static-99R, the 95% CIs of the smallest and largest AUCs did not overlap, indicating between-study differences in these AUCs (figure 2 and table S1 in the appendix).

For the LSI-R, the study reporting the smallest AUC (AUC = 0.480, 95% CI = 0.343–0.617) was conducted in Germany and had a sample size of 85 individuals with a migration background, who had been convicted of violent index and recidivism offences and were followed for a fixed period of 2 years [43]. The study reporting the largest AUC (AUC = 0.770, 95% CI = 0.620–0.910) was conducted in the USA and had a sample size of 56 individuals who had committed violent or sexual index offences, were charged with a range of different recidivism offences, and were followed for a fixed period of 1 year [44].

For the Static-99R, the study reporting the smallest AUC (AUC = 0.550, 95% CI = 0.450–0.650) was conducted in Canada and had a sample size of 399 individuals, who had committed sexual index and recidivism offences and were followed for an average of 2.4 years [45]. The study reporting the largest AUC (AUC = 0.824, 95% CI = 0.608–0.742) was conducted in the USA and had a sample size of 338 individuals who had committed a sexual index offence, were charged with a sexual recidivism offence, and were followed for a fixed period of 5 years [46].

For the ODARA, the study reporting the smallest AUC (AUC = 0.629, 95% CI = 0.477–0.781) was conducted in Canada and had a sample size of 97 individuals who had committed an intimate partner violent index offence, were charged with a violent recidivism offence, and were followed for a fixed period of 2 years [47]. The study reporting the largest AUC (AUC = 0.780, 95% CI = 0.620–0.940) was conducted in Switzerland and had a sample size of 30 individuals who had committed an intimate partner violent index offence, were charged or convicted with a violent recidivism offence, and were followed for an average of 8 years [48].

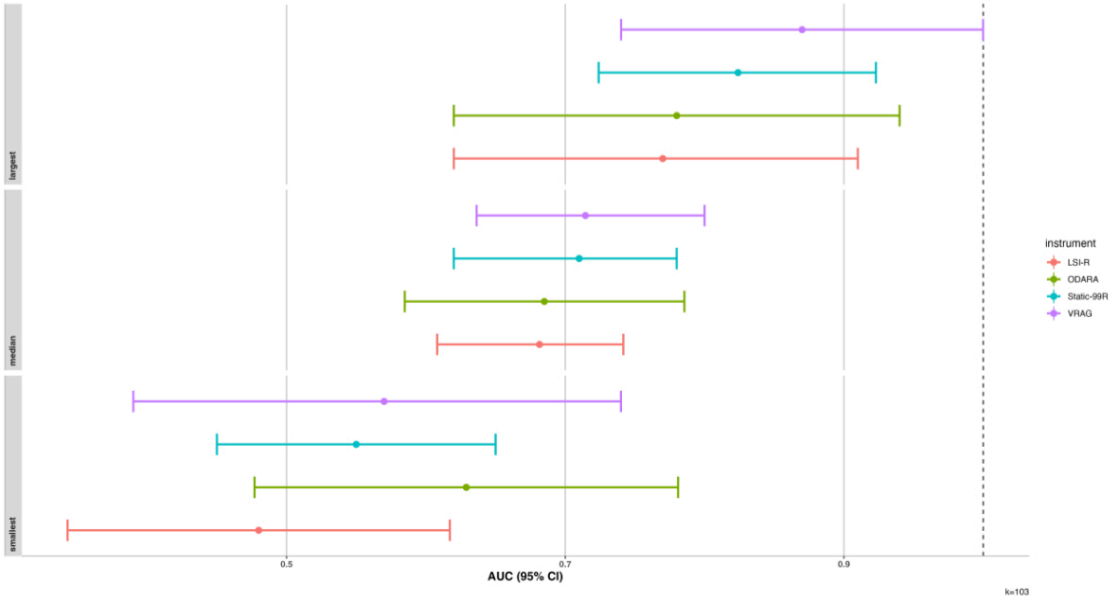
For the VRAG, the study reporting the smallest AUC (AUC = 0.570, 95% CI = 0.390–0.740) was conducted in Belgium and had a sample size of 191 individuals who had committed various types of index offences but were convicted of violent or sexual recidivism offences, were in psychiatric care after the index offence and were followed for an average of 2.44 years [49]. The study reporting the largest AUC (AUC = 0.870, 95% CI = 0.740–1.000) was conducted in the UK and had a sample size of 25 individuals who had committed a general index offence and a violent recidivism offence in the institution in which they were incarcerated, and were followed for an average of 6 months [50].

Meta-analysis of sensitivity and false positive rates

Descriptive summary statistics showed that the sensitivities and false positive rates were sufficiently equal for all risk assessment instruments. Correlations of sensitivities and false positive rates were rho = 0.520 (95% CI = −0.669–0.961) for the LSI-R, rho = 0.922 (95% CI = 0.213–0.995) for the ODARA, rho = 0.730 (95% CI = −0.051–0.957) for the Static-99R, and rho = 0.811 (95% CI = 0.148–0.971) for the VRAG.

We estimated the largest summary sensitivity and false positive rate for studies concerning the ODARA, followed by studies on the LSI-R and VRAG; the smallest sensitiv-

Figure 2: Median, smallest, and largest areas under the curve (AUC) of the four risk assessment instruments (including their corresponding 95% confidence intervals [CI]). Median corresponds to the calculated median AUC for each risk assessment instrument. Smallest corresponds to the smallest AUC of each risk assessment instrument found in our systematic review, and largest corresponds to the largest AUC found. LSI-R: Level of Service Inventory-Revised; ODARA: Ontario Domestic Assault Risk Assessment; Static-99R: sexual recidivism risk assessment instrument; VRAG: Violence Risk Appraisal Guide.



ity for studies on the Static-99R (table 2). The Static-99R correctly identified one in two, both the VRAG and the LSI-R three in five, and the ODARA four in five recidivists as being at high risk of recidivism. Conversely, three in five non-recidivists were correctly identified as being at low risk of recidivism by the ODARA, more than one in two by the LSI-R, seven in ten by the VRAG, and more than four in five by the Static-99R.

Base rates

The current reconviction rates for violent recidivism ranged from 13% to 21%. The lowest rate was reported in Austria, for a fixed follow-up period of 4 years and for offenders who were convicted or released in 2017; the highest was reported in Germany, for a fixed follow-up period of 6 years and for offenders who were convicted or released in 2004. Both rates were based on national statistics with large sample sizes and included offenders with different types of violent index offences (table S2 in the appendix). The base rate reported in the VRAG construction sample (31%) was higher than current base rates; however, the VRAG construction sample also showed a time of initial conviction or release many decades earlier than the samples for the current base rates, and included Canadian prisoners and psychiatric inpatients [51]. The construction sample therefore differs from the current samples in terms of geographic region and psychiatric history, as the current base rates are taken from German-speaking countries among general offender cohorts.

The current reconviction rates for sexual recidivism ranged from 2% to 13%. The lowest rate was reported in Germany for a fixed follow-up period of 3 years, based on a national statistic that included offenders with sexual abuse as the index and recidivism offences, who were convicted or released in 2004. The highest rate was reported in Australia for offenders with mental disorders and a high recidivism risk at baseline, who had been treated in a statutory agency between 1987 and 2011 and followed for a fixed period of 5 years (table S3 in the appendix). The base rate reported in the Static-99R construction sample (11%) [20] was comparable to the highest currently reported base rate. The construction sample differed from the current sample in the following ways: the base rate was based on a meta-analysis of 24 samples from Anglo-Saxon and European countries, whereas the current samples were restricted to individual studies based on total offender cohorts; and the range of release dates was larger and dated back considerably longer (1957–2007; see table S3 in the appendix).

Current police-registered intimate partner violent recidivism over a fixed 1-year follow-up period differed between countries. The lowest rate was reported in Germany (13%), and the highest was reported in Australia (46%) (table S4 in the appendix). Both rates were based on total cohorts. The base rate reported in the ODARA construction sample (30%) [21] lies between the lowest and highest current base rates.

The current reconviction rates for general offences over a fixed follow-up period of three years ranged from 27% to 53% (table S5 in the appendix). The lowest was reported in Austria and the highest in the Netherlands. Both rates were based on total cohorts. The base rate reported in the LSI-R construction sample (41%) was in between the highest and lowest current base rates [18].

Base rates varied by length of follow-up, study population, country, and type of recidivism. For example, in the culturally comparable countries of Austria and Germany, the base rates of violent recidivism were higher when the follow-up period was longer. Compared with a national sample of offenders with all types of sexual index offences in

Table 2:
Summary estimates of sensitivities and false positive rates.

Risk assessment instrument	Sensitivity (95% CI)	False positive rate (95% CI)
Level of Service Inventory-Revised (LSI-R) (k = 5)	0.641 (0.598, 0.681)	0.431 (0.365, 0.499)
Static-99R (sexual recidivism risk assessment instrument) (k = 7)	0.464 (0.256, 0.686)	0.138 (0.034, 0.420)
Ontario Domestic Assault Risk Assessment (ODARA) (k = 5)	0.815 (0.561, 0.938)	0.394 (0.215, 0.606)
Violence Risk Appraisal Guide (VRAG) (k = 7)	0.618 (0.460, 0.755)	0.302 (0.216, 0.404)

k: independent samples.

Table 3:
Positive and negative predictive values based on summary sensitivity and false positive rates for the three base rate scenarios.

Risk assessment instrument	Positive predictive value			Negative predictive value		
	Construction sample (95% CI)	Low (95% CI)	High (95% CI)	Construction sample (95% CI)	Low (95% CI)	High (95% CI)
Level of Service Inventory-Revised (LSI-R) (k = 5)	0.508 (0.487, 0.532)	0.355 (0.335, 0.377)	0.626 (0.606, 0.649)	0.694 (0.693–0.694)	0.810 (0.809, 0.810)	0.583 (0.582–0.583)
Static-99R (sexual recidivism risk assessment instrument) (k = 7)	0.294 (0.168, 0.482)	0.064 (0.032, 0.133)	0.334 (0.196, 0.529)	0.929 (0.913, 0.937)	0.987 (0.985, 0.989)	0.915 (0.897, 0.925)
Ontario Domestic Assault Risk Assessment (ODARA) (k = 5)	0.470 (0.399, 0.528)	0.236 (0.188, 0.281)	0.638 (0.569, 0.690)	0.884 (0.807, 0.937)	0.933 (0.884, 0.964)	0.794 (0.677, 0.925)
Violence Risk Appraisal Guide (VRAG) (k = 7)	0.479 (0.456, 0.489)	0.234 (0.218, 0.241)	0.352 (0.332, 0.361)	0.803 (0.764, 0.844)	0.924 (0.907, 0.942)	0.873 (0.845, 0.901)

k: independent samples.

The base rates used for modelling were for general recidivism 0.27 (low), 0.41 (base rate based on the LSI-R construction sample), and 0.53 (high); for sexual recidivism 0.02 (low), 0.11 (base rate based on Static-99R construction sample), and 0.13 (high); for intimate partner violent recidivism 0.13 (low), 0.3 (base rate based on ODARA construction sample), and 0.46 (high); for violent recidivism 0.13 (low), 0.31 (base rate based on VRAG construction sample), and 0.21 (high). The specified cut-off values were as follows: For the LSI-R = 19, 23, and 28 (k = 1 each; k = 2 missing values); for the Static-99R 4 (k = 4) and 6 (k = 1; with k = 2 missing values); for the ODARA = 4 (k = 2), 6 (k = 1), and 7 (k = 2); and for the VRAG 7 and 14 (k = 2 each, with k = 3 missing values).

Germany, base rates were higher when assessing offenders with mental disorders in Australia. Base rates were generally lower for sexual recidivism compared to other types of recidivism. For intimate partner violent, the country in which the study was conducted seemed to affect the base rate. Despite comparable follow-up periods, study designs, and legal recidivism statuses, the base rate in an Australian sample was higher than that in a German sample (tables S2–S5 in the appendix).

Modelling of positive and negative predictive value

Across risk assessment instruments and base rate scenarios, positive predictive values varied between 6% and 64%. In the low-base rate scenario, the ODARA and LSI-R demonstrated the highest positive predictive values, with comparable values, while the VRAG showed a slightly lower positive predictive value. The Static-99R had the lowest. In the high-base rate scenario, the LSI-R and ODARA exhibited the highest positive predictive values, with comparable values, while the Static-99R and VRAG showed lower, comparable positive predictive values. Negative predictive values were relatively high and comparable across risk assessment instrument and base rate scenarios, with one exception (table 3). In the high-base rate scenario, the negative predictive value of the LSI-R was lower than that of the other risk assessment instruments.

A minority of individuals identified as high risk for recidivism re-offended. The summary sensitivity, false positive rate, and current base rates were highest for both general and intimate partner violent recidivism. Specifically, between three and seven out of ten individuals identified as high risk by the ODARA had a subsequent police registration for another intimate partner violent offence. A comparable proportion of individuals identified as high risk by the LSI-R were reconvicted within a three-year period. Summary sensitivity, false positive rates, and current base rates were lowest for sexual recidivism, with between 2 in 30 and 3 in 10 individuals identified as high risk being reconvicted for a sexual offence. For violent recidivism, summary sensitivity, false positive rate, and current base rates fell between those observed for general, intimate partner violent, and sexual recidivism, with 2 to 3 in 10 high-risk individuals being reconvicted for a violent offence (table 3).

Since positive predictive values are influenced by base rates, as well as by sensitivity and specificity (1−false positive rate), they also vary based on follow-up length, study population, country, and the sensitivity/specificity of the risk assessment instruments. Therefore, low base rates and low sensitivity resulted in low positive predictive values (as seen in sexual recidivism), while higher base rates and higher sensitivity led to higher positive predictive values (as observed in general and intimate partner violent recidivism).

Discussion

In the current study, we examined the predictive validity of four commonly used risk assessment instruments that were developed for different offender populations. We modelled positive and negative predictive value based on a systematic review and meta-analysis of different aspects of the instruments' discrimination combined with current base rates.

Our study had four main findings. First, we found that the majority of the identified validation studies did not report the necessary information for assessing validity beyond the area under the curve (AUC). This finding is in line with prior research [16, 52, 53]. Consequently, many studies could only be included in the systematic review and were excluded from the meta-analysis.

Second, the median AUCs of all four risk assessment instruments showed moderate discrimination (0.68–0.71), corresponding to a medium effect size [54]. These findings are consistent with previous research [14, 26, 28, 30]. However, AUCs alone have limited practical utility as they do not inherently include any statement on the prospective prediction of adverse outcomes. As Harris and Rice [55, p. 1638] have pointed out, "receiver operating characteristic statistics are independent of base rates, but optimal decisions are not".

Third, while sensitivity varied by instrument, it was rather high. The meta-analysis of sensitivity and false positive rates revealed a high proportion of recidivists identified by the Ontario Domestic Assault Risk Assessment (ODARA) and a high proportion of non-recidivists identified by the Static-99R (sexual recidivism risk assessment instrument). This pattern can be partly explained by the ODARA's development as a screening instrument to be used by frontline workers, thus aiming to maximise sensitivity. However, a high sensitivity does not correspond to a high probability that an individual who scores highly on the instrument will actually re-offend.

Fourth, the results of the meta-analysis of sensitivity and false positive rates showed low positive predictive values, especially for low-base rate scenarios and offence categories with low base rates, as was the case for sexual recidivism. However, there were large variations in base rates between scenarios, leading to a wide range of positive predictive values. Regarding violent recidivism, the base rate reported in the Violence Risk Appraisal Guide (VRAG) construction sample was higher than the maximum currently reported base rate, leading to an overestimation of recidivism risk. This difference in base rates may be explained by the decline in recidivism rates observed over the past decades. Overall, at low base rates, high risk assessment instrument scores do not necessarily indicate a high risk of recidivism, whereas low scores may well indicate a low risk of recidivism.

Implications for research and practice

Base rates are an important anchor for forensic risk assessment but must be properly collected and reported. Fazel, Wolf, and Yukhnenko [56] developed a standardised reporting checklist for this purpose.

In health research, the reporting standards of diagnostic accuracy studies require 2 × 2 contingency tables of the results of the index test and reference standard [57]. The standards further recommend providing details on how these estimates were derived and how they should be interpreted [58]. Equivalent standards should be applied to studies examining the validity of risk assessment instruments and should include reporting of the AUC with cor-

responding measures (such as 95% CIs) for comparisons between samples, 2 × 2 contingency tables with the results of the risk assessment instrument and actual recidivism, including the cut-off scores, and base rates to enable the calculation of positive and negative predictive value [5, 59, 60].

Risk assessments often form the basis for criminal court decisions on sentence severity, including court-mandated treatments aimed at reducing the recidivism risk. However, both mock jurors and professional judges tend to overestimate risk, even when specific recidivism rates are provided [61, 62]. As low base rates will lead to low positive predictive values, there is a considerable threat of overestimating recidivism risk, which can have considerable negative consequences for the individuals being assessed. This may, for example, lead to a negative release decision [52]. Conversely, high negative predictive values indicate that a large proportion of individuals assessed as low risk do not re-offend [63]. Therefore, risk assessment instrument results can be particularly useful in identifying low-risk offenders and excluding them from further assessment [53, 64]. However, interpretation of expected recidivism rates is not recommended given the poor calibration across different populations and settings. The result of a risk assessment instrument can only be interpreted in relation to a reference group of offenders by using percentiles or categorisation of relative risk levels, such as below average, average, or above average [17, 65].

Given the far-fetching consequences of the results of risk assessment instruments [52], forensic experts must appropriately communicate recidivism risk in court [66]. The interpretation and communication of the results of risk assessment instruments should be based on information regarding practically useful performance indices, as it is provided by positive and negative predictive values [52, 60, 63, 67, 68].

Limitations and future directions

Several limitations of this study are worth mentioning. First, the Level of Service Inventory-Revised (LSI-R), VRAG, Static-99R, and ODARA are only a representative selection of established risk assessment instruments. Although it seems reasonable to assume that other instruments would produce similar results [68], future research should extend the current findings to other risk assessment instruments.

Second, the study findings have limited generalisability. Most of the included studies were conducted in North America and Western Europe. Due to a lack of information provided in the original studies on measures of validity, we could only include a small proportion of the identified studies in the meta-analysis. Furthermore, we did not contact the authors of the studies to obtain missing information. Future research should use structured reporting checklists such as STARD 2015 [57] to ensure complete reporting.

Third, identifying current base rates for modelling positive and negative predictive values proved to be challenging. For many countries, no information was available. Comparing countries is difficult for several reasons, including variations in their legal systems [69–72]. Moreover, base rates are not stable over time, across countries, or between offence categories. Therefore, future research should update the present meta-analysis. In addition, base rates are affected by interventions aimed at reducing recidivism [11, 69] and an ageing prison population, which poses a fairly low recidivism risk [73]. Further declines in base rates [10, 11] could exacerbate the implications of low positive predictive values, leading to an overestimation of recidivism risk.

Fourth, sensitivity, specificity, positive and negative predictive value depend on the chosen cut-off. All studies included in the meta-analysis selected a clinically meaningful cut-off to identify high-risk offenders. It is important to note, however, that a major limitation of this study is that not all studies reported underlying cut-offs; even when reported, the cut-offs differed between studies even for the same instrument, possibly due to differing sample characteristics. Thus, it would be useful if future research on the validity of risk assessment instruments reported the 2 × 2 contingency table of not only a single cut-off, but also other possible and reasonable cut-offs [67]. This would make findings more comparable and allow clinicians and criminal justice decision-makers to choose between different cut-offs depending on the purpose of the risk assessment (i.e., maximising positive or negative predictive value).

Fifth, up to half of the primary studies had a higher risk of bias, which indicates that the reporting standards of studies investigating the accuracy of risk assessment instruments might be questionable. The cut-off we chose for a study to be of lower or higher risk was somewhat flexible and based on a reasoned, though not rigid, criterion. If a stricter cut-off were chosen, even more studies would have been classed as being of higher risk of bias.

Conclusion

In the present study, we modelled positive and negative predictive value for four commonly used risk assessment instruments. Collecting internationally comparable base rates proved challenging, and we showed that primary studies on risk assessment instruments lack clinically relevant measures of validity. Current base rates tend to be lower than the base rates in the construction samples of the risk assessment instruments, leading to low positive predictive values. Relying on the AUC alone as a measure of discrimination can lead to an overestimation of recidivism risk, resulting in negative consequences for assessed individuals. Risk communication based on the results of a risk assessment instrument must refer to the positive predictive value as a clinically relevant measure for the prospective prediction, and address its implications for the specific case. Due to the dynamic nature of base rates, expected recidivism rates should be interpreted with caution; percentile ranking should be the primary method of interpretation of risk assessment instruments.

Data sharing statement

All data underlying the present research is secondary data. Data and code used for this study are available on the Open Science Framework (https://osf.io/jbgka/).

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All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. *AR* and *JE* contributed to the authorised German translations of the Violence Risk Appraisal Guide (VRAG) and the Ontario Domestic Assault Risk Assessment (ODARA). They do not gain any financial benefits from these instruments. No other potential conflict of interest related to the content of this manuscript was disclosed.

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Appendix

Table of Content

Supplementary Material 1: Reporting of the Preferred Reporting Items for Systematic Review and Meta-Analyses Statement (PRISMA) expanded checklist (Page et al., 2021) throughout the manuscript

Section and Topic	Item #	Elements recommended for reporting	Reported on manuscript page #
Title			
Title	1	• Identify the report as a systematic review in the title. • Report an informative title that provides key information about the main objective or question the review addresses (e.g. the population(s) and intervention(s) the review addresses).	p. 1 (I)
Abstract			
Abstract	2	• Report an abstract addressing each item in the PRISMA 2020 for Abstracts checklist.	p. 2 (I)
Introduction			
Rationale	3	• Describe the current state of knowledge and its uncertainties. • Articulate why it is important to do the review. • If other systematic reviews addressing the same (or a largely similar) question are available, explain why the current review was considered necessary. If the review is an update or replication of a particular systematic review, indicate this and cite the previous review. • If the review examines the effects of interventions, also briefly describe how the intervention(s) examined might work.	pp. 1-2 (II)
Objectives	4	• Provide an explicit statement of all objective(s) or question(s) the review addresses, expressed in terms of a relevant question formulation framework.	p. 2 (II)

		• If the purpose is to evaluate the effects of interventions, use the Population, Intervention, Comparator, Outcome (PICO) framework or one of its variants, to state the comparisons that will be made.	
Methods			
Eligibility Criteria	5	• Specify all study characteristics used to decide whether a study was eligible for inclusion in the review, that is, components described in the PICO framework or one of its variants, and other characteristics, such as eligible study design(s) and setting(s), and minimum duration of follow-up. • Specify eligibility criteria with regard to report characteristics, such as year of dissemination, language, and report status (e.g. whether reports, such as unpublished manuscripts and conference abstracts, were eligible for inclusion). • Clearly indicate if studies were ineligible because the outcomes of interest were not measured, or ineligible because the results for the outcome of interest were not reported. • Specify any groups used in the synthesis (e.g. intervention, outcome and population groups) and link these to the comparisons specified in the objectives (item #4).	pp. 2-3 (II)
Information Sources	6	• Specify the date when each source (e.g. database, register, website, organisation) was last searched or consulted. • If bibliographic databases were searched, specify for each database its name (e.g. MEDLINE, CINAHL), the interface or platform through which the database was searched (e.g. Ovid, EBSCOhost), and the dates of coverage (where this information is provided). • If study registers, regulatory databases and other online repositories were searched, specify the name of each source and any date restrictions that were applied. • If websites, search engines or other online sources were browsed or searched, specify the name and URL of each source. • If organisations or manufacturers were contacted to identify studies, specify the name of each source. • If individuals were contacted to identify studies, specify the types of individuals contacted (e.g. authors of studies included in the review or researchers with expertise in the area). • If reference lists were examined, specify the types of references examined (e.g. references cited in study reports included in the systematic review, or references cited in systematic review reports on the same or similar topic).	p. 3 (II); Figure 1

		• If cited or citing reference searches (also called backward and forward citation searching) were conducted, specify the bibliographic details of the reports to which citation searching was applied, the citation index or platform used (e.g. Web of Science), and the date the citation searching was done. • If journals or conference proceedings were consulted, specify of the names of each source, the dates covered and how they were searched (e.g. handsearching or browsing online)	
Search Strategy	7	• Provide the full line by line search strategy as run in each database with a sophisticated interface (such as Ovid), or the sequence of terms that were used to search simpler interfaces, such as search engines or websites. • Describe any limits applied to the search strategy (e.g. date or language) and justify these by linking back to the review's eligibility criteria. • If published approaches, including search filters designed to retrieve specific types of records or search strategies from other systematic reviews, were used, cite them. If published approaches were adapted, for example if search filters are amended, note the changes made. • If natural language processing or text frequency analysis tools were used to identify or refine keywords, synonyms or subject indexing terms to use in the search strategy, specify the tool(s) used. • If a tool was used to automatically translate search strings for one database to another, specify the tool used. • If the search strategy was validated, for example by evaluating whether it could identify a set of clearly eligible studies, report the validation process used and specify which studies were included in the validation set. • If the search strategy was peer reviewed, report the peer review process used and specify any tool used such as the Peer Review of Electronic Search Strategies (PRESS) checklist. • If the search strategy structure adopted was not based on a PICO-style approach, describe the final conceptual structure and any explorations that were undertaken to achieve it.	p. 3 (II); Suppl. Material 3
Selection Process	8	*Recommendations for reporting regardless of the selection processes used:* • Report how many reviewers screened each record (title/abstract) and each report retrieved, whether multiple reviewers worked independently at each stage of screening or not, and any processes used to resolve disagreements between screeners.	pp. 3-4 (II)

		• Report any processes used to obtain or confirm relevant information from study investigators. • If abstracts or articles required translation into another language to determine their eligibility, report how these were translated. *Recommendations for reporting in systematic reviews using automation tools in the selection process:* • Report how automation tools were integrated within the overall study selection process. • If an externally derived machine learning classifier was applied (e.g. Cochrane RCT Classifier), either to eliminate records or to replace a single screener, include a reference or URL to the version used. If the classifier was used to eliminate records before screening, report the number eliminated in the PRISMA flow diagram as 'Records marked as ineligible by automation tools'. • If an internally derived machine learning classifier was used to assist with the screening process, identify the software/classifier and version, describe how it was used (e.g. to remove records or replace a single screener) and trained (if relevant), and what internal or external validation was done to understand the risk of missed studies or incorrect classifications. • If machine learning algorithms were used to prioritise screening (whereby unscreened records are continually re-ordered based on screening decisions), state the software used and provide details of any screening rules applied. *Recommendations for reporting in systematic reviews using crowdsourcing or previous 'known' assessments in the selection process:* • If crowdsourcing was used to screen records, provide details of the platform used and specify how it was integrated within the overall study selection process. • If datasets of already-screened records were used to eliminate records retrieved by the search from further consideration, briefly describe the derivation of these datasets.	
Data Collection Process	9	• Report how many reviewers collected data from each report, whether multiple reviewers worked independently or not, and any processes used to resolve disagreements between data collectors. • Report any processes used to obtain or confirm relevant data from study investigators. • If any automation tools were used to collect data, report how the tool was used, how the tool was trained, and what internal or external validation was done to understand the risk of incorrect extractions.	p. 4 (II)

		• If articles required translation into another language to enable data collection, report how these articles were translated. • If any software was used to extract data from figures, specify the software used. • If any decision rules were used to select data from multiple reports corresponding to a study, and any steps were taken to resolve inconsistencies across reports, report the rules and steps used.	
Data Items (outcomes)	10a	• List and define the outcome domains and time frame of measurement for which data were sought. • Specify whether all results that were compatible with each outcome domain in each study were sought, and if not, what process was used to select results within eligible domains. • If any changes were made to the inclusion or definition of the outcome domains, or to the importance given to them in the review, specify the changes, along with a rationale. • If any changes were made to the processes used to select results within eligible outcome domains, specify the changes, along with a rationale.	p. 4 (II); Suppl. Material 5
Data Items (other variables)	10b	• List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). • Describe any assumptions made about any missing or unclear information from the studies. • If a tool was used to inform which data items to collect, cite the tool used.	p. 4 (II); Suppl. Material 5
Study Risk of Bias Assessment	11	• Specify the tool(s) (and version) used to assess risk of bias in the included studies. • Specify the methodological domains/components/items of the risk of bias tool(s) used. • Report whether an overall risk of bias judgement that summarised across domains/components/items was made, and if so, what rules were used to reach an overall judgement. • If any adaptations to an existing tool to assess risk of bias in studies were made, specify the adaptations. • If a new risk of bias tool was developed for use in the review, describe the content of the tool and make it publicly accessible. • Report how many reviewers assessed risk of bias in each study, whether multiple reviewers worked independently, and any processes used to resolve disagreements between assessors. • Report any processes used to obtain or confirm relevant information from study investigators.	pp. 5-6 (II)

		• If an automation tool was used to assess risk of bias, report how the automation tool was used, how the tool was trained, and details on the tool's performance and internal validation.	
Effect Measures	12	• Specify for each outcome (or type of outcome [e.g. binary, continuous]), the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. • State any thresholds (or ranges) used to interpret the size of effect (e.g. minimally important difference; ranges for no/trivial, small, moderate and large effects) and the rationale for these thresholds. • If synthesized results were re-expressed to a different effect measure, report the method used to re-express results (e.g. meta-analysing risk ratios and computing an absolute risk reduction based on an assumed comparator risk). • Consider providing justification for the choice of effect measure.	pp. 6-7, 14, 1 (II)
Synthesis Methods (Eligibility for Synthesis)	13a	• Describe the processes used to decide which studies were eligible for each synthesis.	p. 4 (II); Suppl. Material 4
Synthesis Methods (Preparing for Synthesis)	13b	• Report any methods required to prepare the data collected from studies for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	p. 3-5 (II)
Synthesis Methods (Tabulation and Graphical Methods)	13c	• Report chosen tabular structure(s) used to display results of individual studies and syntheses, along with details of the data presented. • Report chosen graphical methods used to visually display results of individual studies and syntheses.	pp. 4, 7 (II)
Synthesis Methods (Statistical Synthesis Methods)	13d	• If statistical synthesis methods were used, reference the software, packages and version numbers used to implement synthesis methods. • If it was not possible to conduct a meta-analysis, describe and justify the synthesis methods or summary approach used. • If meta-analysis was done, specify: - the meta-analysis model (fixed-effect, fixed-effects or random-effects) and provide rationale for the selected model. - the method used (e.g. Mantel-Haenszel, inverse-variance).	pp. 6-7 (II)

		- any methods used to identify or quantify statistical heterogeneity (e.g. visual inspection of results, a formal statistical test for heterogeneity, heterogeneity variance (τ 2), inconsistency (e.g. I2), and prediction intervals). • If a random-effects meta-analysis model was used: - specify the between-study (heterogeneity) variance estimator used (e.g. DerSimonian and Laird, restricted maximum likelihood (REML)). - specify the method used to calculate the confidence interval for the summary effect (e.g. Wald-type confidence interval, Hartung-Knapp-Sidik-Jonkman). • If a Bayesian approach to meta-analysis was used, describe the prior distributions about quantities of interest (e.g. intervention effect being analysed, amount of heterogeneity in results across studies). • If multiple effect estimates from a study were included in a meta-analysis, describe the method(s) used to model or account for the statistical dependency (e.g. multivariate meta-analysis, multilevel models or robust variance estimation). • If a planned synthesis was not considered possible or appropriate, report this and the reason for that decision.	
Synthesis Methods (Methods to Explore Heterogeneity)	13e	• If methods were used to explore possible causes of statistical heterogeneity, specify the method used (e.g. subgroup analysis, meta-regression). • If subgroup analysis or meta-regression was performed, specify for each: • which factors were explored, levels of those factors, and which direction of effect modification was expected and why (where possible). • whether analyses were conducted using study-level variables (i.e. where each study is included in one subgroup only), within-study contrasts (i.e. where data on subsets of participants within a study are available, allowing the study to be included in more than one subgroup), or some combination of the above. • how subgroup effects were compared (e.g. statistical test for interaction for subgroup analyses). • If other methods were used to explore heterogeneity because data were not amenable to meta-analysis of effect estimates (e.g. structuring tables to examine variation in results across studies based on subpopulation), describe the methods used, along with the factors and levels.	pp. 6-7 (II)

		• If any analyses used to explore heterogeneity were not pre-specified, identify them as such.	
Synthesis Methods (Sensitivity Analyses)	13f	• If sensitivity analyses were performed, provide details of each analysis (e.g. removal of studies at high risk of bias, use of an alternative meta-analysis model). • If any sensitivity analyses were not pre-specified, identify them as such.	p. 7 (II)
Reporting Bias Assessment	14	• Specify the methods (tool, graphical, statistical or other) used to assess the risk of bias due to missing results in a synthesis (arising from reporting biases). • If risk of bias due to missing results was assessed using an existing tool, specify the methodological components/domains/items of the tool, and the process used to reach a judgement of overall risk of bias. • If any adaptations to an existing tool to assess risk of bias due to missing results were made, specify the adaptations. • If a new tool to assess risk of bias due to missing results was developed for use in the review, describe the content of the tool and make it publicly accessible. • Report how many reviewers assessed risk of bias due to missing results in a synthesis, whether multiple reviewers worked independently, and any processes used to resolve disagreements between assessors. • Report any processes used to obtain or confirm relevant information from study investigators. • If an automation tool was used to assess risk of bias due to missing results, report how the automation tool was used, how the tool was trained, and details on the tool's performance and internal validation.	N/A
Certainty Assessment	15	• Specify the tool or system (and version) used to assess certainty (or confidence) in the body of evidence. • Report the factors considered (e.g. precision of the effect estimate, consistency of findings across studies) and the criteria used to assess each factor when assessing certainty in the body of evidence. • Describe the decision rules used to arrive at an overall judgement of the level of certainty, together with the intended interpretation (or definition) of each level of certainty. • If applicable, report any review-specific considerations for assessing certainty, such as thresholds used to assess imprecision and ranges of magnitude of effect that might be considered trivial, moderate or large, and the rationale for these thresholds and ranges (item #12). • If any adaptations to an existing tool or system to assess certainty were made, specify the adaptations.	pp. 6-7, 14 (II)

		• Report how many reviewers assessed certainty in the body of evidence for an outcome, whether multiple reviewers worked independently, and any processes used to resolve disagreements between assessors. • Report any processes used to obtain or confirm relevant information from investigators. • If an automation tool was used to support the assessment of certainty, report how the automation tool was used, how the tool was trained, and details on the tool's performance and internal validation. • Describe methods for reporting the results of assessments of certainty, such as the use of Summary of Findings tables. • If standard phrases that incorporate the certainty of evidence were used (e.g. "hip protectors probably reduce the risk of hip fracture slightly"), report the intended interpretation of each phrase and the reference for the source guidance.	
Results			
Study Selection (Flow of Studies)	16a	• Report, ideally using a flow diagram, the number of: records identified; records excluded before screening; records screened; records excluded after screening titles or titles and abstracts; reports retrieved for detailed evaluation; potentially eligible reports that were not retrievable; retrieved reports that did not meet inclusion criteria and the primary reasons for exclusion; and the number of studies and reports included in the review. If applicable, also report the number of ongoing studies and associated reports identified. • If the review is an update of a previous review, report results of the search and selection process for the current review and specify the number of studies included in the previous review. • If applicable, indicate in the PRISMA flow diagram how many records were excluded by a human and how many by automation tools.	p. 7 (II), Figure 1
Study Selection (Excluded Studies)	16b	• Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	pp. 7-8 (II), Figure 1
Study Characteristics	17	• Cite each included study. • Present the key characteristics of each study in a table or figure (considering a format that will facilitate comparison of characteristics across the studies).	see Table 1
Risk of Bias in Studies	18	• Present tables or figures indicating for each study the risk of bias in each domain/component/item assessed (e.g. blinding of outcome assessors, missing outcome data) and overall study-level risk of bias.	see Table 1; pp. 5-6 (II)

		• Present justification for each risk of bias judgement, for example in the form of relevant quotations from reports of included studies.	
Results of Individual Studies	19	• For all outcomes, irrespective of whether statistical synthesis was undertaken, present for each study summary statistics for each group (where appropriate). For dichotomous outcomes, report the number of participants with and without the events for each group; or the number with the event and the total for each group (e.g. 12/45). For continuous outcomes, report the mean, standard deviation and sample size of each group. • For all outcomes, irrespective of whether statistical synthesis was undertaken, present for each study an effect estimate and its precision (e.g. standard error or 95% confidence/credible interval). For example, for time-to-event outcomes, present a hazard ratio and its confidence interval. • If study-level data is presented visually or reported in the text (or both), also present a tabular display of the results. • If results were obtained from multiple data sources (e.g. journal article, study register entry, clinical study report, correspondence with authors), report the source of the data. • If applicable, indicate which results were not reported directly and had to be computed or estimated from other information.	see Table 1; pp. 6-7 (II)
Results of Syntheses (Characteristics of Contributing Studies)	20a	• Provide a brief summary of the characteristics and risk of bias among studies contributing to each synthesis (meta-analysis or other). The summary should focus only on study characteristics that help in interpreting the results (especially those that suggest the evidence addresses only a restricted part of the review question, or indirectly addresses the question). • Indicate which studies were included in each synthesis (e.g. by listing each study in a forest plot or table or citing studies in the text).	pp.8-11 (II)
Results of Syntheses (Results of Statistical Syntheses)	20b	• Report results of all statistical syntheses described in the protocol and all syntheses conducted that were not pre-specified. • If meta-analysis was conducted, report for each: - the summary estimate and its precision (e.g. standard error or 95% confidence/credible interval) - measures of statistical heterogeneity (e.g. τ 2 , I2 , prediction interval)	pp.8-11 (II)

		• If other statistical synthesis methods were used (e.g. summarising effect estimates, combining P values), report the synthesized result and a measure of precision (or equivalent information, for example, the number of studies and total sample size). • If the statistical synthesis method does not yield an estimate of effect (e.g. as is the case when P values are combined), report the relevant statistics (e.g. P value from the statistical test), along with an interpretation of the result that is consistent with the question addressed by the synthesis method. • If comparing groups, describe the direction of effect (e.g. fewer events in the intervention group, or higher pain in the comparator group). • If synthesising mean differences, specify for each synthesis, where applicable, the unit of measurement (e.g. kilograms or pounds for weight), the upper and lower limits of the measurement scale (e.g. anchors range from 0 to 10), direction of benefit (e.g. higher scores denote higher severity of pain), and the minimally important difference, if known. If synthesising standardised mean differences, and the effect estimate is being re-expressed to a particular instrument, details of the instrument, as per the mean difference, should be reported.	
Results of Syntheses (Results of Investigations of Heterogeneity)	20c	• If investigations of possible causes of heterogeneity were conducted: - present results regardless of the statistical significance, magnitude, or direction of effect modification. - identify the studies contributing to each subgroup. - report results with due consideration to the observational nature of the analysis and risk of confounding due to other factors. • If subgroup analysis was conducted: report for each analysis the exact P value for a test for interaction, as well as, within each subgroup, the summary estimates, their precision (e.g. standard error or 95% confidence/credible interval) and measures of heterogeneity. • If meta-regression was conducted: report for each analysis the exact P value for the regression coefficient and its precision. • If informal methods (i.e. those that do not involve a formal statistical test) were used to investigate heterogeneity, describe the results observed.	pp.8-11 (II)
Results of Syntheses (Results of Sensitivity Analyses)	20d	• If any sensitivity analyses were conducted: - report the results for each sensitivity analysis.	pp. 12-13 (II)

		- comment on how robust the main analysis was given the results of all corresponding sensitivity analyses.	
Reporting Biases	21	• Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. • If a tool was used to assess risk of bias due to missing results in a synthesis, present responses to questions in the tool, judgements about risk of bias and any information used to support such judgements. • If a funnel plot was generated to evaluate small-study effects (one cause of which is reporting biases), present the plot and specify the effect estimate and measure of precision used in the plot. If a contour-enhanced funnel plot was generated, specify the 'milestones' of statistical significance that the plotted contour lines represent (P = 0.01, 0.05, 0.1, etc.) • If a test for funnel plot asymmetry was used, report the exact P value observed for the test, and potentially other relevant statistics, for example the standardised normal deviate, from which the P value is derived. • If any sensitivity analyses seeking to explore the potential impact of missing results on the synthesis were conducted, present results of each analysis (see item #20d), compare them with results of the primary analysis, and report results with due consideration of the limitations of the statistical method.	N/A
Certainty of Evidence	22	• Report the overall level of certainty (or confidence) in the body of evidence for each important outcome. • Provide an explanation of reasons for rating down (or rating up) the certainty of evidence (e.g. in footnotes to an evidence summary table). • Communicate certainty in the evidence wherever results are reported (i.e. abstract, evidence summary tables, results, conclusions), using a format appropriate for the section of the review.	pp. 1 (I) – 25 (II)
Discussion			
Discussion (Interpretation)	23a	• Provide a general interpretation of the results in the context of other evidence.	pp. 13-17 (II)
Discussion (Limitations of Evidence)	23b	• Discuss any limitations of the evidence included in the review.	pp. 16-17 (II)

Discussion (Limitations of Review Processes)	23c	• Discuss any limitations of the review processes used, and comment on the potential impact of each limitation.	p. 16 (II)
Discussion (Implications)	23d	• Discuss implications of the results for practice and policy. • Make explicit recommendations for future research.	
Other Information			
Registration and Protocol (Registration)	24a	• Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/A
Registration and Protocol (Protocol)	24b	• Indicate where the review protocol can be accessed (e.g. by providing a citation, DOI or link), or state that a protocol was not prepared.	N/A
Registration and Protocol (Amendments)	24c	• Report details of any amendments to information provided at registration or in the protocol, noting: (a) the amendment itself; (b) the reason for the amendment; and (c) the stage of the review process at which the amendment was implemented.	N/A
Support	25	• Describe sources of financial or non-financial support for the review, specifying relevant grant ID numbers for each funder. If no specific financial or non-financial support was received, this should be stated. • Describe the role of the funders or sponsors (or both) in the review. If funders or sponsors had no role in the review, this should be declared.	p. 18 (II)
Competing Interests	26	• Disclose any of the authors' relationships or activities that readers could consider pertinent or to have influenced the review. • If any authors had competing interests, report how they were managed for particular review processes.	p. 18 (II)
Availability of Data, Code, and Other Materials	27	• Report which of the following are publicly available: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. • If any of the above materials are publicly available, report where they can be found (e.g. provide a link to files deposited in a public repository).	p. 18 (II)

		• If data, analytic code, or other materials will be made available upon request, provide the contact details of the author responsible for sharing the materials and describe the circumstances under which such materials will be shared.	

Supplementary Material 2: Eligibility criteria

Inclusion criteria

Population

- Criminal offenders from any country or cultural background
- No restrictions regarding the characteristics of offenders

Prognostic factor *(RAI, measure of accuracy, and index offence)*

- One of the four actuarial RA instruments:
    - Level of Service Inventory-Revised (LSI-R; Andrews & Bonta, 1995) for general recidivism;
    - Violence Risk Appraisal Guide (VRAG; Quinsey et al., 2006) for violent recidivism;
    - Static-99R (Hanson & Thornton, 2000; Helmus, Thornton, et al., 2012) for sexual recidivism;
    - Ontario Domestic Assault Risk Assessment (ODARA; Hilton et al., 2004) for intimate partner violent recidivism (IPV)
- Measures of predictive accuracy:
    - For the systematic review:
        - AUC including corresponding measures (i.e., 95% confidence interval [95% CI] and/or standard error [SE])
    - For the meta-analysis:
        - True/false positive and true/false negative, or
        - Sensitivity and specificity, or
        - Positive and negative predictive values

Outcome *(type of recidivism, legal status of recidivism, length follow-up, and base rate)*

- Reported base rate
- No restrictions regarding type of recidivism, legal status of recidivism, or length of follow-up

Study design

- Diagnostic or prognostic
- Test accuracy

Additionally, studies had to:

- Report sample size
- Report length of follow-up
- Be written in English, German, or French

Exclusion criteria

Population

- Samples including individuals that did not offend prior to risk assessment

Prognostic factor *(index offence and measure of accuracy)*

- Studies that did not report the index offence
- For the systematic review: studies that did not report 95%-confidence interval or standard error for the AUC
- The same sample was included in the analysis only once to avoid overlapping and inflation of results. If a sample was analysed in more than one study per instrument, the following criteria have been applied hierarchically to choose the study to be included:
    1. Better fit of the study characteristics to construction study (offender age and sex, type of index offence, type of recidivism, legal status of recidivism, and length of follow-up),
    2. Larger sample size,
    3. Studies published in peer-reviewed journals,
    4. Original study rather than re-analysis of data.

Outcome *(recidivism)*

- Studies that did not report base rates

Study design

- Systematic reviews or meta-analyses
- Randomised-controlled trials, case-control studies, observational studies, qualitative research

- Associations between total score (or risk bins) of actuarial RA instrument and recidivism (yes/no) or time to recidivism were assessed with correlations, regressions, or survival analyses

Supplementary Material 3: Full search strings

PsycINFO *(EBSCO interface)*

The search was updated March 30th, 2023, using the following search strings:

((("Level of Service Inventory") AND (Revised)) OR LSI-R) AND ((valid* OR accura* OR replicat*))

((VRAG) OR (Violence Risk Appraisal Guide)) AND ((valid* OR accura* OR replicat*))

(Static-99R) AND (valid* OR accura* OR replicat*)

((ODARA) OR (Ontario Domestic Assault Risk Assessment)) AND ((valid* OR accura* OR replicat*))

PubMed *(MEDLINE, PMC, and Bookshelf)*

((("Level of Service Inventory") AND (Revised)) OR LSI-R) AND ((valid* OR accura* OR replicat*))

((VRAG) OR (Violence Risk Appraisal Guide)) AND ((valid* OR accura* OR replicat*))

(Static-99R) AND (valid* OR accura* OR replicat*)

((ODARA) OR (Ontario Domestic Assault Risk Assessment)) AND ((valid* OR accura* OR replicat*))

Supplementary Material 4: Hierarchy of full-text exclusion reasons (for PRISMA flow-chart)

Some studies were not eligible for more than one reason. For reporting purposes, we categorised the reasons for exclusion as follows:

1. Other RA instrument
2. No diagnostic or prognostic study (e.g., systematic review or meta-analysis)
3. At least one item of instrument was modified
4. No index offence committed prior to RA
5. No sample size reported
6. No measure of accuracy reported
7. AUC reported but not corresponding 95%-CI or SE
8. No length of follow-up reported
9. No base rate reported
10. Data used in previous research

Supplementary Material 5: Study variables

Variable name	Variable label	Variable type	Value and labels (if applicable)	Annotation
ID	Unique identifier for each study	text (character)		
source	Source where study has been identified	categorical	0 = snowball 1 = systematic	
author	Name of first author with et al. for following	text (character)		
year	Year of study	text (character)		
title	Title of study	text (character)		
country	Country where study has been conducted	categorical	0 = Belgium 1 = Canada 2 = Germany 3 = Sweden 4 = Switzerland 5 = UK 6 = USA 7 = Norway 8 = Netherlands 9 = China 10 = Singapore 11 = New Zealand 12 = Austria 13 = Australia 14 = South Korea 15 = mixed	
instrument	Instrument that has been used	categorical	0 = LSI-R 1 = ODARA 2 = Static-99R 3 = VRAG	

crit_sex_met	Criterion of sex met	categorical	0 = no 1 = yes . = missing / not reported	**Criterion different depending on instrument:** VRAG: male ODARA: male LSI-R: male/female Static-99R: male
%female	% of females	continuous	0 to 100	
crit_age_met	Criterion for age met	categorical	0 = no 1 = yes . = missing / not reported	**Criterion different depending on instrument:** LSI-R: 16 years+ ODARA: 18 years+ Static-99R: adults (and adolescents if 18 years at the time of release and 17 years at the time of committing the offence) VRAG: adults (and adolescents if 18 years at the time of release)
age_mean	Mean age of population	continuous	0 to xy . = missing / not reported	Age at time of assessment or time of release. If age was reported only for time of index offence, it was handled as missing value.
age_sd	Standard deviation of age of population	continuous	0 to xy . = missing / not reported	
age_range_l	Lower bound age range of population	continuous	0 to xy . = missing / not reported	
age_range_u	Upper bound age range of population	continuous	0 to xy . = missing / not reported	
sample_size	Sample size used for calculation of predictive accuracy	continuous	0 to xy . = missing / not reported	
crit_type_io_met	Criterion of index offence met (original RA criteria)	categorical	0 = no 1 = yes . = missing	**Criterion different depending on instrument:** **LSI-R**: general **ODARA**: domestic violence against a current or former cohabiting partner or dating partner (physical contact; or a credible threat of death with weapon in hand in presence of the victim) **Static-99R**: sexual (incl. hands-off) **VRAG**: violent/sexual hands-on

type_io	Type of index offence	categorical	0 = general 1 = violent/sexual 2 = violent only 3 = sexual only 4 = IPV 5 = other . = missing	
crit_type_recid_met	Criterion of type of recidivism met	categorical	0 = no 1 = yes . = missing / not reported	**Criterion different depending on instrument:** **LSI-R**: general **ODARA**: IPV (includes sexual contact forced by any means; includes actual or attempted use of weapon or threat of physical harm with weapon in hand) **Static-99R**: sexual (incl. hands-off) **VRAG**: violent/sexual hands-on
type_recid	Type of recidivism	categorical	0 = general 1 = violent/sexual 2 = violent only 3 = sexual only 4 = IPV 5 = other . = missing	
crit_legal_stat_recid_met	Criterion legal status of recidivism met	categorical	0 = no 1 = yes . = missing / not reported	**Criterion different depending on instrument:** **LSI-R**: any; should not be used as inclusion criterion but measured separately **ODARA**: police report/charge **Static-99R:** arrest/charge/conviction **VRAG**: charge/conviction
legal_stat_recid	Legal status of recidivism	categorical	0 = arrest 1 = charge 2 = conviction (incl. criminal record) 3 = incarceration 4 = police report 5 = self-report 6 = other	
crit_length_FU_met	Criterion length of follow-up met	categorical	0 = no 1 = yes	**Criteria different depending on instrument:** **LSI-R**: NA (follow-ups of 0.5 years to 8 years recommended) **Static-99R**: 5 years/15 years

				ODARA: average 5 years; follow-ups of 0.5 years to 8 years recommended **VRAG**: 7 years/10 years
length_FU1	Length follow-up in years (mean or median)	continuous	0 to xy . = missing / not reported	If FU was provided in months or days, the number was converted to years (e.g. 6 months = 6/12 = 0.5 or 97 days = 97/365.25 = 0.27)
length_FU1_SD	Standard deviation of lenght of follow-up in years	continuous	0 to xy . = missing / not reported	
length_FU1_range_l	Lower bound of follow-up range in years	continuous	0 to xy . = missing / not reported	
length_FU1_range_u	Upper bound of follow-up range in years	continuous	0 to xy . = missing / not reported	
crit_no_RA_met	Number of criteria met	continuous	0 to 6	For the LSI-R, the range of this variable is 0 to 5 given that the variable "Criterion length of follow-up met" is always not applicable.
crit_RA_met	All applicable criteria met	categorical	0 = no 1 = yes	
AUC_FU1	AUC reported	numeric	0 to 1 . = missing / not reported	
AUC_FU1_CIL	Lower bound of 95% CI of AUC	numeric	0 to 1 . = missing / not reported	If 95% CI is not reported, it can be calculated using SE and sample size.
AUC_FU1_CIU	Upper bound of 95% CI of AUC	numeric	0 to 1 . = missing / not reported	If 95% CI is not reported, it can be calculated using SE and sample size.
AUC_FU1_SE	Standard error of AUC	numeric		If SE is not reported, it can be calculated using 95% CI and sample size.
AUC_FU1_p	Exact p-value of ROC analysis	numeric	0 to 1 . = missing / not reported	If 95% CI is not reported, it can be estimated by p-value.
sensitivity_FU1	Sensitivity reported	numeric	0 to 1 . = missing / not reported	
specificity_FU1	Specificity reported	numeric	0 to 1 . = missing / not reported	
baserate_FU1	Base rate in % reported	numeric	0 to 100 . = missing / not reported	
PPV_FU1	PPV reported or calculated	numeric	0 to 100 . = missing / not reported	
NPV_FU1	NPV reported or calculated	numeric	0 to 100 . = missing / not reported	
cutoff_score2	Type of reported cut-off score	categorical	0 = no cutoff	

			1 = optimal cutoff 2 = theroretical 3 = unclear	
cutoff_num	Cut-off score used for calculation of sensitivity/specificity	Numerical	-xy - xy	. if cut-off score was not mentioned.
exclusion_narr	Exclusion from systematic review	categorical	0 = no 1 = yes	
exclusion_reason_narr	Reason for exclusion from systematic review	categorical	1 = Wrong actuarial RA instrument 2 = Wrong study design (e.g. systematic review or meta-analysis; not diagnostic or prognostic study) 3 = At least one item of instrument was modified 4 = No index offence 5 = No sample size reported 6 = Wrong measure of diagnostic accuracy (e.g. only AUC reported but not corresponding 95%-CI/SE; different statistics) 7 = No follow-up period reported 8 = No base rate reported 9 = Data used before	
exclusion_meta	Exclusion from meta-analysis	categorical	0 = no 1 = yes	
exclusion_reason_meta	Reason for exclusion from meta-analysis	categorical	1 = Wrong RA instrument 2 = Wrong study design (e.g. systematic review or meta-analysis; not diagnostic or prognostic study) 3 = At least one item of instrument was modified 4 = No index offence 5 = No sample size reported 6 = Wrong measure of diagnostic accuracy (i.e., no values for TP/TN; Sens./Spec.; PPV/NPV presented) 7 = No follow-up period reported 8 = No base rate reported 9 = Data used before	
comment	Other comments	text (character)		

coder	Who coded the study/extracted the data	text (character)	MK = Madeleine Kirschstein MW = Michael Weber NS = Nina Schnyder
checkedby	Who checked the coding/extraction	text (character)	MK = Madeleine Kirschstein MW = Michael Weber NS = Nina Schnyder
JBI_1	JBI random sample	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_2	JBI case control avoided	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_3	JBI avoid inappropriate exclusion	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_4	JBI result interpretation reference standard	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_5	JBI threshold	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_6	JBI correctly classify target condition	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_7	JBI result interpretation index test	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported
JBI_8	JBI appropriate interval	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported

JBI_9	JBI same reference standard	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported	
JBI_10	JBI patients included	categorical	0 = no 1 = yes 2 = unclear . = missing (NA) / not reported	
JBI_sum	JBI sum yes items	continuous	0 to 10	max sum might be smaller than 10 if one item is always NA
BR_domestic_low	Lowest current base rate identified for IPV recidivism (police record)			
BR_domestic_high	Highest current base rate identified for IPV recidivism (police record)			
BR_domestic_man	Base rate of the ODARA construction sample			
BR_violent_low	Lowest current base rate identified for violent recidivism (reconviction / criminal record)			
BR_violent_high	Highest current base rate identified for violent recidivism (reconviction / criminal record)			
BR_violent_man	Base rate of the VRAG construction sample			
BR_sex_low	Lowest current base rate identified for sexual recidivism (reconviction / criminal record)			
BR_sex_high	Highest current base rate identified for violent recidivism (reconviction / criminal record)			
BR_sex_man	Base rate of the Static-99R construction sample			

Supplementary Material 6: Characteristics of construction samples

	LSI-R	VRAG	Static-99R	ODARA
Offender age	≥16 years	Opportunity to reoffend begins at ≥ 18 years	≥ 18 years (and adolescents if 18 years at the time of release and 17 years at the time of committing the offence)	≥ 18 years
Offender sex	Male or female	Male	Male	Male
Type of index offence	General	violent/sexual hands-on (no arson)	sexual (including hands-off)	IPV (i. e., physical violence, threat with a weapon)
Type of recidivism	General	Violent/sexual hands-on (no arson); violent, including hands-on sexual	Violent/sexual hands-on	IPV (including forced sexual contact; actual or attempted use of weapon; threat of physical harm with weapon in hand)
Legal status of recidivism	Any (no restrictions)	Charge, conviction or criminal record; return to prison (e.g., parole violation) or a maximum security psychiatric institution for a violent offence for which the offender could have been charged	Arrest, charge, or conviction	Police report, charge, or criminal record
Length of follow-up	Any (no restrictions)	7 or 10 years (fixed)	5 or 10 years (fixed)	Average follow-up of 5 years (±0.5); subsequent follow-ups 0.5 years to 8 years recommended

Supplementary Material 7: Extraction rules in case of multiple values for the same study variables

Supplementary Material 7.1: Sample

If sample characteristics were presented both in the methods and in the results sections, the latter were extracted (differing information due to attrition or reduced availability of data for further analyses). If provided, values for the total sample were extracted. Some authors reported sample (including index offence) characteristics at baseline but not at follow-up. Due to attrition, this information may not pertain to the same individuals. Whenever possible, we extracted sample (and index offence) characteristics at follow-up. If this was not possible, we relied on the information at baseline.

Supplementary Material 7.2: Length of follow-up

If results for more than one follow-up period were reported, the results of the period with more detailed information was reported (e.g., AUC including SE/95%-CI versus only AUC and approximate p-value; or, demographics were reported only for the full sample that was analysed for an average follow-up period, but not for the sub-sample with a fixed follow up). In case of an identical amount of information, data from the follow-up period that more closely corresponded to the follow-up period suggested in the manual was extracted. If both follow-up periods were in accordance with the manual, we extracted data for the shorter period.

Supplementary Material 7.3: Type of recidivism

If more than one outcome category was analysed and reported separately within the same study (e.g., violent, sexual, and general recidivism), we chose the one that better fit to the aims of the instrument (e.g., sexual recidivism instead of violent recidivism for the Static-99R); if measurement of both outcomes was indicated based on the manual (e.g. non-physical assault and physical abuse in case of the ODARA), we extracted data for the offence category with the higher base rate to maximize PPVs.

Supplementary Material 7.4: Legal status of recidivism

Similarly, if authors included different types of the legal status of recidivism (e.g., charge vs. conviction vs. institutional records), we chose the legal status that a) better corresponded to the manual (e.g., criminal charges instead of violent infractions recorded in an institutional file for the VRAG); b) a greater number of participants were likely to meet (charge in this case, since there are no convictions without preceding charges); c) with the higher base rate.

Supplementary Material 8: Search strategy for current base rates

- Scientific and grey literature from the following databases: Google, Google Scholar, PsycInfo, PubMed
- Search terms:
    - recidivism OR reconviction OR re-arrest OR reimprisonment AND [countries]
    - recividism rates OR reconviction rate AND sexual OR violent OR IPV
    - crime statistics AND [countries]
    - base rate AND crime OR sexual OR IPV or violent AND [countries]
    - prisoners AND (prevalence OR rates) AND (recidivism OR reoffending) AND [countries]
    - Websites of national police agencies
    - Systematic reviews on recidivism rates used to identify primary studies:
        - Fazel S, Wolf A. A Systematic Review of Criminal Recidivism Rates Worldwide: Current Difficulties and Recommendations for Best Practice. Plos one. 2015; 10(6):e0130390. DOI: 10.1371/journal.pone.0130390. PMID: 26086423; PMCID: PMC4472929.
        - Wartna, B.S.J., Nijssen, L.T.J.: National studies on recidivism. An inventory of large-scale recidivism research in 33 European countries. WODC, The Hague, February, 2006; Ministry of Justice: Comparing International Criminal Justice Systems. Briefing for the House of Commons Justice Committee, London 2012, S. 32ff.
        - Yukhnenko D, Sridhar S, Fazel S. A systematic review of criminal recidivism rates worldwide: 3-year update. Wellcome Open Res. 2020 Nov 3;4: 28. DOI: 10.12688/wellcomeopenres.14970.3. PMID: 31544154; PMCID: PMC6743246.
- Quality criteria for choosing base rates
    - The overarching aim was to identify studies with high relevance for forensic practice (i.e.., current base rate data on representative offender samples that can be accessed by practitioners). This approach led to the following inclusion and exclusion criteria:
    - Inclusion criteria
        - National statistic or peer-reviewed publication
        - Total offender cohort
        - Adult offenders (at the time of the index offence)
        - Fixed follow-up period
        - Start of time at risk ≥ year 2000
        - Pertinent offence type: index offence = recidivism
        - Legal status of recidivism

- sex offences: conviction or criminal record
- violent offences: conviction or criminal record
- IPV: police records

- Exclusion criteria
  - Missing value(s) in one or more of the relevant study characteristics (i.e., type of index offence, date of index offence, follow-up period, legal status of recidivism, type of recidivism,
  - Time at risk too short (i.e., less than three years follow-up period for conviction or criminal record data)

Supplementary Material 9: Formulas for calculating measures of calibration

We calculated TP, TN, FP, and FN based on sample size (n), base rate (BR in %), sensitivity (TPR), and specificity (TNR) as follows:

m (number of individuals who recidivated) = BR * N / 100

n (number of individuals who did not recidivate) = N - m

False positive rate (FPR) = 1 - TNR

False negative rate (FNR) = 1 - TPR

TP = m * TPR

FP = n * FPR

TN = n * TNR

FN = m * FNR

Predictive values were calculated using the pooled sensitivities and false positive rates as follows:

PPV = (pooled sensitivity * base rate) / [(pooled sensitivity * base rate) + (pooled FPR * (1 - base rate))]

NPV = ((pooled 1 – FPR) * (1 - base rate)) / [((1 – pooled sensitivity) * base rate) + ((pooled 1 – FPR * (1 - base rate))]

Supplementary Table 1. Median, smallest and largest AUC including their corresponding 95%-confidence intervals (95%-CI) by risk assessment instrument (k = 103)

	Median		Smallest		Largest	
	AUC	*95%-CI*[1]	*AUC*	*95%-CI*[2]	*AUC*	*95%-CI*[3]
LSI-R (k = 16)	0. 681	0.608-0.742	0.480	0.343-0.617	0.770	0.620-0.910
Static-99R (k = 40)	0.710	0.620-0.780	0.550	0.450-0.650	0.824	0.724-0.923
ODARA (k = 14)	0.685	0.585-0.786	0.629	0.477-0.781	0.780	0.620-0.940
VRAG (k = 33)	0.714	0.637-0.800	0.570	0.390-0.740	0.870	0.740-1.000

Note. 95%-CI: 95% confidence interval, *k* = independent samples; [1] calculated median 95%-CI; [2] 95%-CI corresponding to smallest reported AUC; [3] 95%-CI corresponding to largest reported AUC.

Supplementary Table 2. Current base rates for violent reoffending and base rate from VRAG construction sample

Author(s)	Country	Type of Publication	Offender Population	Time at Risk [years]	Base Rate [%]
Jehle et al. (2021)	Germany	National statistic	N=98,229 offenders convicted or released in 2004 [a)]	3	15.5
Jehle et al. (2021)	Germany	National statistic	N=98,229 offenders convicted or released in 2004 [a)]	6	20.8 [c)]
Rossegger, Endrass, Gerth, & Singh (2014)	Switzerland	Scientific publication	N=206 offenders supervised by the Zurich criminal justice system in 2000 [b)]	7	18.0
Statistik Austria (2022)	Austria	National statistic	N=4,977 offenders convicted or released in 2017	4	12.6 [c)]
Harris, Rice, & Quinsey (1993) [d)]	Canada	Scientific publication	N=618 offenders, N=332 thereof admitted for treatment to a maximum security psychiatric institution in Ontario between 1965 and 1980	6.8	31.0

Notes. All base rates relating to identical offence type (index offence = recidivism). Recidivism criterion = reconviction. [a)] Convictions for assault; [b)] release date between 2000 and 2011; violent including hands-on sexual offences (child sexual abuse and rape); [c)] has been used to calculate positive and negative predictive values (PPV and NPV); [d)] VRAG construction sample.

Supplementary Table 3: Current base rates for sexual reoffending and base rate from Static-99R construction sample

Author(s)	Country	Type of Publication	Offender Population	Time at Risk [years]	Base Rate [%]
Reeves et al. (2018)	Australia	Scientific publication	N=520 offenders treated in Victoria's public statutory agency in 1987-2011 [a)]	5	13.0 [d)]
Statistik Austria (2022)	Austria	National statistic	N=603 offenders convicted or released in 2017	4	4.6
Jehle et al. (2021)	Germany	National statistic	N=2,395 offenders convicted or released in 2004 [b)]	3	2.9
Jehle et al. (2021)	Germany	National statistic	N=2,395 offenders convicted or released in 2004 [b)]	6	4.3
Jehle et al. (2021)	Germany	National statistic	N=3,156 offenders convicted or released in 2004 [c)]	3	2.3 [d)]
Jehle et al. (2021)	Germany	National statistic	N=3,156 offenders convicted or released in 2004 [c)]	6	3.8
Gonçalves et al. (2020)	Switzerland	Scientific publication	N=142 offenders treated by the Zurich criminal justice system in 1997-2009 [a)]	5	9.9
Helmus, Thornton et al. (2012) [e)]	Canada (n=11 samples), USA (n=6), UK (n=2), Denmark, Austria, Sweden, Germany, New Zealand (n = 1 each)	Scientific publication	8,390 sex offenders released between 1957 to 2007	5	11.0

Notes. All base rates relating to identical offence type (index offence = recidivism). Recidivism criterion = reconviction. [a)] Mentally disordered sample, indicating a high recidivism risk at baseline; [b)] index offence = rape, recidivism = sexual violence including sexual abuse; [c)] sexual abuse; [d)] has been used to calculate positive and negative predictive values (PPV and NPV); [e)] Static-99R construction sample.

Supplementary Table 4: Current base rates for IPV reoffending and base rate from ODARA construction sample

Author(s)	Country	Type of Publication	Offender Population	Time at Risk [years]	Base Rate [%]
Kerr et al. (2017)	Australia	Scientific publication	N=10,557 offenders registered by Northern Territory Police in 2010	1	46.4 [b)]
Greuel et al. (2010)	Germany	Scientific publication	N=1,140 offenders registered by police in 2006 [a)]	1	13.0 [b)]
Gerth et al. (2017)	Switzerland	Scientific publication	N=185 offenders registered by police in 2008	5	31.9
Hilton et al. (2004) [c)]	Canada	Scientific publication	N=589 IPV offenders reported to police between 1996 and 2001	1.3	30.0

Notes. All base rates relating to identical offence type (index offence = recidivism). Recidivism criterion = police record including charges. [a)] Total cohort of IPV perpetrators in six cities participating in a pilot intervention program; [b)] has been used to calculate positive and negative predictive values (PPV and NPV); [c)] ODARA construction sample.

Supplementary Table 5. Current recidivism rates for general delinquency and BR from LSI-R construction sample

Author(s)	Country	Type of Publication	Offender population (N)	Base Rate [%]
Statistik Austria (2022)	Austria	National Statistic	Offenders convicted or released in 2017 (total cohort, N = 28,286)	27% [a), b)]
Ministère de la Justice (2013)	France	National Statistic	Offenders released in 2004 (total cohort, N = 78,580)	48% [a)]
Jehle et al. (2020)	Germany	National Statistic	Adult offenders released in 2013 (total cohort, N = 23,856)	46% [a)]
Central Statistics Office (2019)	Ireland	National Statistic	Offenders convicted in 2013 (total cohort, N = 9,339)	45% [a)]
Research and Documentation Centre (2021)	Netherlands	National Statistic	Offenders released in 2017 (total cohort, N = 23,302)	53% [a), b)]
Swedish National Council on Crime Prevention (n.d.)	Sweden	National Statistic	Offenders released in 2014 (total cohort, N = 71,193)	40% [a)]
Federal Statistical Office (2020)	Switzerland	National Statistic	Adult offenders released in 2013 (total cohort, N = 1,309)	35% [a)]
Andrews & Bonta (1995) [c)]	Canada	Scientific Publication	N = 956 men from the Toronto jail, the Ottawa-Carleton and the Hamilton Wentworth detention centre; and N = 1414 women from a medium-security institution for adult women operated by the Ontario ministry of correctional services	41% [d)]

Notes. [a)] 3-year reconviction rate; [b)] has been used to calculate positive and negative predictive values (PPV and NPV); [c)] LSI-R construction sample; [d)] 1-year reincarceration rate.