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Identifying potential offenders on the basis of police records: development and validation of the ProKid risk assessment tool

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Abstract

Purpose – *The purpose of this paper is to describe the development and validation of the ProKid risk assessment tool, which was designed to enable Dutch police officers to identify youths with elevated risk of committing violent and/or property crimes.*

Design/methodology/approach – *The ProKid algorithms were based on the results of logistic regression analyses of police data from a sample of 31,769 adolescents in the former police regions "Amsterdam-Amstelland" and "Gelderland-Midden". For the validation, logistic regression analyses were performed on police data of youths in the police region "Amsterdam-Amstelland" who had been in contact with the police in 2011 ($n = 39,977$). Furthermore, receiver operating characteristic analyses were performed to assess the instrument's accuracy.*

Findings – *Results indicated that higher ProKid risk categories were associated with greater odds of being registered as a suspect of either a violent or property offence. The instrument was found to have good predictive accuracy. Area under the curve values ranged from 0.83 to 0.84 for violent offences and from 0.82 to 0.83 for property offences.*

Practical implications – *The current study demonstrates that ProKid is a valid and accurate tool to be used by police officers to identify youths with elevated risk of future violent and property offending. The automated assessment procedure enables a quick screening of large numbers of both non-offenders and offenders. This study confirms the value of official police records for assessing the risk of future offending for preventive purposes.*

Originality/value – *The present study demonstrates the validity of a risk assessment tool based on Dutch police records for both non-offenders and offenders.*

Keywords *Treatment, Policing, Offenders, Risk, Assessment, Crime prevention and reduction*

Paper type *Research paper*

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Juvenile delinquency is a serious societal problem with, in the first place, negative emotional, physical, and economic consequences for the victims involved. In particular violent and property crimes are known to have a large, often traumatising, impact on victims (e.g. McGue and Iacono, 2005; Piquero *et al.*, 2007). In addition to the negative consequences for the individual victims, juvenile delinquency is associated with high societal costs. Estimates of these costs in the Netherlands range from €17.2 to €31.5 billion per year (Bakker, 2012). Further, criminal behaviour is associated with negative consequences for the juvenile delinquent perpetrators, as they often experience problems in the areas of health, education, employment, and relationships (Borduin, 1994; Kazdin, 1987). These problems tend to be most severe for the relatively small group of juveniles whose criminal behaviour started at a young age, gradually became more serious, and persisted into adulthood (Loeber *et al.*, 2009).

Research has shown that early interventions can prevent youths from developing a criminal career (Deković *et al.*, 2011; Farrington and Coid, 2003; Weisburd *et al.*, 2016). Early intervention is important because once behaviour patterns have been established over some time, they are

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ProKid was developed by the Dutch police in cooperation with Praktikon and Radboud University Nijmegen. The authors have no commercial interest in the instrument.

difficult to alter (Bernazzani *et al.*, 2001; Farrington, 2007; Farrington and Loeber, 2000). In addition to early interventions for youths with a history of offending, preventive efforts should target youths with an elevated risk for criminal behaviour even though they have not yet displayed such behaviours (DeMatteo and Marczyk, 2005). Preventing them from developing a criminal career is a high priority.

In the Netherlands, the police have an important task with regard to the prevention of both the continuation and onset of delinquent behaviour (Assink *et al.*, 2016). That is, police officers come in contact with not only many juvenile offenders but also with youths who are in other ways involved in an offence, for example, as victim or witness. Research has shown that not only suspects, but also victims and witnesses of offences are at elevated risk for criminal behaviour (Hurt *et al.*, 2001; Loeber *et al.*, 2001; Patchin *et al.*, 2006). Therefore, preventive efforts should not only focus on the suspects but also on the victims and witnesses of criminal behaviour.

To fulfil its preventive task properly, it is essential that the police are equipped with a tool to identify youths with elevated risk so that they can be referred to specialised youth care agencies for further assessment in a timely manner, and, if necessary, receive treatment aimed at reducing the risk of future offending. In the Netherlands, several instruments have been developed to enable police officers to estimate the risk of future offending. These instruments are all based on official police records only, which enables a quick and automated assessment procedure. The instruments differ, among other aspects, with regard to the target group for which risk assessments are generated and the predictor variables used to base the risk assessments on. With regard to target group, for example, the Landelijk Instrumentarium Jeugdstrafrechtketen (LIJ) (National Instruments Juvenile Criminal Law) (van der Put *et al.*, 2011) and the Youth Actuarial Risk Assessment Tool (Y-ARAT; van der Put, 2014) focus on predicting recidivism of youths who already were suspected of violent offences in the past. In contrast, the Youth Actuarial Risk Assessment Tool for First-Time Offending (Y-ARAT-FO; Assink *et al.*, 2016) focusses on first-time offending for youths who have not yet committed an offence. With regard to the predictor variables used to base the risk assessments on, the LIJ only uses data on the youth's own criminal history, whereas both the Y-ARAT and Y-ARAT-FO also use data on the police contacts of the youth's family members.

Although the instruments available confirm the utility of official police records for risk assessment (see also Berk, 2012; Cocx, 2009), they are limited in several ways. First, they focus either on predicting the chances of recidivism for youths with a criminal history, or on predicting the chances of first-time offending for youths without prior offences. To date, no comprehensive instrument is available that generates risk scores for both groups, that is, recidivists and first-time offenders. It is important to note that risk factors associated with recidivism do not necessarily apply to first-time offending. Second, none of these instruments incorporate peer influences into their predictive models. Research has shown that, in addition to family members, peers are an important social context for the development of delinquent behaviour (Farrington, 2015; Haynie and Osgood, 2005). Third, previous instruments have generally used relatively small samples for validation. To overcome these limitations, the ProKid risk assessment tool was developed.

ProKid

ProKid is a risk assessment tool for adolescents aged 12-18 years to be used by police officers to assess the risk of future violent and property offending. ProKid generates risk scores for youths who have come in contact with the police as a suspect, victim, or witness. Given the limited time and resources available to police officers, the instrument only uses information available in operational police systems, thus enabling an automated assessment procedure. The instrument enables police officers who lack formal clinical training to perform an initial screening that identifies at whom preventive efforts should be targeted, either by the police themselves or by specialized youth care agencies.

ProKid is an actuarial risk assessment instrument. Actuarial prediction has become one of the dominant approaches to risk assessment of delinquent behaviour (Singh, 2012). Actuarial (or statistical) risk assessment instruments estimate the risk of future delinquency through the assignment of weights to variables that empirically have shown to be associated with delinquency (Assink *et al.*, 2016). These weights are incorporated into an algorithm with which the risk of future offending can be calculated.

Because the aim was to develop an automated risk assessment tool, there were hardly any limitations, aside from computer performance limits, regarding the number of predictors to be incorporated in the predictive model underlying ProKid. The included predictor variables were chosen based on the scientific literature on risk factors for the development of juvenile delinquency (e.g. Loeber, 1990; Smith, 2004; Youth Justice Board, 2005). First, variables pertaining to the youth's own criminal history were included in the model. One's criminal history is generally one of the strongest and most consistent predictors of future delinquent behaviour. The more offences that have been committed in the past, the greater are the chances that offences will be committed in the future (Assink, van der Put, Hoeve, de Vries, Stams and Oort, 2015). The seriousness of past offences also strongly predicts future offences, with more serious offences associated with higher risks of future criminal behaviour (Ramchand *et al.*, 2009). In addition to the youth's own criminal history, delinquent behaviours by family members and peers generally are seen as important risk factors for the development of delinquency (see, e.g. Farrington, 2015; Haynie and Osgood, 2005; Knecht *et al.*, 2010; Nijhof *et al.*, 2007). Therefore, the incidents in which the youth's cohabitants (parents and siblings) and fellow suspects were involved as a suspect were included in the model.

In addition to the predictors mentioned above, which all pertain to the role of suspect, data concerning the role of victim and witness were included in the model. This was the case for the youths themselves as well as for their cohabitants and fellow suspects. The inclusion of these variables was based on research showing that not only offenders, but also victims and witnesses of crime have elevated risks of developing criminal careers (see, e.g. Hurt *et al.*, 2001; Loeber *et al.*, 2001; Patchin *et al.*, 2006).

Two additional predictor variables were constructed on the basis of information in the database: offending frequency and versatility. Offending frequency, defined as the number of crimes committed by an offender during a well-defined time period has been the topic of much empirical research in criminology (Blumstein *et al.*, 1986; Brame *et al.*, 2004; Cohen, 1986). Higher rates of past offending have been shown to be associated with higher risks of future criminal behaviours. In addition, versatility is a predictor of future crime (see, e.g. Brame *et al.*, 2004). Versatility reflects the tendency to switch between different types of criminal activity.

Finally, gender and age were included in the model. Gender is a strong and consistent predictor of criminal behaviour, since males have been found to be more likely to display criminal behaviour than females (see, e.g. Loeber *et al.*, 2013). Also, delinquent behaviour has been shown to be strongly related to age. The age-crime curve describes a peak in criminal behaviour during mid-adolescence that has been demonstrated frequently in empirical research (see, e.g. Caspi and Moffitt, 1995; Daigle *et al.*, 2008; Farrington *et al.*, 2013; Gottfredson and Hirschi, 1990; Hirschi and Gottfredson, 1983; Leal and Mier, 2017; Wright *et al.*, 2008). In the predictive model underlying ProKid, age is also included as a quadratic component to account for the curvilinear relationship between age and delinquency based on the age-crime curve.

With regard to outcome variables, ProKid focusses on violent offending and property offending. The choice of these outcomes was guided by the work of Loeber *et al.* (LeBlanc *et al.*, 1991; Loeber *et al.*, 1993; Loeber *et al.*, 1992; Loeber and Hay, 1997). They hypothesised and provided empirical support for an overt and a covert disruptive behaviour pathway (Loeber *et al.*, 1992). Covert behaviour development is theorised to develop from minor covert behaviour to property damage, and then to moderately serious, and finally, serious property offences (e.g. fraud, burglary, serious theft). The overt pathway progresses from minor aggression such as bullying to physical fighting, and then to violence and rape (Loeber and Hay, 1997). In line with the pathways model, separate algorithms were constructed for the prediction of property crimes and violent crimes. These types of crime pertain to the final stage of the covert pathway and the overt pathway, respectively.

ProKid can be regarded a third-generation risk assessment tool. It includes both static and dynamic risk factors, and uses objective, actuarial methods based on advanced statistical techniques.

First-generation instruments, in contrast, relied mainly on subjective, clinical, and professional judgments. Second-generation instruments used more objective, actuarial methods than first-generation instruments, but relied almost exclusively on static, criminal history factors (Andrews and Bonta, 2010; Bonta, 1996; Brennan *et al.*, 2009). Several international validation studies have shown that second- and third-generation risk instruments outperform structured clinical instruments in the prediction of future delinquency (Guy, 1998; Hanson and Morton-Bourgon, 2009).

Present study

The goal of this study was to demonstrate the construction and predictive validity of ProKid, which comprised several steps. First, it was examined to what extent past police records were related to future offending. Second, an actuarial risk screening instrument was built based on the results from step 1. Third, the predictive validity of the instrument was examined to determine whether it could predict future offending. With regard to validation, the following two research questions were formulated:

RQ1. To what extent are adolescents classified in a higher risk category more likely to become a suspect of a future offence than adolescents classified in a lower risk category?

RQ2. What is the accuracy of ProKid in terms of sensitivity and specificity?

Method

Data

For the development of the ProKid algorithms, data were used from a sample of 31,769 adolescents (20,141 boys, 11,628 girls) between 12 and 18 years of age ($M = 15.6$; SD = 1.6) who were registered in official Dutch police records in 2007 because they were involved in an offence as a suspect, victim, or witness (construction sample). These juveniles were selected at random from all juveniles who came in contact with the Dutch police in 2007 in the former police regions "Amsterdam-Amstelland" and "Gelderland-Midden". Thus, the 2007 incident was the index incident. The juveniles' records were retrieved from the police database for a period of five years prior to the date of the index incident (i.e. from 2002 to 2007) and for a period of four years after the index incident (i.e. from 2007 to 2011). In addition to data on the juveniles' own police contacts, data of their cohabitants and fellow suspects (in any role) over the same time periods were included in the analyses.

The predictive power of the instrument was assessed in an independent sample of 46,652 juveniles (validation sample). Data were used of all youths in the police region "Amsterdam-Amstelland" who had come into contact with the police in 2011 and who were between 7 and 22 years of age[1]. For 39,977 (25,174 boys, 14,796 girls) of them, ProKid risk classifications were available on index date 1 january 2012, as well as data on their police contacts during the four years after the index date (for 6,675 youths, no risk score was available because they fell outside the age range for which risk scores can be generated or because gender information was lacking). The mean age of these youths on the index date was 17.9 years (SD = 3.3).

Variables

Offence-type variables (e.g. violent offences, property offences, sexual offences) were constructed by grouping together incidents with similar content. As a guideline, Soothill *et al.*'s (2008) categorisation of offences was used. The offence-type variables were entered as independent variables into the model. The dependent variable of interest was a binary variable reflecting whether or not a youth was registered as a suspect of an offence after the index incident. Separate models were run for violent and property offending. Property offending was based on 49 incident codes pertaining to criminal acts with mostly a financial motive (e.g. theft, burglary, fraud). Violent offending was based on 45 incident codes pertaining to purely violent offences (e.g. violent theft, shooting, bombing) as well as sexual offences with a violent component (e.g. rape). In the validation analyses, the ProKid risk category classification was the independent variable. The dependent variables regarding violent and property offending were identical to the ones in the construction analyses.

Results

ProKid was based on logistic regression analyses which were conducted in two steps. In step 1, a logistic regression analysis was performed on the construction sample data to assess to what extent incidents in the five-year period before the index incident predicted whether or not youths were registered as a suspect of a violent or property offence during the four-year period after the index incident. In step 2, again a logistic regression analysis was conducted, but only the variables that had a significant effect on the outcome in step 1 were kept as predictors in the analysis. In step 2, the data were transposed into a person-period file in which each row contained the records of each month (108 rows in total per individual). This enabled us to use each month's incidents as a predictor of the next month's violent or property offences. In this step, versatility and offence frequency were included as additional predictors. The weights resulting from the final regression analysis were translated into an algorithm (i.e. regression equation) with which for each individual, on the basis of their past incidents, the chance of becoming registered as a suspect of a violent or property offence was computed. On the basis of these risk scores, boundaries were defined for six risk categories reflecting increasing risk (ranging from very low risk to very high risk). The mean predicted probability of the non-suspects was chosen as the upper boundary of the lowest risk category. On the basis of this value, initially an additional 20 categories were constructed with upper boundary values of, respectively, 1.1, 1.2, 1.3, 1.4, 1.5, etc., times the value of the upper boundary of the previous category. In the next step, the 21 categories were grouped into six risk categories. The guiding principle was to maximise the number of suspects in the higher risk categories and the number of non-suspects in the lower risk categories. Based on this principle, the very low risk category was specified to be comprised of category 1, the low risk category of categories 1-3, the low/moderate risk category of categories 4-7, the moderate risk category of categories 8-10, the high risk category of categories 11-15, and the very high risk category of categories 16-21.

Descriptive statistics

Table I shows the descriptive statistics for the youths in the validation sample. The table shows the numbers (and percentages) of youths in each ProKid risk category with a registration as a suspect of a violent and property offence across 1-4-year follow-up periods. Note that the same offenders can be represented across multiple columns. For example, an individual with an offence registration 2.5 years after the index incident is represented in the 3- and 4-year column.

First, the table shows that at the end of the 4-year follow-up period, 4,285 (10.7 per cent) and 4,640 (11.6 per cent) adolescents were registered as suspect of a violent and property offence, respectively. Second, the ProKid risk categories appear to differentiate well with regard to risk of becoming suspected of an offence. This was evidenced by the increasing proportions of

Table I Prevalence of violent and property offences within ProKid risk categories within 1-4 years after the index date

	Violent offences Length follow-up				*Property offences Length follow-up*			
Risk level	*1-year*	*2-years*	*3-years*	*4-years*	*1-year*	*2-years*	*3-years*	*4-years*
Very low	329 (1.1%)	563 (1.9%)	770 (2.5%)	979 (3.2%)	429 (1.4%)	677 (2.2%)	891 (3.0%)	1,073 (3.6%)
Low	116 (3.9%)	222 (7.5%)	318 (10.8%)	378 (12.8%)	149 (5.1%)	261 (9.0%)	367 (12.6%)	460 (15.8%)
Low/moderate	450 (10.8%)	742 (17.9%)	996 (24.0%)	1,189 (28.7%)	460 (10.8%)	727 (17.0%)	943 (22.1%)	1,138 (26.6%)
Moderate	433 (22.4%)	755 (39.0%)	980 (50.7%)	1,122 (58.0%)	533 (27.5%)	836 (43.2%)	1,060 (54.7%)	1,213 (62.6%)
High	267 (41.5%)	431 (67.0%)	505 (78.5%)	553 (86.0%)	304 (46.3%)	458 (69.7%)	541 (82.3%)	584 (88.9%)
Very high	38 (52.8%)	52 (72.2%)	60 (83.3%)	64 (88.9.8%)	113 (60.4%)	151 (80.7%)	165 (88.2%)	172 (92.0%)
Total	1,633 (4.1%)	2,765 (6.9%)	3,629 (9.0%)	4,285 (10.7%)	1,988 (5.0%)	3,110 (7.7%)	3,967 (9.9%)	4,640 (11.6%)

offenders within higher risk categories. This pattern was consistent across follow-up periods (1-4 years) and offence types (violent and property offences). For example, across the full four-year follow-up period, adolescents with very high risk levels are violent offenders 53 per cent more often than adolescents with moderate risk levels (i.e. 88.9 vs 58.0 per cent). Likewise, adolescents with very high risk levels were property offenders 47 per cent more often than adolescents with moderate risk levels (i.e. 92.0 vs 62.6 per cent), when considering the full four-year follow-up period.

Logistic regression analyses

Table II shows the results of logistic regression analyses in which violent and property offences during the validation period were predicted from ProKid risk levels. The odds ratios reflect the chance of being registered as a suspect of a violent and property crime, respectively, compared with the reference category (the very low risk category). The results clearly indicated that youths classified in the higher risk categories were significantly more likely to be registered as a suspect of an offence than youths in the very low risk category. This pattern was consistent across follow-up periods and type of offence. For example, youths with low risk scores were more than three times as likely than youths with very low risk scores to be suspected of a violent offence within one year after the index date (OR = 3.74). In the same column, it can be seen that across increasing risk levels, the odds ratios increased to 102.15, indicating that very high risk youths were more than 102 times more likely than the very low risk group to be suspected of a violent offence within one year after the index date.

Similar patterns of increasing odds ratios with increasing risk levels were found for property offences. For example, youths with low risk scores were more than three times as likely than youths with very low risk scores to be suspected of a property offence within one year after the index date (OR = 3.74). Youths with very high risk scores were more than 105 times as likely than youths with very low risk levels to be suspected of a property offence within one year after the index date (OR = 105.92). Values of Nagelkerke R^2 are also given in Table II. Although these values are not interpreted the same as an R^2 in a linear regression, they suggest increasing model fit with increasing lengths of the validation period.

Receiver operating characteristic (ROC) analyses

Tables III and IV show the results from ROC analyses for violent offences and property offences, respectively. An ROC analysis provides an area under the curve (AUC) value that indicates the instrument's sensitivity and specificity (Flores *et al.*, 2017). An AUC value of 0.5 indicates no ability to discriminate, while a value of 1.0 (or 0.0) indicates perfect separation of suspects from non-suspects. AUC values from 0.5 to 0.7 indicate low accuracy, from 0.7 to 0.8 indicate reasonable accuracy, from 0.8 to 0.9 indicate an accurate test, and above 0.9 indicate a very accurate test (Streiner and Cairney, 2007). The AUC has become the most commonly used

Table II Logistic regression results for predicting violent and property offences from ProKid risk levels

	Violent offences Length follow-up				*Property offences Length follow-up*			
Risk level	*1-year*	*2-years*	*3-years*	*4-years*	*1-year*	*2-years*	*3-years*	*4-years*
Low	3.74** (0.11)	4.31** (0.08)	4.64** (0.07)	4.41** (0.06)	3.74** (0.10)	4.30** (0.08)	4.75** (0.07)	5.09** (0.06)
Low/moderate	11.12** (0.08)	11.54** (0.06)	12.16** (0.05)	12.07** (0.05)	8.37** (0.07)	8.94** (0.06)	9.31** (0.05)	9.85** (0.05)
Moderate	26.37** (0.08)	33.94** (0.06)	39.53** (0.06)	41.52** (0.05)	26.33** (0.07)	33.10** (0.06)	39.74** (0.06)	45.46** (0.06)
High	64.90** (0.10)	107.74** (0.09)	140.81** (0.10)	184.64** (0.12)	59.74** (0.09)	100.32** (0.09)	153.34** (0.11)	217.06** (0.13)
Very high	102.15** (0.24)	137.78** (0.27)	192.39** (0.32)	240.40** (0.38)	105.92** (0.16)	182.83** (0.19)	246.59** (0.23)	311.12** (0.27)
Nagelkerke R^2	0.263	0.328	0.360	0.374	0.277	0.336	0.368	0.387

Notes: Odds ratios reported with standard errors in parentheses. Reference category is very low. $^{**}p \leqslant 0.01$

Table III Sensitivity, specificity, and AUC values for the various cutoff scores of ProKid: violent offences

	Length follow-up							
	1-year		*2-years*		*3-years*		*4-years*	
Cutoff score between	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*
Very low and low	0.799	0.81	**0.796**	**0.798**	**0.788**	**0.811**	**0.772**	**0.820**
Low and low/moderate	**0.727**	**0.854**	0.716	0.871	0.700	0.883	0.683	0.892
Low/moderate and moderate	0.452	0.950	0.448	0.962	0.426	0.970	0.406	0.975
Moderate and high	0.187	0.989	0.175	0.994	0.156	0.996	0.144	0.997
High and very high	0.023	0.999	0.019	0.999	0.017	1.000	0.015	1.000
AUC [95% CI]	0.828 [0.816, 0.840]		0.835 [0.826, 0.845]		0.835 [0.827, 0.844]		0.830 [0.822, 0.838]	

Notes: AUC, area under the curve; CI, confidence interval. The cutoff score with the highest Youden index is indicated in bold

Table IV Sensitivity, specificity, and AUC values for the various cutoff scores of ProKid: property offences

	Length follow-up							
	1-year		*2-years*		*3-years*		*4-years*	
Cutoff score between	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*
Very low and low	**0.784**	**0.780**	**0.782**	**0.797**	**0.775**	**0.810**	**0.769**	**0.820**
Low and low/moderate	0.709	0.852	0.698	0.868	0.683	0.880	0.670	0.892
Low/moderate and moderate	0.478	0.952	0.465	0.964	0.445	0.972	0.424	0.975
Moderate and high	0.210	0.989	0.196	0.994	0.178	0.999	0.163	0.997
High and very high	0.057	0.998	0.049	0.999	0.042	1.000	0.037	1.000
AUC [95% CI]	0.823 [0.812, 0.834]		0.829 [0.820, 0.838]		0.830 [0.822, 0.838]		0.829 [0.822, 0.837]	

Notes: AUC, area under the curve; CI, confidence interval. The cutoff score with the highest Youden index is indicated in bold

performance indicator to measure the predictive validity of structured risk assessments (Babchishin and Helmus, 2016; Rice and Harris, 2005).

It can be seen that the AUC values of ProKid ranged from 0.828 to 0.835 for violent offences and from 0.823 to 0.830 for property offences. These values indicate that the instrument discriminated very well between the risk groups, irrespective of the length of the follow-up period (1-4 years) or the offence type (violent and property offences). Also shown in Tables III and IV are the sensitivity and specificity for the various cutoff scores between the six ProKid risk categories. Sensitivity refers to the proportion of juveniles who have a registration as a suspect of an offence during the follow-up period and have a risk score in the particular category or higher. Specificity refers to the proportion of juveniles who do not have a registration as a suspect and have a score below the particular risk category. Cutoff values maximising sensitivity and specificity on the basis of the Youden index (Youden, 1950) are indicated in bold. In general, maximum sensitivity and specificity are obtained with ProKid when employing a cutoff between the very low and the low risk categories.

Discussion

The aim of the current study was to assess the predictive validity of the ProKid risk assessment tool. ProKid was developed on the basis of police records with the aim to provide police officers with a tool to perform an initial screening to identify youths at risk of future offending. Our findings indicated that higher ProKid risk levels regarding violent and property offences were associated with a greater likelihood of being registered as a suspect of a violent and property crime, respectively. Findings were consistent across follow-up periods of various lengths (1-4 years). ROC analyses of the violence and property models revealed AUC values between 0.828 and 0.835 and between 0.823 and 0.830, respectively. These values indicate good discriminative accuracy and compare favourably to most other actuarial risk assessment instruments (Fazel *et al.*, 2012; Schwalbe, 2007). The AUC values are also well above the lower bound of 0.70 as recommended by Swets (1988). Taken together, these findings suggest that ProKid is a powerful tool for assessing risk of future offences. Our findings also confirm that data concerning police contacts stored in the police database are an important source of information for identifying youths with elevated risk of delinquent behaviours (Assink, van der Put, Hoeve, de Vries, Stams and Oort, 2015; Assink *et al.*, 2016; Berk, 2012; Cocx, 2009; Francis *et al.*, 2007; van der Put, 2014).

ProKid should be used by police officers as a preliminary screening instrument in the first stage of risk assessment. On the basis of the results of the ROC analyses, it can be concluded that sensitivity and selectivity are maximised when employing a cutoff between the very low and low risk category. Assuming that sensitivity and selectivity are equally important, this suggests that the initial focus of prevention should be on youths scoring in the low risk category or higher. For these youths, it should be evaluated whether referral to more specialised youth care agencies for further assessment or treatment is necessary.

The current study has several limitations. First, the accuracy of an automated risk instrument depends on the quality of the registrations entered into the computer system. Although police professionals receive regular training aimed at improving registrations, we neither know to what extent the data on which the algorithms were based were accurate and complete, nor do we know to what extent the risk scores that eventually will be generated (i.e. when the instrument is implemented in the police computer system) are based on accurate registrations. The risk score generated by ProKid should therefore not be used as a single criterion, but as complementary to the professional judgment of police officers and other relevant professionals. Also, an authorised professional should manually inspect the youth's registrations in the police database to see whether an elevated risk score is justified.

Second, the sample used consisted of youths who were randomly selected from two police regions in the Netherlands. Although we included a relatively urban region (i.e. "Amsterdam-Amstelland") and a region with more rural areas ("Gelderland-Midden"), our findings may not fully generalise to other regions. We have no reason to believe, however, that the predictors of criminal behaviour and their relative importance will be very dissimilar across different regions in the Netherlands. Future research using a national police database, however, should further confirm the applicability of ProKid across Dutch police regions.

Third, it should be noted that important information necessary for predicting future offending is inevitably lacking from the police database. For example, the database does not contain information on all predictors relevant for criminal behaviour (e.g. truancy, mental health, cognitions). Such predictors could therefore not be included in the statistical model underlying ProKid. In addition, there may be a discrepancy between police registrations and actual offending. Data about official documented convictions could not be used because these are not registered in the Dutch police system. Furthermore, only information from the past five years is available in the police database due to restrictions stipulated in the Police Data Act regarding the length of time that data can be kept.

Fourth, ProKid provides an overall risk score regarding violent and property offending, respectively. Although the instrument does include dynamic risk factors in its predictive model, it does not provide a complete overview of changeable risk factors (criminogenic needs) which could serve as a starting points for intervention or treatment (Andrews and Bonta, 2010). Fourth-generation risk instruments which have recently been developed could be used for this purpose. In the Netherlands, two such instruments are available for police officers to assess care needs of non-offenders and offenders, respectively: The Youth Actuarial Care Needs Assessment Tool for Non-Offenders (Assink, van der Put, Oort and Stams, 2015) and the Youth Offender Care Needs Assessment Tool (Van der Put and Stams, 2013). These instruments could be used in conjunction with ProKid to provide a more comprehensive picture of a youth's risk and care needs.

Finally, the predictive model underlying ProKid was based on logistic regression analyses. A limitation of logistic regression analysis is that it is not adaptive and depends on the researcher to specify an effective model. For example, if important non-linearities or interaction effects are omitted, logistic regression will provide less accurate predictions. More adaptive procedures like machine learning techniques have recently been developed and applied successfully to forecast criminal behaviour (Berk and Bleich, 2013).

Notwithstanding these limitations, the present study showed that ProKid is a valid and accurate tool to identify youths with elevated risk of future violent and property offending. The automated assessment procedure enables police offers to perform a quick screening of large numbers of both non-offenders and offenders they come into contact with. Future research should confirm the generalisability of ProKid across Duth police regions. In addition, it could be explored what additional predictor variables could be retrieved from other databases, preferably in an automated way, to further improve the instrument's accuracy. Finally, additional models for other outcome variables may be developed and tested.

Note

1. Although ProKid was initially developed using a sample of youth aged 12-18 years, it was deemed desirable to test the utility of the algorithms in a population with a somewhat broader age range. Therefore, the validation sample included youth aged 7-22 years.

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