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The contribution of DNA databases for stored sexual crimes evidences in the central of Brazil



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ABSTRACT

Accumulation of sexual assault evidences unsubmitted to forensic DNA testing raises concern and it favors low rates of sexual crimes resolution. However, with the advent of DNA databases, these evidences have provided valuable information for investigations. In Brazil, the use of DNA databases is recent and few studies assessed their contribution to criminal resolution. In this regard, this study aimed to evaluate the potential of the DNA Database of Goias State, Central Brazil (BPG-SPTC/GO) in the resolution of sexual crimes without suspects through the insertion of profiles obtained from stored untested evidences collected between 2004 and 2018. Samples were submitted to DNA extraction by differential lysis, followed by the amplification of STR autosomal markers, capillary electrophoresis analysis in the ABI 3500 genetic analyzer and insertion in the BPG-SPTC/GO using CODIS 7 software. The rate of eligible samples for insertion and rates related to the obtained matches were evaluated. Statistical analyses were performed with Epi Info™ v.7 and BioEstat 5.0 software. A total of 275 samples were submitted to DNA testing, 202 out of them (73.5%) presented eligible profiles for insertion. A total of 176 (64%; 176/202) were inserted, one crime scene profile from each case. Overall, 60 hits were generated, all series sexual matches; a higher prevalence of forensic hits was detected (81.7%; 49/60) and a total of 32 criminal investigations were assisted (18.2%; 32/176). As the use of DNA databases in Brazil is recent and Brazilian criminal law has stringent requirements, our results reinforce that the use of DNA databases for stored sexual crimes evidences is a feasible forensic tool and that the increasing of the number of both types of profiles in DNA databases, evidences and criminals, causes positive reflects on the number of matches generated. However, further studies are necessary to evaluate if this effectiveness reflects positively on conviction rates of sexual crimes.

1. Introduction

Although applied technology in forensic genetics is increasing, a chronic concern remains regarding accumulation of sexual assault evidences unsubmitted to DNA testing [1–12]. Estimates for the year 2015 indicated that there were 200,000–400,000 sexual assault kits (SAKs) in United States (USA) police departments without genetic testing [3,13]. In Brazil, to date, there are no official surveys published to measure this demand, but a much larger number is expected due to the recent use of DNA databases for criminal investigation purposes [14,15]. Chronic scarcity of trained professionals, time and resources allow that SAKs remain stored indefinitely at police units [3,11,16].

Processing and submitting these evidences to forensic DNA typing were not considered important until recently. However, with the advent of DNA databases, these evidences became valuable sources of information for police investigations. DNA databases can be used to identify suspects by searching a crime scene profile against criminals' profiles in the database. Further, it may be used to determine if different crime scene profiles originate from the same individual [2,17–20].

DNA databases have been found to be useful in assisting the police to solve crimes such as rape, other sexual crimes, burglaries and violent assaults [21–23]. Due to the achieved results, the creation of these databases is highly defended and fostered [24]. Previous studies have

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demonstrated how their use is economically viable [9,19,25–27]. However, controversial results regarding the real effectiveness of DNA databases to decrease crime rates need to be further addressed [28]. In Brazil, only after law no.12,654/2012 this reality was admitted and despite the short time of operation many results have already been achieved [18,29].

Previous studies have addressed the processing of sexual violence evidences on a large scale to evaluate the rate of yielding profiles for database upload, the rate of matches achieved and identification of series aggressions. These studies demonstrated a high frequency of hits, with approximately 62% of the inserted samples, thus, elucidating previously unsolved investigations [1–3,5,6,30,31].

Considering that in Brazil the recent use of DNA databases was not evaluated and Brazilian criminal law has stringent requirements, this study aimed to evaluate the potential of a State database from Central Brazil (BPG-SPTC/GO) in the resolution of sexual crimes through the insertion of profiles obtained from stored and untested evidences related to sexual assaults without suspect.

2. Material and methods

2.1. Setting and samples

This study was conducted at Biology and Forensic DNA Laboratory, the local forensic lab (Leonardo Rodrigues Institute of Criminalistics, Goiânia, Goiás, Central Brazil - LBDF-SPTC/GO). It was approved by two Research Ethics Review Boards and certified by Brazil Platform for studies with human beings (Pontifical Catholic University of Goiás, under protocol nº70090317.9.3002.0034 and Dr. Anuar Auad Hospital for Tropical Diseases, under protocol nº 70090317.9.0000.0037). We performed an intentional sampling of sexual crimes that occurred in Goiás state (Central Brazil) between January 2004 and July 2018.

The following inclusion criteria were used to select samples for this study: (a) female victim; (b) tested positive for the presence of spermatozoa; (c) the police report contained information that attributed the sample directly to the offender (negative history of sexual intercourse in the previous three days before sexual assaul, vulnerability or appropriate history); (d) absence of investigation-related suspect (e) presence of reference sample of the victim and (f) untested to forensic DNA testing. These criteria were based on the requirements of the Brazilian Integrated Network of DNA Database (RIBPG) and the established protocols of the local forensic DNA lab (LBDF-SPTC/GO) [32].

2.2. DNA typing

DNA extraction was performed by differential lysis protocol, using the commercial PrepFiler Express[™] Forensic DNA Extraction kit (Applied Biosystems[®], California, USA), according to the manufacturer's recommendations and general standards issued by Brazilian Justice Ministry [33].

Quantification of DNA was performed by Real-Time PCR with TaqMan-type probe technology, using the Quantifiler[®] Trio DNA Quantification kit and the 7500 Real-Time PCR System (Applied Biosystems[®], California, USA), according to manufacturer's instructions. Data were analyzed in the HID Real-Time PCR Analysis Software Version 1.1.

The non-sperm fraction (NSF) and sperm fraction (SF) obtained from samples were amplified for twenty-one autosomal STR genetic markers, using the GlobalFiler [™] PCR Amplification kit (Applied Biosystems®, California, USA). Then, fragments analysis was performed by capillary electrophoresis in the ABI 3500® Genetic Analyzer (Applied Biosystems®, California, USA). The profiles obtained were analyzed with ABI 3500 Series Data Collection Software 3 and GeneMapper® ID-X (Applied Biosystems®, California, USA).

2.3. Insertion in DNA database and automated searches

The profiles were uploaded to the DNA Database of Goiás State (BPG-SPTC/GO) using CODIS 7 software (Washington, USA). Automated searches were performed weekly according to the legal protocols. The profiles obtained from the evidences were compared with each other and against profiles of criminals, at local (Goiás) and national level. All matches identified were automatically sent to the police laboratories involved and reports were sent to the investigating authorities [32].

2.4. Data analysis

DNA databases are continuously updated with new profiles that can match with one or more profiles previously inserted. We considered as 'one match' the genetic coincidence of two profiles (evidence versus evidence; evidence versus offender) per unit of time. A match between evidences is considered as a forensic hit and it is useful to identify serial aggressions or to indirectly identify the suspect when the evidence profile previously inserted in the database was already linked to an offender. A match between evidences and offenders is considered as an offender hit and it is useful for directly identification of the suspect.

For evaluation of sexual crimes recidivism (serial aggressions), we subclassified as a serial sexual match a forensic hit between evidences from different sexual assaults or an offender hit between evidence and a criminal previously convicted of sexual crimes. This subclassification was necessary to differentiate matches between sexual crimes profiles from matches between evidences and offenders related to other type of crimes.

A descriptive analysis of data was performed. Variables were compared using Chi-Square, Pearson and Spearman correlation tests with a significance level of 5%, after normality evaluation by the Kolmogorov-Smirnov test. Missing information was not considered in the statistical analyses. For correlation tests, the results were compared with the data provided by DNA Database of Goiás State (BPG-SPTC/GO).

3. Results and discussion

3.1. General findings

Until September 2018, the BPG-SPTC/GO database had a total of 765 profiles: 510 from evidences and 255 from criminals. Between January 2004 and July 2018, a total of 2165 cases of sexual assaults were registered in Goiás State with 2545 collected evidences testing positive for spermatozoa. Overall, a total of 214 cases with 275 related stored evidences fit the sampling criteria and were included for DNA analyses. Study sampling is demonstrated in Fig. 1.

From the 275 analyzed samples, 202 (74%) yielded DNA profiles eligible for upload to BPG-SPTC/GO DNA database, corresponding to 176 out of 214 cases of sexual assault (82%). Quality rate of DNA profiles obtained from crime scenes is usually presented in relation to the number of tested samples and not to the number of cases of sexual assaults [2,6,7]. A previous study involving DNA evidences typing from different types of crime demonstrated that about half of the analyzed cases presented eligible profiles for insertion in databases [34].

Lower rates of eligible DNA for database upload were presented by Campbell et al. (2016a) in a study with 894 sexual assault samples, out of which 419 (47%) were uploaded to the USA DNA database [2]. A lower rate of yield of quality samples was also described by Peterson et al. (2012) in a survey conducted in Los Angeles, with an insertion rate of 53% [6]. Compared to these previous studies, the high database upload rate observed in this research may be due to variations in the inclusion criteria, since samples that had previously tested positive for spermatozoa were prioritized, and differences in the criteria to qualify a profile for upload in the database may occur. When compared to the local forensic DNA laboratory (LBDF-SPTC/GO), we also noticed a



Fig. 1. Flowchart of the sample selection criteria and results.

higher rate of eligible DNA for database upload. This may be due to sample testing performed by chronological order and not to a previous screening of samples containing sperm [35].

Only one crime scene profile from each case was uploaded to the DNA database to avoid unequivocal matches between samples from the same case. Therefore, a total of 176 out of 202 DNA profiles were inserted and are referred as registered cases. Of the 176 inserted profiles, 32 (18%) generated 60 matches. So, 32 investigations were assisted with information about the suspect identity or the identification of serial sexual assaults assigned to the same individual. According to Brazilian protocols, one case is considered as an assisted investigation only one time after a match with a profile previously upload in the DNA database, even if more matches occur thereafter [32]. In this regard, the number of matches is usually higher than the number of cases or assisted investigations.

3.2. Number of matches per number of uploaded profiles

In the present study, of the 176 registered cases in BPG-SPTC/GO, 32 generated hits (18.2%), a total of 60 matches (Fig. 1). The high rate observed in this research may be attributed to the recurrence of sexual crimes (serial aggressors) and the fact that this research involves only sexual crimes without suspects. There are no similar studies in Brazil to compare this data, however, the last report of the Brazilian Integrated Network of DNA Database (RIBPG) demonstrated that 10.5% of evidence profiles registered in the Brazilian National DNA Database (BNPG) generated one or more matches during the total period of their stay in the DNA database [29,36]. This national average includes all types of evidences and represents an all-time percentage, representing therefore, a different kind of match rate.

Higher rates of matches per uploaded profiles was observed in similar international studies [2,6]. The lower rate of matches presented here reflects the early stage of Brazilian legislation about the use of DNA databases when compared to other countries such as the USA [14,17,37–39]. In fact, the USA National DNA Index System (NDIS) has more than seventeen million profiles, while Brazil has not yet reached the thousands [29]. As expected, previous studies demonstrated that higher numbers of uploaded profiles are positively associated with the number of matches [18,40,41]. Higher rates were also referred by the United Kingdom National DNA Database (NDNAD) in the last report, with a percentage above 60% in relation to the inserted samples that resulted in matches [21].

Therefore, it would be more prudent to compare the data of this work with studies developed in Brazil and that are related to RIBPG, however national studies with this approach do not exist yet. In Brazil, the Civil Police of the Federal District (PCDF) published in 2015 a

Table 1

Prevalence of matches according to the type of match within Brazilian DNA databases.

Type of match	h Frequency (n, %)	Frequency (n, %)			
	Current study (BPG- SPTC/GO)	Other local DNA databases (RIBPG and BNPG) ¹	p ²		
Forensic hit Offender hit Total	49 (81.67%) 11 (18.33%) 60 (100%)	427 (83.56%) 84 (16.44%) 511 (100%)	0.8496		

¹Data obtained from the VIII Report of the RIPBG [29]. ²Chi-square with Yates correction.

report about large-scale processing of sexual crimes samples using an in-house DNA database, without linking to RIBPG. They were able to identify 78 serial sexual offenders who had assaulted 223 women [20].

The small sample size is a study limitation. It is important to emphasize that the amount of matches obtained in this study may have been underestimated because it was not possible to process all selected cases and due to inclusion criteria; cases with potential to generate matches were not included in the study (remaining kinds of evidences, like SAKs without sperm).

3.3. Prevalence of matches

The prevalence of forensic hits (evidence versus evidence) was 81.7% (49 out of 60) and the prevalence of offender hit (evidence versus offenders) was 18.3% (11 out of 60), with significant difference between both categories (Table 1).

This result is similar to the national scenario (p = 0.8496) and reflects the recent use of DNA databases in Brazil, once it is expected to occur a higher number of forensic hits than offender hits (Table 1. It's occurs because the routine of Brazilians forensic DNA labs favors the insertion of profiles obtained from evidences, since they usually analyses cases confronting evidences with suspects, and these not usually can be uploaded as reference sample offender into DNA databases. Besides that, there is a small number of offenders' profiles in the DNA databases of Brazilian states, what may be explained by: the recency and constitutionality discussions of federal law no. 12,654/2012 [14,42]; the lack of functional integrated actions among forensic departments, the penitentiary administration and the judiciary; the low criminal punishment and scarcity of resources and professionals [3].

However, strengthening policies to promote national public security are already being developed, optimizing the link between public agents and providing the needed resources and technologies for the Brazilians forensic laboratories [43]. With these actions, it is expected an increase in the number of offender hits in the Brazilian scenario. In countries where a consolidated use of DNA databases occurs, similar studies shows a predominance of matches with direct authorship (offender hit) [2,6,23], a situation that is antagonistic to that of the Brazilian reality (Table 2). This is also observed in the official reports of DNA databases of other countries [21,23,37]. As an example, in Canada, in the last year, approximately 90% of the hits were offender hits [23].

According to the location of matches occurrence, a higher

Table 2	
Prevalence of matches according to the type of match w	within different studies

Survey	Matches (n)	Type of matches (%)
Current study (BPG-SPTC/GO)	60	49 forensic hits (81.7%) 11 offender hits (18.3%)
Peterson et al, 2012 [6]	347	347 offender hits (100.0%)
Campbell et al, 2016 [2]	259	244 offender hits (94.0%) 15 forensic hits (6.0%)

concentration of hits was observed within the state of Goiás (71.7%) rather than national (28.3%), with a significant difference (p < 0.0001). There is a congruence (p = 0.3595) with what is observed among others local DNA databases in Brazil, with a higher incidence of matches within their coverage (62.6%), despite having national matches (37.4%) [29].

However, the occurrence of national matches is expected for crimes occurred involving Goiás States, since it has a central position in the Brazilian territory [44,45]. In this way, the interstate displacement of criminals occurs; a situation that, without the performance of DNA databases could never be solved.

The habituality of recurrence of sexual crimes already described in the literature [11,46,47] was also observed in this study. All matches obtained were subclassified into series sexual hits, i.e., all forensic hits occurred between evidences of sexual assaults. In the same way, in all offender hits, the offender involved was already convicted to sexual assaults. The recurrence observed in sexual crimes reaffirms the importance of the use of DNA databases and reflects the non-application of punishment to the criminals, who, continue to incur crime.

3.4. Correlation between uploaded profiles and occurrence of matches

Despite the possible underestimation of the number of matches in this project, a very strong positive association (r = 0.9542) was observed, with a significant difference (p < 0.05) between the increase in the number of profiles uploaded and the number of matches generated (Table 3).

Ideally, in order to evaluate the correlation between the increase of profiles yielded from sexual crimes evidences in the local DNA database (BPG-SPTC/GO) with the increase of generated matches, alterations in the quantity of profiles should occur only in consequence of addition of cases selected and processed in this study. However, as the DNA database is used as part of the laboratory routine it was not possible to isolate other variables, such as the insertion of evidences profiles related to other criminal types and offenders that could have contributed to the increase in the number of matches.

In addition, when considering the use of DNA databases as a tool for criminal resolution, the interfering variables in the quantity and nature of the profiles inserted as well as the scenario of the public security system must be considered. Those can be measured and analyzed statistically, but these involve political and legal aspects [24]. Despite this, the correlation results were not affected by the variations in the quantity of profiles associated with other types of crime and with criminals, since all the obtained matches involved only the study processed samples or samples and offenders uploaded in the DNA database before the study period.

The probability of obtaining matches when registering a profile of evidences related to crimes that have not yet been solved is directly proportional to the number of profiles of criminals and evidences already inserted in the database, that is, the greater the number of profiles registered, the greater the possibility of occurrence of new matches [18,40,41]. In this way, it is always necessary to increase the number of profiles registered in the DNA databases, in order to generate positive Table 4

Num	ber	of	match	ıes	and	profiles	; in	the	national	context.	
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State	Number of matches ¹	Number of profiles ¹	<i>r</i> ²	p^2
São Paulo	133	2428	0.4805	0.0319
Polícia Federal	128	1837		
Goiás	51	635		
Paraná	37	679		
Paraíba	23	366		
Rio Grande do Sul	16	1178		
Minas Gerais	16	1141		
Amazonas	12	131		
Mato Grosso do Sul	10	335		
Mato Grosso	6	148		
Bahia	4	222		
Pará	4	748		
Distrito Federal	3	509		
Amapá	2	131		
Santa Catarina	2	275		
Pernambuco	1	366		
Rio de Janeiro	0	510		
Maranhão	0	477		
Ceará	0	451		
Espírito Santo	0	237		

¹Data obtained from the VIII Report of the RIPBG [29].

²Spearman's correlation; variables without normal distribution.

reflexes in the amount of hits.

However, although the number of profiles registered in the databases generate positive effects in the recognition of matches, other aspects should be considered. A DNA database that presents only profiles of criminals will not have matches and, consequently, will not offer aid to the criminal investigations. Likewise, a DNA database that presents a higher number of evidences profiles, will present matches that allow the perception of serial crimes, information that is valuable for the investigations, although still without identification of the criminal.

These interfering conditions can be observed in the Brazilian scenario, in which states without an expressive number of profiles registered, present a high frequency of matches and assisted investigations. This is the case of Goiás State, which ranks in the seventh position in the number of profiles registered and in the third position in the ranking of matches and assisted investigations (Table 4) [29]. This explains why in the national context, despite a positive linear correlation between the number of profiles and the number of matches identified, this correlation is moderate (r = 0.4805 and p < 0.05) (Table 4).

Thus, in order to optimize the number of matches and, consequently, information for police investigations, it is necessary to increase the profiles' registration into DNA databases, but this increase must be linked to a greater variability of profiles inserted. In the context of these analyzes, the Brazilian Justice Ministry is developing incentive actions, and two national projects are already underway to strengthen the insertion of profiles related to criminals and sexual evidences that remains untested for forensic DNA typing [43,48,49].

Table 3

Correlation between the number of uploaded profiles and the number of matches during the study period.

	Number of profiles associated with sexual crimes (n) $^{\rm 2}$	Number of matches of sexual crimes (n) $^{\rm 2}$	r ³	p^3
May, 2017	160	35	0.9542	0.0458
November, 2017	260	36		
May, 2018	374	64		
September, 2018	487	96		

May and November: months of the regularly publication of RIBG's reports.

¹The research was developed between May 2017 and September 2018.

²Data available by BPG-SPTC/GO.

³Pearson's correlation; variables present normal distribution.

4. Conclusions

This study demonstrates that the use of a DNA database for untested stored evidences is a powerful tool for elucidating sex crimes without suspects, though some controversial results remain regarding its effectiveness. Besides that, the results reaffirm that the increasing of the number of profiles in DNA databases is associated with increased numbers of matches generated, but this increasing must include both types of profiles, evidences and criminals.

In Brazil, the use of DNA databases is available for less than a decade and there is a lack of studies evaluating its effectiveness in a national context. Besides that, discussions about economic viability and Brazilian criminal law may disturb the growth of this tool. So, it's important to reinforce that the use of DNA databases for stored sexual crimes evidences is a feasible forensic tool, even more because others policing investigative tools are usually not available (like fingerprints and witness statements). However, further studies are necessary to evaluate if this effectiveness reflects positively on conviction rates of sexual crimes.

Declaration of Competing Interest

The authors have none conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.fsigen.2020.102235.

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