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REVIEW

Suspects identification through ''familial searching'' in DNA databases of criminal interest. Social, ethical and scientific implications☆

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Abstract In recent years, DNA technology has revolutionised forensic science, becoming an invaluable tool in the investigation and forensic identification processes. Moreover, the creation of DNA databases has allowed to efficiently link people and crime scenes.

Familial searching is an important strategy for establishing family relationships between the genetic profile at the centre of the investigation, found at the crime scene, and any family members who might be in the database. This identification of potential relatives can lead to identification of the unknown person and the crime being solved.

In the legal, social, ethical and scientific fields, this investigation strategy has both promoters and detractors regarding the effectiveness of its use. This article aims to review all these aspects and provide an overview of the current situation.

PALABRAS CLAVE
Búsqueda familiar;
Base de datos de ADN;
Interés criminal;
Implicaciones

Identificación de sospechosos a través de búsquedas familiares en la base de datos de ADN de interés criminal. Implicaciones sociales, éticas y científicas

Resumen El uso de la tecnología del ADN ha revolucionado la ciencia forense en los últimos años, convirtiéndose en una herramienta de incalculable valor en los procesos de investigación e identificación forense. Además, la creación de bases de datos de perfiles genéticos de ADN ha permitido relacionar de manera eficiente personas y escenas del delito.

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La búsqueda familiar es una estrategia importante que permite establecer relaciones familiares entre el perfil genético hallado en la escena del delito, y objeto de la investigación, y eventuales familiares que pudieran encontrarse en dicha base de datos. Esta identificación de potenciales familiares puede permitir la identificación de la persona desconocida y la resolución del hecho delictivo.

Esta estrategia de investigación cuenta con impulsores y detractores en relación con su utilización en el ámbito legal, social, ético y científico. El presente artículo revisa todos estos aspectos y aporta una visión general de la situación actual.

Introduction

Research into deoxyribonucleic acid (DNA) genetic polymorphisms has revolutionised the Forensic Sciences and, in particular, Criminology. The possibility of including genetic profiles obtained from samples found at the scene of the crime or on the victim's body in police DNA databases, as well as those of individuals that could be connected to the events, make the DNA database a very powerful tool in criminal research.

Various countries have implemented search mechanisms in their police DNA databases in order to increase the efficiency of the same. Some of these strategies are based on the genetic similarity existing between relatives, which increases in line with the degree of kinship between them. This methodology is the one used to search for missing persons in social databases, where the aim is to use the same tool to establish kinship between the donor of the biological evidence found at the scene of the events and a potential relative that might be registered in the police (rather than social) database. As such, if there is no match in the DNA database between the genetic profile from the corresponding biological evidence under investigation and the other profiles entered in the database, why not use the genetic similarity between relatives as another search strategy in criminal databases?

This type of strategy is known as familial searching. The aim is to seek partial matches between the genetic profiles being investigated and those in the database, with a view to establish kinship relationships between the donor of the evidence in question and the existing database profiles (Fig. 1).

In its annual report for 2012,[1] the Spanish National Commission for the Forensic Use of DNA distinguishes between two different types of familial searches:

- Direct familial search: a search for the donor of the anonymous criminal evidence recorded in the DNA database by comparing the DNA profile of the evidence to the DNA profile of the accused individuals, using a familial search algorithm or markers that do not allow for the genetic distinction of certain members within the same familial group.
- Indirect familial search: a search for individuals who are genetically related to the donor of the anonymous criminal evidence.

The use of familial searching for criminal investigation purposes has its pros and cons from the legal standpoint, with supporters and critics in both the legal and scientific spheres, and various options and criteria that some countries have provided for by means of legislation. This article seeks to review these aspects, fundamentally those related to indirect familial searching, and to provide an overview of the current situation.

Genetic inheritance and search strategies in DNA genetic profile databases

The individual's genetic inheritance is found mainly in the cell nucleus (99%), where it is condensed and packed, giving rise to chromosomes. The human species contains 23 pairs of chromosomes: 22 pairs of autosomes and one pair of sex chromosomes, each one coming from the components of one progenitor's pairs. An individual's sex is defined by the X and Y sex chromosomes, in the sense that in women this pair will be XX and in men it will be XY. Each male transmits his Y chromosome to his sons in an almost invariable way, hence all the male members of the same paternal lineage will share an identical Y chromosome.

Moreover, the remaining 1% of the genetic material is located in cytoplasmic organelles called mitochondria, which give their name to the DNA they contain: mitochondrial DNA (mtDNA). This type of DNA is transmitted entirely and exclusively from mother to child, which means that, as with Y-chromosome inheritance, individuals who are related on their mother's side will share the same mtDNA.

The searches run in most of the world's DNA databases do not routinely include comparisons with Y-chromosome markers and/or mtDNA, which a priori should help to establish a paternal and/or maternal kinship relationship.

The short tandem repeat markers located in autosomal DNA are the preferred search tools in DNA databases around the world. These markers are based on Mendelian

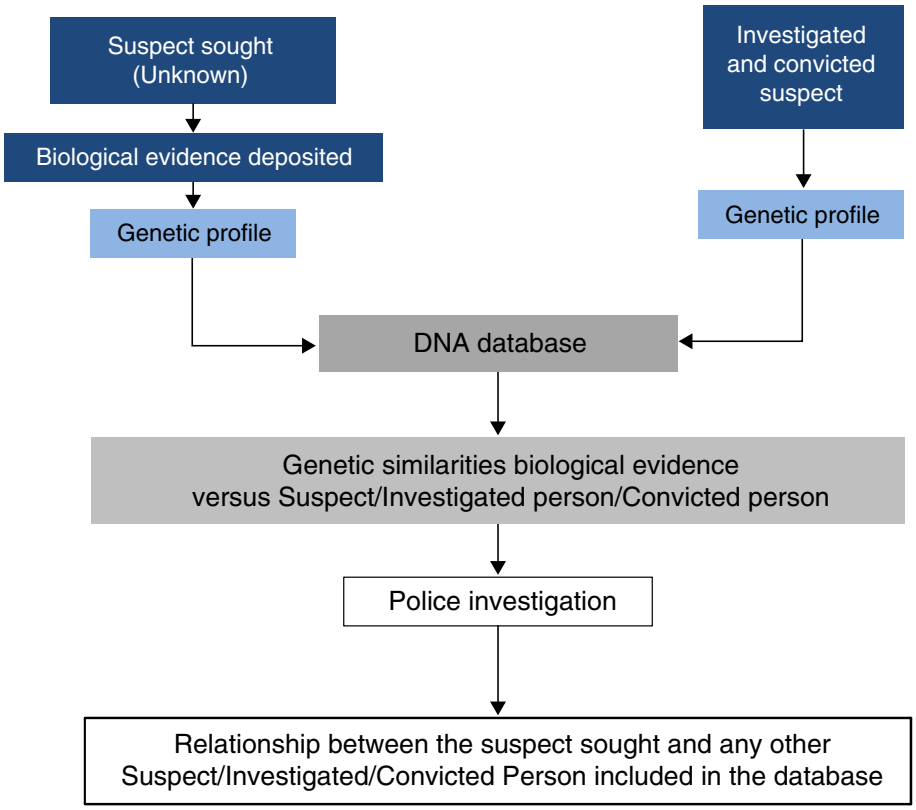

Figure 1 Familial search process diagram. The DNA profile database is fed simultaneously with the genetic profiles obtained from the biological evidence found on the victim's body or at the crime scene and those of suspects, convicts or the people accused of offences in which the legislation, depending on the country, permits their inclusion in the database. Based on different strategies and criteria, the database search algorithm establishes genetic similarities between the profiles included in the database. The ''candidate'' similarities are then investigated with a view to establish a real match.

inheritance patterns, where each one of the marker's alleles is transmitted by the progenitor. On this basis, and given a genetic profile of interest, we can establish a classification of the genetic profiles existing in the database based on the greater or lesser number of alleles that they share, and therefore establish a similarity ranking.

Normally, the method used (Fig. 2 provides a simplified and fictitious example) consists of searching for matches in a large number of alleles, although obviously a greater number of matches will appear in the most frequent alleles among the population. As such, we can direct the search towards the less frequent alleles – those which normally, in view of their scarcity, yield scant investigational success in terms of results. Other search strategies are geared towards using mathematical algorithms that calculate kinship relationships (likelihood ratio [LR]: how often a kinship relationship is more or less probable between two genetic profiles than a non-kinship relationship). This strategy seems to be the better one, as it combines the search for rare alleles and the number of shared alleles.[2,3]

Thus, for example, using the New Zealand DNA database, based on parent-child simulations,[4] and that of Switzerland, based on sibling–sibling simulations,[5] has shown that, as a search strategy, classification by kinship indices is preferable to searching by the number of shared alleles.

As a result of these searches, a list of possible kinships is established between the donor of the sample under investigation and the known samples contained in the database. Subsequently, the police should carry out their investigations using the list of potential persons of interest obtained with a view to solve the crime committed.

The 2014 recommendations of the Scientific Working Group on DNA Analysis Methods, on familial searches,[6] established that, as a method of comparison, the kinship index was preferable to the number of shared alleles.

Arguments in favour of and against the use of familial searching

Arguments in favour

- The genetic profiles of close relatives are more similar than genetic profiles chosen at random from the population. Children receive their parents' genetic information, half from each one of them. There is no fixed value for the genetic information shared by two siblings, although, on average, it stands at just above 50%.[7]
- Familial searching is a useful tool in police investigations, increasing the expectations of success in solving crimes.

Genetic marker	Genetic profile at crime scene
D3S1358	15.16
VWA	17.18
D16S539	9.13
CSF1PO	10.11
TPOX	8.11
D8S1179	15.17

Simplified example of a genetic profile to illustrate the search criteria in the table below. Allele 17 of the D8S1179 marker presents a frequency <1% in the population

Search strategy		Database search on known profiles* that:
A	Number of concordant alleles	Match at least 7 of the 12 alleles contained in the questioned profile**
B	Alleles with low frequencies	Have allele 17 of the D8S1179 marker
C	Establish a LR threshold value	Have a LR >100 for a given kinship relationship (parent-child/sibling-sibling)
D	Establish a ranking of LR values	Have a greater LR (100 profiles) for a given kinship relationship

(*) Profile of suspects, detainees or investigated or convicted persons
(**) Profile from the evidence found at the scene of the events

A Establish a number of matching alleles between the known and questioned profiles.

B Determine the allele(s) that is/are less frequent in the profile from the scene of the events, and based on this, look for profiles in the database that present this allele.

C Establish the search for a given type of kinship between the questioned and known profiles included in the database, and, based on this, investigate the ones that offer LR values of over 100 (for example)

D Establish the search for a given type of kinship between the questioned and the known profiles included in the database, and, based on this, investigate the 100 (for example) relationships with a higher LR value.

Figure 2 Simplified fictitious example regarding different familial searching strategies in the DNA genetic profile database. LR: likelihood ratio.

- It allows for the creation of new lines of investigation when others have been ruled out.
- From the criminological standpoint, there are studies that show that antisocial parents are more likely to have antisocial children because they live together in the same economic and social setting.[8,9] The United States Department of Justice expressed a similar idea when in 1999 it asserted that 46% of the country's prison population said they had a close relative who had also spent time behind bars.

- Several studies highlight that criminality may be partially associated with a particular socioeconomic level, and that economically underprivileged relatives tend to live in nearby geographical areas. Moreover, delinquents normally perpetrate their offences in areas close to where they live.[10–13]

Arguments against

Several, primarily ethical issues must be taken into account when considering this type of investigation[14]:

- This type of investigation requires a great deal of time and economic effort, and in the majority of cases it will not lead to the identification of the perpetrator of the offence or crime. As such, all the effort involved could have been put to traditional lines of investigation.[15]
- Violation of the privacy of the person appearing in the DNA database on revealing to relatives that a member of their family is included in said database.
- With the use of this investigational technique, an individual whose genetic profile is listed in a database exposes his/her relatives to scrutiny without their knowledge or consent.
- Statistically speaking, certain groups (ethnic, social class, etc.) have higher rates of individuals arrested and/or incarcerated for committing crimes. Said groups will thus be overrepresented in the criminal database, which would lead to a high percentage of certain groups being greatly scrutinised, thus giving rise to an increase in racial discrimination and social inequality, etc.[16]
- The abuse of information obtained by means of familial searching may constitute the harassment of innocent people or of the delinquent's relatives, who may feel ashamed that their names appear as potential candidates for investigation, and could even cause family rifts.
- Concealed family information may be revealed (adoption, incest, adultery, illegitimate children, etc.).
- Depending on the legal code of the different countries involved, victims may or may not be included in databases. In countries where they are included, victims may feel more reluctant to report offences if they realise that their genetic profiles could be used to incriminate their own relatives in other offences.
- The absence, up to now, of both legal standards and operating procedures for using this type of search.
- There is a risk of a distant relative being identified in the database search as a first-degree relative (father/mother, son/daughter and siblings), which may give rise to errors and delays in the police investigation.[17]
- In order for familial searches to be effective, DNA databases with a high number of genetic profiles are required.[18]

International legislation

This section will provide an overview of the familial searching situation in various countries, mainly focusing on English-speaking nations, the different legislations of which include the possibility (and the conditions applicable) of performing such familial searches on criminal DNA databases. In Europe, this investigation tool is primarily used in Great Britain and the Netherlands. In other countries located in close proximity to Spain, familial searching is either not used due to the scant development of their DNA databases (Portugal[19] and Italy[19]), or because these countries lack specific legislation in this regard, rendering the use of the tool very sporadic (France).

Netherlands

Dutch legislation (2012)[20] only permits the use of familial searching for the investigation of offences that entail prison sentences of 8 years or more, and as a last resort in the investigation, i.e. when there are no other clues or suspects to follow up (Section 151da). The Dutch system does not impose a minimum number of genetic markers or matching alleles, and is based on establishing a minimum threshold of kinship.

Great Britain

There is no specific legislation that orders or allows the police or forensic community to use the familial searching technique in the national databases. Prior to the use thereof by the team of investigators, the permission of the DNA database controllers must be requested. This request must be approved, after which point, a match of at least 11 of 20 of the analysed alleles is established and the suspects are subsequently classified based on their kinship indices and other information (age, Y chromosome, place of residence, etc.). Since the technique was implemented in 2002, more than 200 investigations have been conducted, assisting in the resolution of about 40 criminal cases (data from 2012).[18]

United States

While there is no national legislation, familial searching *is* provided for in the federal legislation. The FBI makes a distinction between a ''partial match'', which would be the spontaneous identification of a suspect based on a search in the database, due to there being a match in a large number of alleles between the suspect's genetic profile and the one located in the database, and a ''familial search'', which would be a deliberate identification in the database with a view to identify potential candidates who were close relatives of the unknown genetic profile associated with crime scene. According to this distinction, most states perform partial matches, while only a few have specific regulations for the case of familial searching.

In California,[21] the use thereof is only authorised in case of violent crimes that imply a high risk to public safety and when no further information can be obtained from the remaining clues in the case under investigation. A match of at least 15 alleles is needed, along with an investigation of the 168 genetic profiles that have yielded the highest kinship index (parent–child and sibling–sibling). Subsequent confirmation is performed using Y-chromosome markers, with three ethnic groups being taken into account: African-Americans, Caucasians and southwestern Hispanics. This investigation tool was first used in October 2008 and 10

investigations have been performed to date, enabling the resolution of one criminal case.

In Colorado,[22] familial searching is authorised in cases where no direct matches are obtained with the DNA database, while in Virginia[22] the use thereof has been authorised by law since March 2011 in unsolved violent crimes, albeit only as a last-resort investigation tool and provided there is serious concern for public safety.

In Maryland and Washington DC,[22] on the other hand, the use of familial searching is prohibited. In Washington, the law expressly states that such searches cannot be performed on the state-wide DNA database for the purpose of identifying a delinquent in relation to an offence in which the delinquent is a biological relative of the person from whom the DNA sample has been taken. Other states which do not perform partial matches or familial searching, despite there being no specific law on the same, are Alaska, Nevada, Utah, New Mexico, Michigan, Vermont, Massachusetts and Georgia.[17]

Minnesota, Pennsylvania and Tennessee are reviewing the matter in order to decide whether or not to include it in their respective legislations.[17]

Canada

Canadian legislation does not permit this type of investigation.[23]

Australia and New Zealand

In Australia, there is no specific legislation that permits or prohibits this type of search strategy. However, there is a perception that familial searching constitutes something other than the purpose for which DNA databases were originally conceived.[24]

In New Zealand, familial searching has been used as a last-resort tool for solving criminal cases on at least 38 occasions (data from 2010),[18] the first of which was in 2004.

Successful searches

Throughout this section, we will present a series of cases where familial searching in criminal DNA databases has enabled the resolution of the events being investigated, leading to the arrest and prosecution of the presumed culprits. By way of example, to demonstrate the investigation tool's potential, we have gathered several cases that received major exposure in the media, particularly in countries with specific legislation regulating this question.

England

An individual tossed a brick from a motorway bridge that broke the windscreen of a vehicle and hit the driver in the chest, who died following a heart attack. Before this incident, the person who threw the brick had attempted to steal a car, leaving blood remains which, following analysis, matched the DNA on the brick. While the subject's genetic profile was not in the database, it was highly similar to a relative of the suspect who was present in the database, thus putting the police on his trail. After he was arrested and his DNA had been analysed, a complete match was obtained between the subject's genetic profile and the DNA located both in the stolen car and on the brick. The suspect admitted his involvement in the events and was sentenced to 6 years in jail. This case was the first successful familial search of the English DNA database.[25]

United States

A serial killer nicknamed the ''Grim Sleeper'' was thought to be behind the deaths of at least 10 young women in south Los Angeles dating back to the mid 1980s. A search for his genetic profile in the database came back negative in 2008, but a new search in April 2010 returned a partial match with the genetic profile of a person who had been arrested for a firearms-related offence. This led the police to suspect that the person could be the serial killer's father. After his son had been located, and using a piece of pizza discarded by the latter, a full match with the genetic profile located at the different crime scenes was confirmed, leading to the killer's arrest.[26]

Netherlands

Following a series of sexual assaults committed by the same individual in Utrecht between 2013 and 2014, a genetic profile was obtained, although said profile was not present in the country's criminal DNA database. In view of the social repercussion, a familial search of the database was authorised, yielding a total of 26 individuals to be investigated based on their kinship indices. A profile with a kinship index (sibling-sibling) of about 5 million (a match of 25 of 40 autosomal alleles and a single difference in mtDNA and Y-chromosome markers) caught the investigators' attention. This individual was investigated, leading to the identification of one of his siblings, who had a police record of sexual assaulting a female. This prompted his arrest and the sampling and analysis of his DNA, where a total match was confirmed between his genetic profile and the profile obtained from the Utrecht sexual assaults. The individual was sentenced to 6 years in prison.[27]

France

In 2002, there was a case of rape and murder in north Paris. The genetic profile obtained from the semen samples was not recorded in the French database or any other European database. The case went unsolved until 2011, when a familial search of the French database was authorised (French legislation authorises familial searching for the identification of cadaveric remains but makes no reference to criminal investigations). At the time, the database contained 1,800,000 genetic profiles (3% of the French population) and yielded an allele compatibility (a match of at least one allele per marker) for 18 autosomal markers and a total match in Y-chromosome markers. This individual's family, who came from and lived near the place of the crime, was investigated. The father and one of the siblings were ruled out due to age and the only other possible familial

candidate had died shortly after the offence. An authorisation was requested to exhume his cadaver, and an analysis demonstrated that his genetic profile was a perfect match for the semen found at the scene of the crime 10 years previously.[28]

New Zealand

In February 2001, a hairdresser (Marie Jamieson) was raped and murdered in Auckland. Semen remains were found on her underwear, although the genetic profile yielded no match when it was compared to the DNA database.

One year later, Anneke Bishop was arrested for reckless driving and a sample of her DNA was taken and added to the database. In 2008, the police obtained an authorisation to carry out a familial search of the database in connection with the Marie Jamieson case, which generated a list of 49 individuals who were potential relatives of the genetic profile found on the victim's underwear. Anneke Bishop was the first person on the list. The LR obtained for one of her siblings was greater than 1,500,000. After several investigations, the police discovered that she had a brother with an extensive police record that included sexual assault and rape. Finally, in 2008, the brother was arrested for robbery at a supermarket and a sample of his DNA matched the one found at the scene of Marie Jamieson's murder. He was found guilty and sentenced to life imprisonment, with a minimum term of 15 years and no possibility of parole.[29]

The situation in Spain

Spanish legislation[30] does not provide for the possibility of familial searching in police DNA databases. However, in 2012, the National Commission for the Forensic Use of DNA produced a technical report which, on the basis of different examples of its application in real cases, as well as legislative experience on the matter in various countries, concluded that familial searching may be a valuable instrument in ascertaining criminal evidence, provided that other investigational channels have been exhausted and that said investigation tool is used with the following guarantees to ensure that the impact on rights is minimal[1]:

- It is only an investigation tool and must not be used as conclusive evidence of culpability.
- It must only be used in serious crimes (such as serial killings or violent crimes).
- Express authorisation is required (judicial or public prosecutor).
- It will be used for evidence that has not yielded any matches in the database and for cases in which all other lines of investigation have been exhausted.
- The DNA profile of the evidence must be complete and there must be sufficient material to be able to perform additional analyses.
- Compatibilities through autosomal short tandem repeats must be completed with Y-chromosome short tandem repeats and/or mtDNA analyses.
- The likelihood value of the compatibility must be high.
- There is an exhaustive review on the DNA data and all of the investigation data before the details of the people who are compatible with the evidence are made public and before said individuals are investigated.

Conclusions and future

This review indicates the usefulness of familial searches using police DNA databases. However, attitudes differ with respect to the matter. On the one hand, there are those against the use of such practices, either because they may give rise to guilt by association and racial discrimination, or because they could violate constitutional rights in the various legislations and/or in a broad sense, because they constitute a deviation from the initial purpose of databases, which was to use a person's DNA with the sole aim of identifying them.[15,31] Another view advocates a more widespread application: if we already have databases with a high number of genetic profiles and if familial searching can be used, the next step could be the creation of universal DNA databases, i.e. the profiling of a country's entire population.[32] Finally, there is another body of opinion that is in favour of allowing familial searches, albeit with strict legal regulation.[33,34]

In light of the foregoing, a clear legal regulation on this matter would be advisable, providing for, among other questions:

- The possibility or not of performing this type of familial investigation and, if such a possibility is accepted, the types of offences (murder, sexual assault, etc.) it could be used for must be clearly established.
- Whether these investigations could be performed with all the people appearing in the database or a distinction would be made between suspects, detainees, convicts, etc.
- The establishment that the object of the analysis would be the genetic profiles existing in the database, in accordance with certain scientific criteria (shared alleles, LR scales obtained, etc.), and subsequently, with a view to refine the search among the selected candidates, considerations such as ethnicity, age and other possible demographic information could be taken into account, and not the other way round.
- That since a familial search will yield candidates to be investigated, and that the majority of them (if not all of them) will ultimately be regarded as unsuitable candidates for the familial search to be investigated, the people who might have access to the findings of a familial search must be clearly defined in order to safeguard the privacy of those individuals with no bearing on the offence under investigation. Moreover, the people who have access to this information should have specialised training.
- The need or not to establish a deadline for solving the case by means of this investigation tool and, in any event, the need to take a new sample and to perform a genetic analysis on the identified suspect using familial search in order to confirm the exact match between a genetic profile and the profile found at the crime scene.
- The necessary factors in order to proceed with the arrest of a suspect following the investigation of relatives in the database (it should be remembered that this search can

only be used to complement other lines of police investigation, and is not an end in itself) and the use of this information in the Courts of Law.

All these questions must be broadly debated in the legal and scientific sphere, taking into account criminological studies, the technique's statistical potential and questions related to social freedoms, while always striking a balance between the freedom, personal privacy and interests of the individuals affected on the one hand, and public safety, the common good and the resolution and clarification of different criminal offences, on the other.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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