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Aiding the interpretation of forensic gait analysis: Development of a features of gait database

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1. Introduction

Forensic gait analysis is the use of gait and features of gait to assist in the process of identification, and it has now been presented in court for this purpose for 15 years [1]. Based on the experience of the authors and their colleagues, its use has increased during the last five years, with many police forces now considering forensic gait analysis as a forensic option, particularly with major crimes. Gait is the manner or style in which a locomotor activity, such as walking or running, is undertaken [2]. A person's gait is the result of a complex interaction of their anatomy, physiology, and in particular their neurology, pathology and injury, and represents a series of alterations, or compensations, to a basic pattern of movement necessitated by the individualities of the person. The resultant gait is then potentially further affected by additional intrinsic factors such as emotions and extrinsic factors such as footwear, terrain and the proximity of other individuals [3–6]. While gait is widely considered to be unique, its uniqueness is at a level that requires accurate and precise measurement of both kinetic and kinematic factors [7–9]. Current forensic gait analysis practice usually relies on the identification of features of gait from closed circuit television (CCTV) footage. This footage is often of poor quality in terms of resolution, lighting and frame rate, and is therefore limited in terms of the information it can provide [10]. It is also a two dimensional record of a three dimensional activity and incapable of yielding kinetic data. As a result forensic gait analysis as currently practiced is not capable of identifying a person. The features of gait that can be identified are class level features, that is to say features that occur in a proportion of the population, and therefore demonstrate compatibility rather than uniqueness. A fundamental skill of a forensic gait analyst is therefore an understanding of the prevalence of the features of gait identified in the population. To date this judgment has been based on past experience gained from sources such as past casework, clinical practice, text books, and published case studies and research papers [11–13]. Information gained from clinical practice requires careful consideration and use. If the practitioner is a specialist in musculoskeletal conditions, it may be expected that the majority of patients that seek their services have a musculoskeletal disorder or injury. As a result the prevalence of some features of gait, based on such a sample of individuals, could be over-estimated. The data gained from these sources has in the past often been supplemented by unpublished ad-hoc surveys carried out by the forensic gait analyst. While such surveys can provide useful information they are particularly prone to skew in terms of demography caused by the location at which they occur. For example, if the data is collected at a location close to numerous healthcare facilities, it is possible that the individuals sampled will have a higher than usual prevalence of health related conditions. In addition to this, these ad hoc surveys are generally limited in size and scope, and although they provide some information regarding the prevalence of certain gait features, they are not able to represent the population in general. Clinical practice and ad-hoc surveys are a valuable source of knowledge regarding prevalence, but have to be used with caution, and should be supplemented wherever possible by reference to published texts and research papers. However, such texts and research papers can only provide an additional but limited source of information based on the specific purpose for which the publication was originally produced. This specific purpose, such as professional education, or a particular research question or subject group, may limit the transferability or currency of the information. The development of databases to hold information on forensic samples and observations has allowed a more robust interpretation of evidence and greater meaning of conclusions in court. Forensic databases have allowed numerical values to represent how common the feature of interest is in the environment and, for known provenance databases, to help identify a sample by providing a match between a suspect sample and a sample of known provenance. The production of these statistics, based on sound research and data collection, provides an objective interpretation of the evidence and enhances a forensic expert's opinion. Many forensic disciplines rely on the development of a database as the central point of reference for prevalence data and in view of the potential limitations of currently used sources of information relevant to forensic gait analysis, the development of a features of gait database is a fundamental step in the evolution of the discipline [14]. While the work described in this paper is a first step in this process, it should be noted that the database is still currently based on a subjective method, and further work needs to be undertaken before the database can legitimately be compared to those used by some other forensic disciplines.

The need for a features of gait database has been expressed by not only gait analysts but also other key individuals in the criminal justice system [15]. The need for underpinning data in order to reach sound

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conclusions for the court of law is particularly important when attempting to provide quantitative opinions utilising the Bayesian approach. The benefits of utilising the Bayesian approach in a range of forensic specialisms have been discussed extensively [16–20]. However, care must be taken when utilising this approach, to ensure transparency as to the origin and limitations of the data used. Failure to be transparent as to the data used to generate likelihood ratios led to conclusions based upon this approach being questioned in the Court of Appeal judgment in R v T [21].

In order for databases to be fit for use in the calculation of likelihood ratios and the interpretation of evidence in court, there are some key features that should be considered. Databases should contain an adequate number of samples so as to represent the population as appropriately as possible, be up-to-date (particularly if the samples are not static in their nature, for example fibre collections, where trends can change dramatically) and demonstrate scope, whether that be geographically and/or in the number of characteristics being collected/analysed.

To ensure that databases and reference collections are a suitable basis on which to make inferences and aid in the interpretation of evidence, the Forensic Science Regulator's (FSR) Codes of Practice and Conduct 2016 outlines the minimum requirements for reference collections and databases [22]. These minimum requirements include the minimum quality standards for sample documentation, data accuracy and data entry. This paper reports the initial development and population of a gait database for use in the forensic context and where possible, outlines how this database currently complies with the Forensic Science Regulator's Codes of Practice and Conduct 2016. The limitations of this database with its current content are discussed along with suggestions of how this database will be developed further.

2. Method

2.1. Database design

Prior to method design and data collection, ethical approval was obtained through the research ethics approval process of Staffordshire University. In order to identify which features of gait should be included in the database, a Delphi strategy was employed to reach a consensus amongst a group of four expert practitioners in this field. While this number is low for a Delphi study, the area of practice concerned is highly specialized, and the number of practitioners known to be practicing in the field at the time in the United Kingdom was small (six) [23]. The Delphi strategy was originally developed as an interactive method of forecasting using a panel of experts to answer questions or give judgements in a series of developmental rounds [24]. After each round the outcomes are summarized and used to inform subsequent rounds, the experts progressively modifying their feedback as they feel appropriate, until a consensus is reached [25,26]. The four practitioners had considerable experience of forensic gait analysis, were all qualified at post graduate level, and trained in observational gait analysis. Each had a minimum of 20 years professional experience and 10 years involvement with forensic gait analysis. The participants were asked to list the features of gait they most commonly encountered and used during forensic gait analysis.

The outcomes of the first round of the exercise were summarized and reported back to the practitioners. The second round of the Delphi consolidated the findings and a consensus was reached. In the third round the practitioners were asked to review the list of features of gait identified in the context of the feasibility of observing and noting the features identified, in the time likely to be available during data collection, i.e. the time taken for a subject to walk towards, past and way from the observer. Consideration was given to a number of the available clinical observational gait analysis assessment tools [27–29]. It was concluded that the data collected using these tools was more detailed than it was feasible to collect in this instance, and relied on the ability to observe the subject for a protracted period of time. Consideration was also given to the likely validity of making the observations, particularly the accuracy with which estimations of magnitude could be made during data collection. It is important to note that the features of gait were therefore limited to those which could, with most certainty, be identified as being present or not present, with any estimations of magnitude being limited to ordinal categorical data, as shown on the data collection sheet. Demographic categories were modelled on a combination of the UK census categorisation, data from the Office for National Statistics [30], the views of the practitioners as to what might be useful in the forensic gait analysis context, and the feasibility of identifying the variables in the short time available.

Minor revisions were made to the list of features agreed in round two, and a consensus was reached in round four of the Delphi. A data collection sheet was produced, designed to facilitate the easy and rapid recording of the observed features of gait in the shortest possible time. The terminology used on the data collection sheet was intentionally kept simple, with the minimum use of technical terminology to ensure an unambiguous understanding of exactly what had been observed and to facilitate the later inclusion of additional data collection observers.

A pilot study was then undertaken of 20 randomly selected participants whose gait was observed, and as a result of the findings, minor amendments made to the data collection sheet to improve its usability under data collection conditions. The project was subsequently presented at national and international conferences attended by forensic gait analysts and their opinions sought as to the appropriateness of the features of gait identified during the Delphi process. The results have substantiated the selection of features made by the original four analysts. Table 1 shows the data collection sheet and features of gait observed.

Table 1
Data collection sheet showing the features of gait observed.

Sex	Male						Female					
Age	18–30			31–50			>51					
Height	Short			Medium			Tall					
Weight	Light			Medium			Heavy					
Ethnicity	White		Black		Asian		S, E and SE Asian		Other			
Gait	Symmetrical						Asymmetrical					
Base of gait	Narrow			Moderate			Wide					
Step length	Short			Moderate			Long					
Pelvic rotation	Limited			Moderate			Exaggerated					
Head/torso roll	More to left			None			Both		More to right			
Head tilted	Left			Forward			Back			Right		
Torso flexed	Left			Forward			Back			Right		
	Left						Right					
Shoulder lower												
Arm swing more pronounced												
Hip movement	Straight			Circumduct			Straight			Circumduct		
Knee points	In		Neutral		Out		In		Neutral		Out	
Knee max extension	Flexed		Straight		Hyper		Flexed		Straight		Hyper	
Foot points	In		Neutral		Out		In		Neutral		Out	
Early heel lift												
Forefoot lift	High			Low			High			Low		
Forefoot slap												