The population of coloured fibres in human head hair

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In 2002 a population study of textile fibres in human hair was carried out using 26 volunteers in Cambridgeshire, UK. Over 12,000 fibres were recovered from a variety of hair lengths using low adhesive tape and classified according to colour, generic type and fibre length. The results of the study showed that the most common fibre colours were black/grey (48%), blue (29.1%) and red (12.7%), the least common being green, orange/brown and yellow which each accounted for less than 5% of the total. Natural fibres (mainly cotton) were predominant (72.3%) and man-made fibres were considerably less frequent. When colour and generic type were classified together, the most common combinations were black and blue cottons. The least common were the man-made fibre/colour combinations with the most frequent of these accounting for less than 7% of the sample. Fibre loads carried by long hair were found to be significantly less than that carried by short hair. The results of this study are in accordance with previous fibre population studies using other types of recipient surfaces and are likely to be influenced by factors such as seasonal and geographical variation.

En 2002, une étude de population de fibres textiles dans les cheveux humains a été menée en utilisant 26 volontaires dans le Cambridgeshire au Royaume-Uni. Plus de 12'000 fibres ont été récoltées d'une variété de longueurs de cheveux en utilisant du ruban adhésif faible et ont été classées selon la couleur, le type générique et la longueur de fibres. Les résultats de cette étude ont montré que les couleurs des fibres les plus communes étaient gris/noir (48%), bleu (29.1%) et rouge (12.7%), les moins communes étant le vert, le brun/orange et le jaune qui chacune représentait moins de 7 % du total. Les fibres naturelles (principalement du coton) étaient prédominantes (72.3%) et les fibres fabriquées étaient considérablement moins fréquentes. Lorsque la couleur et le type générique étaient classés ensemble, les combinaisons les plus communes étaient les cotons noirs et bleus. Les combinaisons les moins communes étaient celles de la fibre fabriquée et de couleur avec une plus haute fréquence de cette combinaison inférieure à 7 % de l'échantillon. Les charges de fibres portées par des longs cheveux ont été significativement inférieures à celles portées par des cheveux courts. Les résultats de cette étude s'accordent avec les études précédentes de populations de fibres qui utilisaient d'autres types de surfaces réceptacles et seront, vraisemblablement, influencées par des facteurs tels que la variation saisonnière ou géographique.

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Im Jahre 2002 wurde in Cambridgeshire, U.K., unter Mitwirkung von 26 freiwilligen Testpersonen eine Populationsstudie zur Verteilung von Textilfasern im menschlichen Haupthaar durchgeführt. Von Kopfhaar unterschiedlicher Länge wurden über 12.000 Fasern mittels Klebeband, das eine geringe Klebekraft besitzt, gesichert und hinsichtlich der Einfärbung, der Faserart und der Faserlänge klassifiziert. Die Ergebnisse dieser Studie zeigen, dass die am häufigsten auftretenden Faserfarben Schwarz/Grau (48%) gefolgt von Blau (29,1%) und Rot (12,7%) sind. Mit weniger als 5% sind die Farbtonbereiche Grün, Orange/Braun und Gelb weitaus weniger häufig verteten. Naturfasern, und hier hauptsächlich Baumwolle, herrschten mit 72,3% vor, während der Anteil an Chemiefasern beträchtlich geringer ausfiel. Betrachtet man die Merkmale Faserart und Faserfarbe gemeinsam, ergeben sich mit schwarzen und blauen Baumwollfasern die am häufigsten vertretenen Kombinationen. Die häufigste Kombination aus Chemiefaser und Farbe betrug dagegen weniger als 7% der Gesamtpopulation. In langem Kopfhaar fanden sich signifikant weniger Fasern als in kurzem. Die Resultate dieser Studie sind in Einklang mit den Ergebnissen früherer Populationsstudien, in denen andere Oberflächen als Spurentäger untersucht wurden, und werden wahrscheinlich durch Faktoren wie jahreszeitliche oder geografische Variationen beeinflusst.

Se realizó un estudio sobre una población de fibras textiles en pelo humano en 2002 utilizando 26 voluntarios en Cambridgeshire, UK. Se recogieron y clasificaron de acuerdo con el color, longitud y tipo genérico, más de 12.000 fibras de una variedad de pelos de diferente longitud utilizando cinta adhesiva. Los resultados del estudio mostraron que los colores más comunes de las fibras eran el negro/gris (48%), azul (29.1%) y rojo (12.7%), siendo el verde, naranja/marrón y amarillo los colores menos frecuentes con menos de un 5% del total. Las fibras naturales (principalmente el algodón) eran predominantes (72,3%) y las fibras sintéticas eran considerablemente menos frecuentes. Cuando el color y el género se estudiaban conjuntamente, la combinación más común era el algodón negro o azul. Las menos frecuentes eran las sintéticas de color con menos de un 7% de la muestra. La carga de fibras sobre pelo largo era significativamente inferior que la transportada por pelo corto. Los resultados de este estudio está de acuerdo con otros estudios de poblaciones de fibras usando otro tipo de superficies de recepción y son presumiblemente influenciables por factores tales como variaciones geográficas y estacionales.

Key words Forensic science, criminalistics, fibres, head hair, population study, taping, recovery, target fibre study.

Introduction

In the commission of crimes, where textile masks such as balaclavas are worn to conceal the perpetrators' identity (e.g. terrorist, armed robbery) transfer of fibres from such items to the head hair of the wearer can occur. The transfer and persistence of fibres in these situations has been the subject of studies, each showing that fibres persist in head hair for a definite time frame [1,2]. Where such a transfer has been demonstrated between a suspect and a garment, then a time frame for wear can be estimated which may contradict an alibi supplied by the suspect. When combined with any DNA evidence obtained from saliva or hair, the summation of these findings can provide extremely compelling evidence.

In attempting to assess the significance of any fibre transfer between the head hair of an individual and a suspect garment, two distinct questions must be asked: how common is a given fibre type/colour combination in head hair and, what are the chances of finding such fibres at random?

In an attempt to address the first question, population studies have been undertaken to determine routine background levels of extraneous fibres within environments commonly encountered in case work. To date, these have included studies of undergarments [3], outdoor surfaces [4], car seats [5], t-shirts [6], cinema seats [7] and bus seats [8]. To the authors' knowledge, head hair has not yet been the subject of such a study.

The second question (regarding the rarity of chance matches between even relatively common textile types) has been addressed by several target fibre studies [9–16]. These studies attempt to help in assessing the likelihood of encountering fibres from an innocent source that match all criteria of a suspect fibre. Importantly, such a study has been conducted within the head hair environment by Cook, Webb-Salter and Marshall [11], who searched for fibres commonly encountered in case work, i.e., blue wool and grey and green acrylics.

The aim of this study was to complement the previously cited studies by gathering information on the relative frequencies of fibre type/colour combinations encountered in head hair and whether this data reflects that obtained from fibre population studies carried out on other recipient surfaces. It is hoped that the study will provide further relevant empirical data, which will assist in the assessment of the significance of fibre evidence in cases involving masks. This may be of particular value when a Bayesian approach is employed.

Experimental

Population sampled

Fibres were recovered from the head hair of 26 volunteers during July 2002. The volunteers were recruited from three differing working environments around Cambridgeshire, and represented a random cross section of the population with a variety of hairstyles and lengths. Locations sampled were the administration section of Cambridgeshire Police headquarters, a business office and warehouse (located in one building), and the data entry section of the Huntingdon Forensic Science Service laboratory. The hair styles of volunteers were classified into one of three categories – short (hair less than 3 cm long), medium (greater than 3 cm, but less than shoulder length, and long (shoulder length and longer). Volunteers were also queried as to their most recent hair washing and if they routinely wore headgear of any sort.

Fibre recovery

In 1996, a study performed by Salter and Cook [1], compared the fibre retrieval efficiency of loaded combs and strips of high-adhesive tape. The results of this study indicated that the average fibre retrieval efficiency of taping exceeded that of combing in all of the hairstyles tested. Countering the conclusions of this study, there is much anecdotal evidence that many laboratories prefer the combing method because it lessens the discomfort to the suspect. In the context of this study, it was found that the combing method did not lend itself to an efficient, rapid counting procedure with subsequent classification. For the reason of efficiency, it was therefore decided to use the method of tape lifting for fibre recovery in this study.

Since there is much anecdotal information on the discomfort caused by using conventional "high adhesive" tape to recover fibres from head hair, "low adhesive tape" (Warrender No. 804) was supplied in a 2 cm wide format. This type of tape is normally supplied to the laboratory in 4 cm format, and is used routinely for fibre recovery from garments with a high 'background' sheddability. It was found that using this specification of tape minimised discomfort (i.e. did not pull out head hairs), allowed easier application with longer hair styles, and recovered acceptable fibre loads.

Two strips of approximately 2 x 20 cm were used to tape the head hair of volunteers A loop of tape, with adhesive facing outward, was wrapped around the fingers of one hand and the tape applied to the entire surface of the hair, using a rocking motion. The second strip was then used to retrieve fibres from under the surface of the hair, by a procedure similar to above but the bundles of hair were pushed upwards so that the tape could reach down to the base of the hair shafts. The tapes were then applied to clear acetate sheets for subsequent examination under the low power microscope.

Fibre classifications

The fibre tapings were searched using a Nikon SMZ 645 stereoscope (maximum magnification 50x), using a marked grid placed under the tapings to aid methodical sequential searching.

All recovered fibres were assigned subjectively to one of the following colour groups: black/grey, blue, red, orange/brown, purple/pink, green, yellow and other (including multi-coloured). Only coloured fibres were considered in this study.

Given the large number of fibres recovered in this study, generic class identification was carried out by randomly sampling two 1 cm^2 "windows" on each taping, and retrieving and mounting all fibres contained within these "windows". The size of the "window" was chosen so that the sampling area was well within the confines of the tape. The validity of this sampling method was confirmed by comparison of the colour distribution data with that obtained from the total count (see Results/Discussion). Fibres were removed from tapes by cutting through the back of the tape and were mounted eight fibres to a slide under individual cover slips. Each fibre was numbered and its length measured by comparison to the measurement scale under the microscope.

Generic type determinations were made via birefringence measurement using a Leitz Ortholux II POL-BK polarising microscope equipped with a tilting compensator. The fibres were assigned to one of the following generic classes: acrylic, cotton, polyamide, polyester, regenerated cellulosic, wool and other.

Length classifications used were <0.5 mm, 0.5–1.0 mm, 1.1–3.0 mm, 3.1–5.0 mm and >5.0 mm.

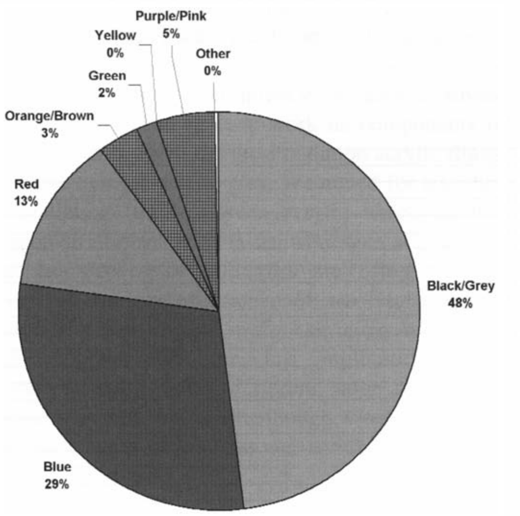
Results and discussion

The low adhesive tape used in this study showed good efficiency of fibre recovery, picking up large numbers of fibres of different sizes as well as any other debris that was present in the hair. All volunteers found this method comfortable, and no hair was pulled out as is the case when tapes of 'normal' adhesive strength are used.

Colour Distribution

A total of 12,149 fibres were classified in this manner. The distribution of fibre colour groups can be seen in Figure 1.

Figure 1 Percentage distribution of fibres in head hair according to colour (n=12149).



Black/grey fibres made up almost one half of the fibres seen (48.0%) followed by blue (29.1%) and red (12.7%). The remaining colour groups all individually made up less than 5%, consisting of pink/purple (4.8%), orange/brown (3.3%), green (1.7%), yellow (0.2%) and "other" coloured fibres (0.2%).

This distribution correlates closely with previously conducted studies. The preponderance of black and blue fibres has also been demonstrated in the population study of white t-shirts carried out by Massonet et al in 1998 [6], as well as in Cantrell and Roux's 1999 study of cinema seats [7]. Results obtained by Roux and Margot in their study of car seats [5] found grey/black fibres to be the most common, followed by blue, colourless and red. This particular study also mirrors the current study in finding red fibres to be more considerably more common than the remaining colour groups, representing about 10.9% in their study. It should be noted, however, that one taping that had an unusually large number of red fibres influenced the figure of 12.7% in the current study. This taping had 531 red fibres out of a total of 1273 (42%). The inclusion of this taping in the final results acts to inflate the frequency of red fibres by about 3%.

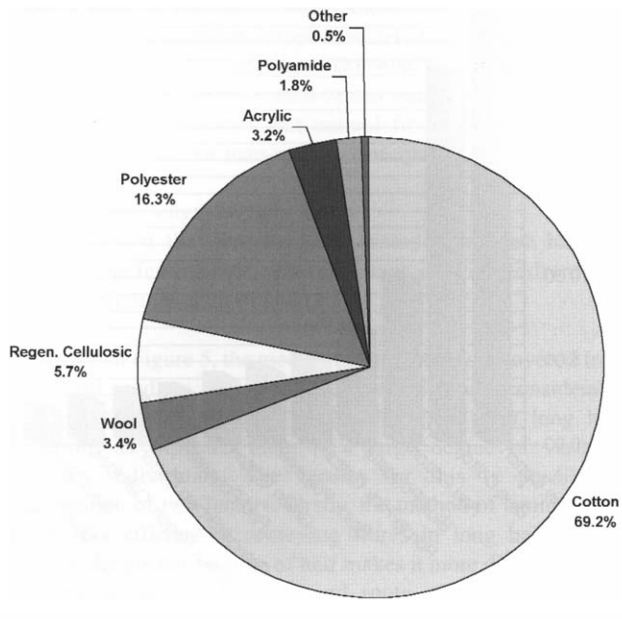
A fibre population study of bus seats [8] differed from this study in finding relatively small numbers of black fibres (8%) and a large number of green (13%).

Generic Class Distribution

A total of 441 fibres randomly sampled from the colour classification group were mounted for classification according to colour, generic class and size (Figure 2). (In order to confirm the representative nature of the random sampling employed, the colour classification distribution of the sampled group was compared to that obtained from the total fibre count and the results found to be in accordance.)

Analysis of the fibre type data showed that the fibre population consisted mainly of natural fibres (72.6%), with the largest generic grouping being cotton (69.2%). This finding is in agreement with all population studies previously mentioned [3–8]. Wool was the other natural fibre type occurring at a frequency of 3%, however this appears to be under-represented in this study compared to the previously mentioned studies. The reasons behind this apparent discrepancy are likely related to both the climatic and seasonal variation between this study and

Figure 2 Percentage distribution of fibres in head hair according to generic class (n=441).



those done previously. The fibre population studies of car seats [5] and cinema seats [7] were all conducted during the winter months of their respective climates. The sampling for this study was conducted in early summer (July) in the UK and it is likely that the low amount of wool encountered in this study is a reflection of the type of clothing generally worn during warmer weather. Since the fibre content of hair is likely to be a direct reflection of the clothing worn by the subjects, it is likely that repeating this study in the winter months would see the relative frequency of wool rise as a consequence of the need for heavier winter clothing. Biermann and Grieve have investigated this aspect of seasonal variation [17], when they examined the content of a mail-order garment database as a means of estimating fibre frequencies within the population. Within the data they collected was a comparison of fibre composition of garments sold during the fall/winter and spring/summer seasons in Germany. Within this breakdown, we see the expected rise of wool and acrylic in the winter season, at the expense of decreasing amounts of cotton.

In this present study, man-made fibres accounted for 27% of the sampled population. Among these, polyester was most commonly seen, accounting for about 60% of the man-made fibres, or 16% of the overall fibre population. This is a marked contrast to a number of studies [4,5,7,8], that have found that the most common man-made fibres consisted of regenerated cellulosic fibres, which includes viscose (rayon), acetate and other cellulosic fibres such as modal and lyocell. Figure 2 shows regenerated cellulosic fibres were the second largest group of man-made, accounting for 5.7%. Acrylic and polyamide confirmed the results of the previous studies as being relatively rare, accounting for 3.2% and 1.8% respectively.

This study shows polyester to be the most prominent man-made fibre in head hair by a considerable margin. Consideration of the results of Biermann and Grieve [17] show no seasonal variation that might account for this finding, in fact their data shows polyester content increases in winter clothing, while viscose tends to decrease. Although not investigated, this apparent disparity may be due to the fibre composition of the bedding used by the subjects (i.e. pillow cases and other bedding with which head hair has contact are often composed of a cotton/polyester mix).

In comparison to Grieve and Dunlop's population study of undergarments [3], the orders of generic classes are the same, with the notable exception of acrylic, which was found to be the second most common class in the 1992 study.

Combined colour/generic class frequencies

Figure 3 shows a summary of the 20 most common colour/generic class combinations and their proportion of the sample. Of a possible 72 combinations, all but 12 comprised less than 1.0% of the sampled population.

The abundance of cottons is clearly illustrated, with black/grey and blue cottons accounting for nearly half of the population. The studies of cinema seats [7], outdoor surfaces [4], car seats [5] and white t-shirts [6] all support this finding, having found black/grey and blue cottons to be most populous in each respective environment. However, the above studies also hold that the next most common colour/generic class combination was coloured (usually black) wool, a finding not supported by this study. Black wool was the most common wool seen, at a frequency of 2.0%. Possible reasons for the under-representation of wool have been previously discussed.

Figure 3 Colour/generic class combinations (n=441).

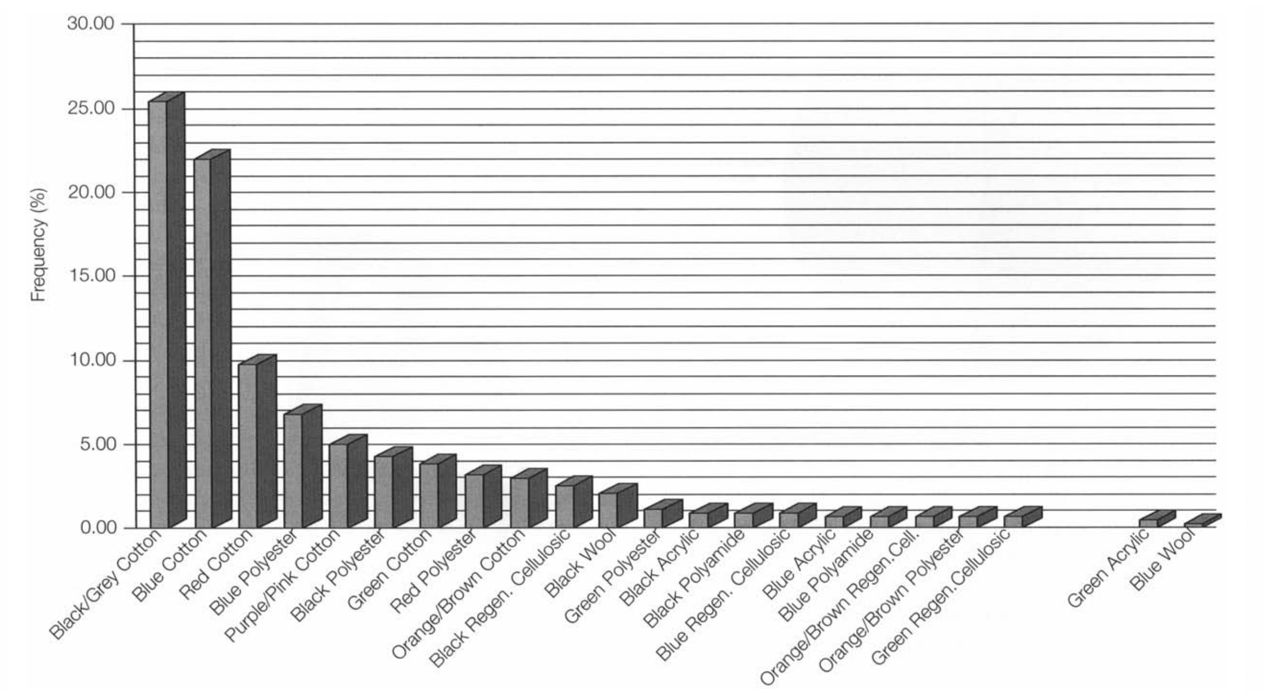
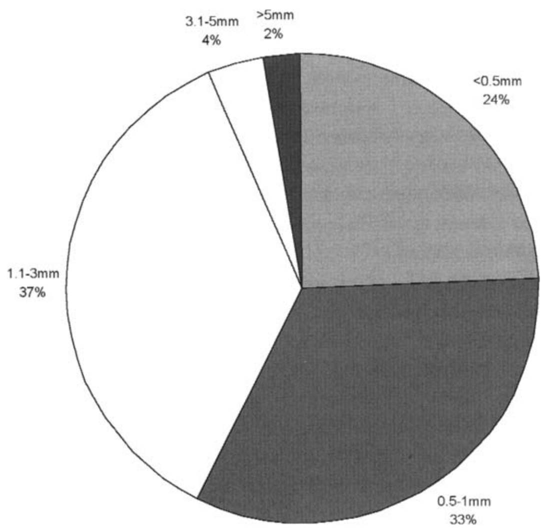


Figure 4 Percentage distribution of fibres length.



Other combinations that were very prominent were red cotton and purple/pink cotton, although the frequency of the latter was boosted slightly by one taping that had an abnormal amount of purple fibres (an outlier in which purple fibres accounted for 44% of the fibre load on the tapings). Again, the prominence of red cotton, in comparison to other coloured cottons, is supported in the previous studies.

The most frequent man-made fibre/colour combination was blue polyester at 6.8%, followed closely by black polyester at 4.3%.

Of particular relevance to crimes involving masks and balaclavas was the relative infrequency of acrylic fibres. Acrylics are commonly seen in case work as components of manufactured balaclavas. Even the most common acrylic fibres, consisting of those being black or grey, accounted for less than 1% of the population (0.9%). Green acrylic fibres, another common component of black balaclavas, were seen at a level of 0.5%. Since the sleeves of pullovers are often used as improvised masks, the low occurrence of wool (a relatively common component of pullovers) in the hair, even in common colours such as black and blue, has implications when considering the evidential value of finding large numbers of wool in a suspect's hair. Such a finding though, would have to be placed within the context of the seasonal variability that wool fibre levels are likely to have.

Interestingly, blue wool is often selected for use in target studies. In a head hair study conducted by Cook et al [11], blue wool was selected due both to its believed high frequency and its commonality in case work. This fibre type/colour combination was also used in a target study performed in 1996 on seats in public houses [9]. Blue wool was selected as a relatively common fibre, and typical of a high selling, mass-produced garment (in this case a Marks & Spencer pullover). As is shown in Figure 3, the present study suggests that blue wool is rarely encountered in head hair (only one blue wool was found out of the 441 fibres identified). Again, it is likely that many of these conflicting observations can be attributed to climatic differences or seasonal fluctuations.

Data application

Since the Bayesian approach to the interpretation of fibre evidence seeks to provide a more qualitative methodology through the use of empirical data in the calculation of a "likelihood ratio", it is therefore possible to directly apply the data from this study to such a method.

Such an approach has previously been demonstrated in the head hair target study conducted by Cook, Webb-Salter and Marshall [11], who calculated the likelihood of finding fibres from an innocent source matching blue wool, and green and grey acrylics found in head hair. Similar calculations were also performed by Roux and Margot [5] in order to obtain probability values for finding given numbers of particular fibre type/colour combinations on car seats.

The authors of the present study would argue that similar applications of the data obtained from this study, would provide a valuable interpretative aid directly applicable to fibre evidence derived from head hair.

Fibre length distribution

Figure 4 summarises the size data in this study. The majority of the fibres observed in this study were less than 1 mm in length. The largest size grouping seen were fibres 1.1–3 mm in length (37%). Only 6% of the fibres seen were greater than 3 mm long. Of the previous population studies that considered fibre length, both had length data similar to this. The data collected in the Roux and Margot study [5], and in the study of outdoor surfaces by Grieve and Biermann [4] agree with this distribution. It is interesting to note that both of these studies, like the current one, employed taping as the means of recovering fibres.

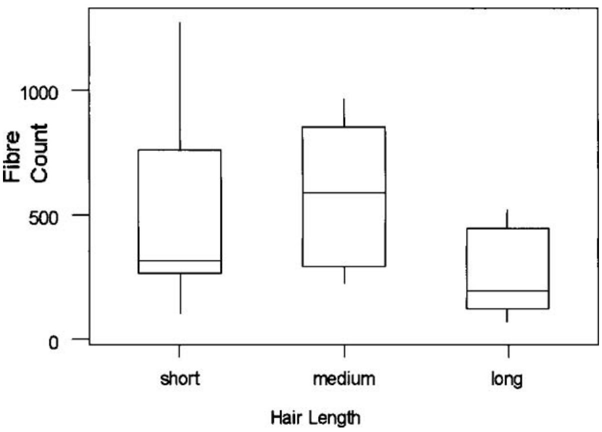
It was generally noted that the majority of small fibres (<0.5–1 mm) in this study were cotton fragments, with man-made fibres representing a proportionately larger amount of each fibre group as the size increases. This may be a reflection of the fragmentation values for cotton versus man-made fibres. It has previously been reported that natural fibres tend to fragment more easily than their man-made counterparts [4].

Effects of hair length on fibre loads

Comparison of the fibre loads recovered from each hairstyle revealed that fewer fibres were consistently recovered from long hair than from medium or short hair.

As shown in Figure 5, the mean number of fibres recovered from short and medium hair lengths are similar and considerably larger than the number of fibres recovered from long hair. However, as expected there is a large degree of variation between individuals. The reason for this is possibly a combination of two factors. Firstly, the method of taping seems to be less efficient at retrieving fibres in long hair, simply because the greater volume of hair makes it more difficult for the collector to access the base and roots of the hair, making

Figure 5 Comparison of fibre loads recovered from different hair lengths.



embedded small fragments that may be there inaccessible. It is also more difficult to touch the tape to every plane and surface of those with long hair. This finding also appears to indirectly support other studies on fibre persistence. Salter and Cook reported that consistently more fibres from headgear were transferred to shorter, coarser hairstyles than to long hair [1]. Their study also noted that the coarse, short hair on one subject exhibited greater persistence than the long hair of another subject. This combination of greater transference and persistence of fibres in short hair should, in theory, combine to mean a larger static fibre load would be retained in shorter hair.

These results do, however, conflict with an earlier head hair persistence study by Ashcroft et al, who reported that greater numbers of fibres were transferred to longer hairstyles [2].

Conclusion

The results of this study are in general accordance with other similar studies in demonstrating the predominance of dark coloured cottons (black, grey and blue) and the relative rarity of most coloured man-made fibre types. In all but 12 combinations of colour and generic class, there was sufficient discrimination to obtain frequency rates of less than 1.0% (including acrylic fibres, which are commonly encountered in casework as components of masks used in crimes).

Regardless of whether a Bayesian approach to the interpretation of fibre evidence is employed, population studies such as this should be of considerable interest to fibre examiners as such data provides a means of objectively evaluating the evidential strength of his or her findings.

Whilst it is the authors' belief that the results of this study are directly applicable to the interpretation of fibre evidence derived from head hair, potential seasonal and/or geographical influences need to be considered.

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