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Variation in forensic DNA profiling success among sampled items and collection methods: a Queensland perspective

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ABSTRACT

Understanding the relative success of recovering DNA profiles from different touched evidentiary items/substrates, and between different methods of collection, is critical for optimal targeting of forensic sample collection and triaging for analysis. Further, reporting of such success statistics allows comparison between jurisdictions that can drive improvements and prompt discussion between stakeholders. This study analysed success statistics for DNA sampling from major and volume crimes attended by the Queensland Police Service, Australia, from February 2018 to September 2019. In total, 36416 total records were analysed, representing the most comprehensive analysis of its kind to date. Percentage successes were determined for various sample types and items, including those that are commonly encountered or have high probative value. Results suggested that, overall, around 9.5% of trace DNA samples returned full profiles, but with some disparity between swabs (13.48%) and tapelifts (6.02%). Nevertheless, trace DNA samples contributed nearly 40% of total suspect identifications (tapelifts 20.05%; swabs 18.76%). Substantial variation in profiling success among items/substrates was observed, as there was between swabs and tapelifts taken from the same item. These data contribute significantly to our understanding of DNA prevalence and recovery and provide a critical evidence base to inform changes to operational procedures.

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Swabs; tapelifts; full profile; mixed profile; suspect identification

Introduction

DNA sampling, particularly of touched objects and surfaces, has become an increasing focus for forensic analysts globally [1,2]. Resolution of DNA profiles from such items can be highly probative and thus understanding the relative success of recovering profiles from items is important for targeting sample collection and triaging for analysis. Such success statistics should be considered in the context of the specific collection and analysis methods used by a given jurisdiction. Comparing data generated from different DNA extraction and profiling methods may not necessarily represent a like-for-like comparison and must be considered with some caution. Nevertheless, there can be great value in comparing between jurisdictions to determine whether substantial differences are apparent and where improvements could be made. Moreover, sampling of putatively touched

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items can be a point of friction between investigators and forensic scientists who may have contrasting anecdotal experience concerning a questioned item. Finally, where jurisdictions use multiple collection methods for similar items (because of officer preference or simply what consumables are available at the time), it is important to assess whether one method outperforms another to ensure operational procedures follow best practice. Therefore, there is a need for additional data to inform decision-making and assist forensic scientists in optimally targeting sampling effort.

There have been sporadic attempts over the last twelve years to address this issue in a range of national and state jurisdictions from New Zealand [3], Switzerland [4], Canada [5], Netherlands [6], Singapore [7], and Australia [8], including a comparative analysis of experimental and casework samples from Western Switzerland [9]. These studies analysed success statistics for various types of casework samples; either those most commonly collected, restricted to volume crime cases, or specific items of interest. Generally speaking, these studies were consistent in suggesting that, as expected, biological fluid traces (blood, saliva, semen) provided the greatest proportions of full profiles (up to 87.5% [9]), whereas touch samples were far less successful overall (<30%). Worn or touched items that often returned above average proportions of full profiles included hats/caps, gloves, adhesive tape, clothing, door handles and steering wheels [3–9], though in some cases these may have represented victim (wearer) profiles.

This study aimed to analyse success statistics for DNA sampling from major and volume crime for the Queensland Police Service, Queensland, Australia over a period of roughly 20 months. Percentage successes were determined for sample types over the entire period, as well as broken down to selected items of interest, including those that are commonly encountered or have high probative value. Queensland data are then discussed in the context of previous literature.

Methods

Samples included in this analysis were collected from exhibits related to both major and volume crime between 22 February 2018 and 11 September 2019. Methods of collection included: swabbing with a rayon swab (Medical Wire, UK) pre-moistened with 70% ethanol; tapelifting with a custom 3M adhesive tape kit (Lovell Surgical Supplies, Australia); excision (e.g. fabric, cigarette butts); and scraping. All samples were processed at Queensland Health Forensic Scientific Services (QHFSS) following standard procedures: DNA extraction conducted using either the DNA IQ™ Casework Pro Kit for Maxwell®16 (Promega Corp., Melbourne, Australia) on a Maxwell® 16 MDx (Promega Corp.) or DNA Investigator Kit (Qiagen, Melbourne, Australia) on a QIASymphony (Qiagen); quantification using Quantifiler® Trio (ThermoFisher Scientific, Melbourne, Australia) on the 7500 Real Time PCR System (Applied Biosystems™, ThermoFisher Scientific), and STR amplification using PowerPlex® 21 (Promega Corp.). DNA quantification results determined progression to profiling, according to QHFSS standard procedures: samples of concentration <0.0088 ng/μL were considered to have insufficient DNA and were thus categorized as 'no DNA'. Samples that yielded sufficient DNA (>0.0088 ng/μL) proceeded to STR profiling.

Data were extracted from the in-house laboratory information management system (LIMS) for all DNA samples sent for processing between 22 February 2018 and

11 September 2019. The LIMS was queried in such a way to return sample type (e.g. swab/tapelift) and exhibit description information, as well as STR profiling results categorized as 'full' (all 42 alleles present), 'partial/mixed' (less than 42 alleles, or more than one contributor), or 'no DNA' (insufficient DNA quantity for profiling, or unsuccessful profiling). In some cases, sample results were classified in multiple categories; for example, full+partial/mixed profile results may indicate full suspect profiles deconvoluted from mixtures, or no DNA+full or partial/mixed where samples were amplified and genotyped more than once. Profiles were also recorded for whether they matched a suspect/offender reference sample. This master spreadsheet was queried using Windows Powershell to extract lines in which the exhibit description matched specific text strings. All resulting sub-sheets were manually reviewed to ensure only relevant data were included. Despite this, inconsistencies in spelling and terminology in the exhibit description limited the completeness of the analysis; however, this is unlikely to have impacted dramatically on the interpretation of DNA success statistics. Percentages of each profile result category were calculated for the total dataset, each collection method across all items, and then broken down for collection method from each selected item. Percentage successes were also assessed for porous versus non-porous substrate surfaces. Sample metadata allowed results for swabs from biological fluid stains (blood, saliva, semen) to be separated from those taken from putative touched areas or handled objects.

Results

In total, 36 416 total records (representing 35 722 unique exhibits) were analysed, the majority of which were swabs or tapelifts (Table 1). Swabs collected from biological fluids represented a much smaller proportion than those from touched areas/objects. Overall, 25.60% of samples returned full profiles: the greatest proportion of full profiles was obtained from samples of obvious stains of biological fluids, with the most successful being swabs of bloodstains (71.15%, Table 2). Partial/mixed profiles were rarely obtained from swabs of semen stains (2.86%), but otherwise ranged up to 30.02% of DNA results from other sample types. Percentages of suspect identifications ranged from 13.14% (hair) to 39.37% (blood swabs). Both swabs and tapelifts of touched objects/surfaces returned suspect identifications from ~14% of samples, but there was a significant disparity between full profile results (swabs = 13.48%; tapelifts = 6.02%). Despite this, tapelifts provided 20% of total suspect identifications compared with nearly 19% for trace swabs (Table 1), suggesting that the success of tapelifting is often reliant on partial profiles or deconvolution of mixtures.

Individual items/surfaces showed great variation in their percentage success (Table 2). The greatest success for exhibits where no visible stain was observed was for clippings from fingernails, which produced full profiles in ~72% of samples taken. Chewing gum, excisions from cigarette butts, bedding and waistbands of lower garments, all samples from drinking straws, and fingernail scrapings all produced full profiles in >40% of samples. The least successful items (no full profiles recorded) included: swabs of rocks, pavers, helmets, mobile phones, firearm barrels, shirt collars, power cords, rubber, metal and plastic key handles, and several tools; tapelifts of cigarette lighters, firearm handles, and several tools; and both swabs and tapelifts of public phones, fingermarks, glovemarks, external car door handles, sweat smears on cars, and axe handles. Despite this,

Table 1. Number of records included for analysis separated into major sample types (minor sample types or those not subsequently analysed are not shown). Percentages of total records, suspect identifications, full or partial/mixed profiles, and no DNA records provided for each sample type.

Sample type	Number of exhibit records	Percentage of total records	Percentage of total suspect identifications (N = 8263)	Percentage of total full profiles (N = 9323)	Percentage of total partial/mixed profiles (N = 7698)	Percentage of total no DNA (N = 21919)
Cigarette butts	1546	4.25	7.50	8.91	6.40	1.91
Fabric	1050	2.88	4.44	4.34	3.38	2.37
Hair	205	0.56	0.33	0.69	0.23	0.61
Scraping	709	1.95	2.94	3.25	0.83	1.94
Swab (blood)	4361	11.98	20.78	33.28	10.07	4.63
Swab (saliva)	2688	7.38	12.45	11.39	10.48	4.86
Swab (semen)	35	0.10	0.10	0.09	0.01	0.13
Swab (trace)	10372	28.48	18.76	15.00	21.71	35.65
Tapelift	12184	33.46	20.05	7.87	33.13	42.46
All trace	22556	61.94	38.81	22.87	54.83	78.11

Table 2. DNA profiling results for samples collected by QPS forensic officers between 22 February 2018 and 11 September 2019.

Item		Collection method	Total results	Percentage suspect identification	Percentage full profile	Percentage partial/mixed profile	Percentage no DNA
All		All	36416	22.69	25.60	21.14	60.19
		Fabric	1050	34.95	38.57	24.76	49.43
		Hair	205	13.14	31.22	8.78	65.37
		Scrapings	709	34.27	42.74	9.03	60.08
		Swab (blood)	4361	39.37	71.15	17.77	23.25
		Swab (saliva)	2688	38.28	39.51	30.02	39.62
		Swab (semen)	35	22.86	22.86	2.86	82.86
		All trace	22556	14.22	9.45	18.71	75.90
		Swab	10372	14.94	13.48	16.11	75.34
		Tapelift	12184	13.60	6.02	20.93	76.39
Cars	Steering wheel	Swab (blood)	20	60.00	60.00	25.00	35.00
		All trace	1934	12.62	4.55	21.04	76.78
		Swab	431	10.67	2.55	18.10	80.74
		Tapelift	1503	13.17	5.12	21.89	75.65
	Airbags	Swab (blood)	37	67.57	81.08	16.22	16.22
		Excised	9	33.33	66.67	22.22	44.44
		All trace	130	26.92	15.38	25.38	70.00
		Swab	8	12.50	0.00	12.50	87.50
		Tapelift	122	27.87	16.39	26.23	68.85
	Gear stick	Swab (blood)	4	50.00	100.00	0.00	25.00
		All trace	371	8.36	3.77	14.82	83.02
		Swab	113	5.31	0.00	9.73	90.27
		Tapelift	258	9.69	5.43	17.05	79.84
	All doors	Swab (blood)	69	60.87	73.91	11.59	27.54
		All trace	99	7.07	2.02	8.08	89.90
		Swab	60	8.33	1.67	8.33	90.00
		Tapelift	39	5.13	2.56	7.69	89.74
	Internal door handle	Swab (blood)	33	60.61	69.70	12.12	36.36
		All trace	61	6.56	3.28	6.56	90.16
		Swab	35	8.57	2.86	8.57	88.57
		Tapelift	26	3.85	3.85	3.85	92.31
	External door handle	Swab (blood)	20	70.00	80.00	20.00	15.00
		All trace	28	3.57	0.00	7.14	92.86
		Swab	17	0.00	0.00	0.00	100.00
		Tapelift	11	9.09	0.00	18.18	81.82
	Seatbelt strap	Swab (blood)	1	0.00	100.00	0.00	100.00
		Fabric	1	0.00	0.00	0.00	100.00
		All trace	85	4.71	3.53	9.41	88.24
		Swab	3	0.00	0.00	33.33	66.67
		Tapelift	82	4.88	3.66	8.54	89.02
	Seatbelt buckle	All trace	63	9.52	4.76	11.11	87.30
		Swab	20	5.00	10.00	0.00	90.00
		Tapelift	43	11.63	2.33	16.28	86.05
Motorcycles		Swab (blood)	4	100.00	100.00	0.00	0.00
		All trace	39	5.13	5.13	7.69	92.31
		Swab	12	0.00	0.00	0.00	100.00
		Tapelift	27	7.41	7.41	11.11	88.89
	Handlebars	Swab (blood)	-	-	-	-	-
		All trace	34	5.88	5.88	8.82	91.18
		Swab	10	0.00	0.00	0.00	100.00
		Tapelift	24	8.33	8.33	12.50	87.50
Cigarette butt		Excised (majority)	1546	40.10	53.75	31.89	27.04
Cigarette packet		Swab (blood)	5	40.00	100.00	0.00	0.00
		Tapelift	4	25.00	25.00	75.00	100.00
Cigarette lighter		All trace	110	3.64	1.82	8.18	90.00
		Swab	88	4.55	2.27	7.95	89.77
		Tapelift	22	0.00	0.00	9.09	90.91

(Continued)

Table 2. (Continued).

Item		Collection method	Total results	Percentage suspect identification	Percentage full profile	Percentage partial/mixed profile	Percentage no DNA
Bindings		All	229	9.17	10.48	17.03	77.73
	Rope	Tapelift (majority)	57	3.51	14.04	22.81	70.18
	Zip/cable ties	All trace	29	13.79	13.79	6.90	82.76
		Swab	16	6.25	12.50	0.00	93.75
		Tapelift	13	23.08	15.38	15.38	69.23
	Power cords	Swab (blood)	4	25.00	50.00	25.00	75.00
		All trace	86	9.30	5.81	11.63	84.88
		Swab	45	2.22	0.00	6.67	93.33
		Tapelift	41	17.07	12.20	17.07	75.61
	Tapes	All trace	92	9.78	5.43	10.87	89.13
		Swab	58	10.34	6.90	13.79	86.21
		Tapelift	34	8.82	2.94	5.88	94.12
	Deceased scenes	Tapelift (majority)	32	3.13	28.13	37.50	59.38
Door handles (premises)		Swab (blood)	38	57.89	65.79	28.95	28.95
		All trace	252	2.78	2.78	7.14	90.87
		Swab	136	2.21	2.94	5.15	93.38
		Tapelift	116	3.45	2.59	9.48	87.93
Window frames/sills		Swab (blood)	113	48.67	76.11	14.16	18.58
		All trace	61	13.11	9.84	8.20	85.25
		Swab	38	13.16	13.16	7.89	84.21
		Tapelift	23	13.04	4.35	8.70	86.96
Flyscreen mesh		Swab (blood)	20	45.00	70.00	10.00	25.00
		Excised	1	100.00	100.00	0.00	0.00
		All trace	611	4.42	3.93	9.17	88.22
		Swab	94	0.00	2.13	4.26	94.68
		Tapelift	517	5.22	4.26	10.06	87.04
Mouth/rim of drinking vessel		All trace	2525	34.93	37.43	28.83	42.85
		Swab	2450	35.67	38.33	29.14	41.63
		Tapelift	75	10.67	8.00	18.67	82.67
Drinking straw		Excised	33	54.55	48.48	36.36	30.30
		All trace	311	47.91	45.98	29.26	38.26
		Swab	305	47.87	45.90	29.51	38.36
		Tapelift	6	50.00	50.00	16.67	33.33
Drug pipe/bong		Swab (majority)	118	28.81	11.86	35.59	56.78
Chewing gum		Whole item (majority)	16	12.50	62.50	18.75	43.75
Keys		All trace	223	4.04	1.79	12.11	87.89
		Swab	134	1.49	0.75	5.97	94.78
		Tapelift	89	7.87	3.37	21.35	77.53
	Rubber	All trace	6	0.00	16.67	0.00	100.00
		Swab	1	0.00	0.00	0.00	100.00
		Tapelift	5	0.00	20.00	20.00	100.00
	Metal	All trace	93	2.15	1.08	7.53	92.47
		Swab	68	1.47	0.00	5.88	94.12
		Tapelift	25	4.00	4.00	12.00	88.00
	Plastic	All trace	87	4.60	2.30	12.64	86.21
		Swab	41	2.44	0.00	4.88	95.12
		Tapelift	46	6.52	4.35	19.57	78.26
Cartridge cases		All trace	130	3.08	5.38	3.85	93.08
		Swab	75	2.67	1.33	1.33	97.33
		Tapelift	55	3.64	10.91	7.27	87.27
	Discharged	All trace	47	4.26	12.77	4.26	87.23
		Swab	25	4.00	4.00	0.00	96.00
		Tapelift	22	4.55	22.73	9.09	77.27
	Live	All trace	77	2.60	1.30	2.60	97.40
		Swab	46	2.17	0.00	2.17	97.83
		Tapelift	31	3.23	3.23	3.23	96.77

(*Continued*)

Table 2. (Continued).

Item		Collection method	Total results	Percentage suspect identification	Percentage full profile	Percentage partial/mixed profile	Percentage no DNA
Firearm		Swab (blood)	8	12.50	75.00	25.00	25.00
		All trace	499	8.02	2.40	8.82	89.98
		Swab	308	7.79	2.60	9.09	90.26
		Tapelift	191	8.38	2.09	8.38	89.53
	Handle	All trace	129	8.53	2.33	10.85	88.37
		Swab	60	8.33	5.00	11.67	86.67
		Tapelift	69	8.70	0.00	10.14	89.86
	Barrel	All trace	13	0.00	7.69	7.69	92.31
		Swab	7	0.00	0.00	14.29	100.00
		Tapelift	6	0.00	16.67	0.00	83.33
	Trigger	All trace	164	7.93	3.05	7.93	89.63
		Swab	121	8.26	3.31	9.09	88.43
		Tapelift	43	6.98	2.33	4.65	93.02
Knife		Swab (blood)	218	33.49	47.25	37.16	27.52
		All trace	769	15.34	6.11	19.25	77.89
		Swab	491	13.85	6.31	18.13	78.82
		Tapelift	278	17.99	5.76	21.22	76.26
	Handle	All trace	578	15.74	3.81	19.55	79.24
		Swab	330	13.94	3.03	17.58	81.82
		Tapelift	248	18.15	4.84	22.18	75.81
	Blade	All trace	138	13.04	12.32	21.74	69.57
		Swab	132	12.88	12.88	21.21	69.70
		Tapelift	6	16.67	0.00	33.33	66.67
Gloves		Swab (blood)	8	37.50	25.00	37.50	37.50
		Excised	7	71.43	0.00	71.43	28.57
		All trace	1003	15.05	4.49	22.33	75.27
		Swab	228	7.02	3.95	13.16	85.09
		Tapelift	775	17.42	4.65	25.03	72.39
	Inside surfaces	All trace	640	14.22	4.69	23.28	74.22
		Swab	139	7.91	5.04	13.67	83.45
		Tapelift	501	15.97	4.59	25.95	71.66
Fingermarks		Swab (blood)	6	16.67	33.33	33.33	33.33
		All trace	67	4.48	0.00	7.46	92.54
		Swab	58	5.17	0.00	8.62	91.38
		Tapelift	9	0.00	0.00	0.00	100.00
Glovemarks		All trace	64	0.00	0.00	0.00	100.00
		Swab	60	0.00	0.00	0.00	100.00
		Tapelift	4	0.00	0.00	0.00	100.00
Sweat smears	Premises	All trace	73	5.48	4.11	2.74	95.89
		Swab	67	4.48	2.99	2.99	97.01
		Tapelift	6	16.67	16.67	0.00	83.33
	Cars	All trace	20	0.00	0.00	5.00	95.00
		Swab	18	0.00	0.00	5.56	94.44
		Tapelift	2	0.00	0.00	0.00	100.00
Phones	Mobile phone	Swab (blood)	19	52.63	57.89	42.11	21.05
		All trace	81	19.75	2.47	22.22	75.31
		Swab	63	15.87	0.00	22.22	77.78
		Tapelift	18	33.33	11.11	22.22	66.67
	Public phone	Swab (blood)	2	100.00	100.00	0.00	100.00
		All trace	8	0.00	0.00	0.00	100.00
		Swab	5	0.00	0.00	0.00	100.00
		Tapelift	3	0.00	0.00	0.00	100.00
Keypad (eg., safe/alarm)		Swab (majority)	18	5.56	11.11	11.11	83.33
Computer keyboard		Swab (blood/trace)	2	50.00	50.00	0.00	50.00
Fingernails		Scrapings	357	53.50	41.46	44.26	32.21
		Clippings	47	17.02	72.34	25.53	19.15
Condom		Swab (majority)	205	50.24	17.56	49.27	46.83

(Continued)

Table 2. (Continued).

Item		Collection method	Total results	Percentage suspect identification	Percentage full profile	Percentage partial/mixed profile	Percentage no DNA
Sexual assault-related		All	3428	22.35	45.92	22.58	42.68
		High vaginal	478	26.78	50.42	31.59	32.64
		Low vaginal	473	20.93	50.95	25.79	34.46
		Hymen	8	12.50	62.50	12.50	37.50
		Vaginal other	55	30.91	61.82	23.64	18.18
		Vulval	756	17.59	51.59	19.97	38.23
		Labial	158	15.19	61.39	20.25	32.28
		Perineum	12	0.00	58.33	0.00	41.67
		Perianal	319	14.73	34.17	19.75	55.17
		Anal	111	8.11	36.94	9.91	63.06
		Rectal	176	9.66	39.77	11.36	57.95
		Breast	33	39.39	9.09	42.42	66.67
		Oral	213	6.57	67.61	6.10	35.68
		Penis	320	55.63	27.19	34.06	52.19
Clothing	Collar	Swab (blood)	2	100.00	50.00	50.00	50.00
		Fabric	10	30.00	40.00	20.00	50.00
		All trace	256	24.61	5.86	31.64	66.80
		Swab	11	27.27	0.00	36.36	63.64
		Tapelift	245	24.49	6.12	31.43	66.94
	Beanie	Tapelift (majority)	65	33.85	3.08	40.00	60.00
	Balaclava	Tapelift (majority)	56	26.79	17.86	16.07	73.21
	Helmet	Swab (blood)	6	66.67	100.00	0.00	33.33
		All trace	89	25.84	4.49	31.46	67.42
		Swab	8	0.00	0.00	0.00	100.00
		Tapelift	81	28.40	4.94	34.57	64.20
	Hat/cap	Swab (blood)	27	59.26	40.74	40.74	33.33
		All trace	509	25.54	7.86	34.97	62.48
		Swab	29	13.79	3.45	20.69	75.86
		Tapelift	480	26.25	8.13	35.83	61.67
	Underwear	Excised/scraped	193	29.02	21.76	22.80	64.25
		All trace	308	25.32	14.94	43.18	49.35
		Swab	14	42.86	21.43	50.00	28.57
		Tapelift	294	24.49	14.63	42.86	50.34
	Waistband shorts/ pants	Excised/scraped	12	33.33	41.67	8.33	83.33
		All trace	120	20.00	4.17	35.83	64.17
		Swab	4	50.00	0.00	50.00	50.00
		Tapelift	116	18.97	4.31	35.34	64.66
Screwdriver		All trace	498	9.24	2.41	16.06	83.13
		Swab	253	8.70	2.37	13.44	85.38
		Tapelift	245	9.80	2.45	18.78	80.82
Sledge hammer		Swab (blood)	3	0.00	66.67	0.00	66.67
		All trace	35	11.43	2.86	11.43	85.71
		Swab	10	10.00	10.00	0.00	90.00
		Tapelift	25	12.00	0.00	16.00	84.00
Hammer		Swab (blood)	17	35.29	64.71	17.65	58.82
		All trace	183	7.10	2.73	11.48	86.89
		Swab	60	5.00	3.33	10.00	86.67
		Tapelift	123	8.13	2.44	12.20	86.99
Spanner		Swab (blood)	4	25.00	100.00	0.00	0.00
		All trace	57	3.51	3.51	3.51	94.74
		Swab	32	0.00	3.13	0.00	100.00
		Tapelift	25	8.00	4.00	8.00	88.00
Chisel		All trace	30	13.33	3.33	10.00	90.00
		Swab	17	0.00	0.00	0.00	100.00
		Tapelift	13	30.77	7.69	23.08	76.92
Shovel		Swab (blood)	1	0.00	100.00	0.00	100.00
		All trace	45	13.33	2.22	11.11	86.67
		Swab	19	10.53	0.00	10.53	89.47
		Tapelift	26	15.38	3.85	11.54	84.62

(*Continued*)

Table 2. (Continued).

Item		Collection method	Total results	Percentage suspect identification	Percentage full profile	Percentage partial/mixed profile	Percentage no DNA
Crow bar		All trace	158	5.70	3.16	6.33	93.04
		Swab	59	3.39	3.39	3.39	96.61
		Tapelift	99	7.07	3.03	8.08	90.91
Axe		Swab (blood)	1	100.00	100.00	0.00	100.00
		All trace	60	8.33	0.00	13.33	86.67
		Swab	14	0.00	0.00	7.14	92.86
		Tapelift	46	10.87	0.00	15.22	84.78
Mattock/Pickaxe		All trace	18	0.00	5.56	5.56	88.89
		Swab	5	0.00	20.00	0.00	80.00
		Tapelift	13	0.00	0.00	7.69	92.31
Torch		All trace	212	17.92	8.49	19.81	75.47
		Swab	100	16.00	12.00	15.00	80.00
		Tapelift	112	19.64	5.36	24.11	71.43
Brick/rock		All	298	6.71	8.39	6.71	87.25
	Rock	Swab (blood)	9	11.11	66.67	11.11	22.22
		All trace	143	1.40	0.70	3.50	96.50
		Swab	10	0.00	0.00	0.00	100.00
		Tapelift	133	1.50	0.75	3.76	96.24
	Brick/paver	Swab (blood)	17	35.29	76.47	5.88	23.53
		All trace	129	8.53	3.88	10.08	89.92
		Swab	13	0.00	0.00	0.00	100.00
		Tapelift	116	9.48	4.31	11.21	88.79
Clip-seal plastic bag		All trace	150	12.67	4.67	14.67	83.33
		Swab	125	12.00	4.00	13.60	84.00
		Tapelift	25	16.00	8.00	20.00	80.00
Bedding		All	968	25.72	27.79	22.62	58.68
		Excised	241	25.31	40.25	19.50	48.96
		Scraping	276	22.83	34.42	10.87	65.22
		Other	253	32.41	11.07	38.74	60.08
		Swab (blood)	56	26.79	55.36	23.21	35.71
		All trace	142	19.72	12.68	22.54	69.01
		Swab	5	0.00	40.00	20.00	60.00
		Tapelift	137	20.44	11.68	22.63	69.34
	Mattress	All	88	14.77	22.73	12.50	72.73
	Mattress protector	All	63	11.11	11.11	11.11	100.00
	Sheets	All	679	32.78	28.25	25.57	53.40
	Blanket	All	403	17.01	28.91	19.39	63.27
Pillow	All		179	21.26	24.41	22.05	62.20

many of these items did return suspect identifications based on partial profiles (either single source or deconvoluted mixtures); including, external car door handles, shirt collars, and mobile phones. Among sexual assault-related samples, breast swabs identified the greatest percentage of suspects after penis swabs (suspect reference samples); no suspect identifications were recorded from perineum samples. The highest percentage of full profiles were reported from oral swabs (most likely complainant profiles, though 6.57% identified a suspect), whereas the lowest proportion of full profiles were from breast swabs.

Some distinct differences in the recovery of full profiles from swabs and tapelifts of trace samples were observed for specific items. Swabs were at least twice as successful as tapelifts for seatbelt buckles, adhesive tapes, cigarette lighters, window frames/sills, drinking vessels, firearm handles, knife blades, sledgehammers, mattock/pickaxes, torches, and bedding. In contrast, tapelifts were more successful for discharged car

airbags, steering wheels, gearsticks, seatbelt straps, motorcycles (including handlebars), power cords, keys, clip seal plastic bags, cartridge cases (both discharged and live), firearm barrels, sweat smears on buildings, mobile phones, shirt collars, helmets, hats, rocks, pavers, and several tools. In contrast to conventional wisdom, tapelifts of non-porous surfaces recovered slightly more full profiles than swabs, and did so also from porous surfaces (Table 3). Furthermore, porous surfaces returned a greater percentage of full profiles and suspect identifications than non-porous surfaces.

Data caveats

A small number of samples were recorded as returning results in more than one category: 106 records were categorized as both partial/mixed and full (likely representing full profiles deconvoluted from mixtures), representing 1.4% of partial/mixed records and 1.1% of full profile results; 339 samples were categorized as both partial/mixed and no DNA, representing 1.5% of no DNA results and 4.4% of partial/mixed results; 2103 samples were categorized as both no DNA and full, representing 9.6% of no DNA results and 22.5% of full profile results; and 23 samples were categorized across all three categories. The bulk of such multiple categorizations were due to samples being reworked, either by concentrating dilute samples that initially fell below the quantification threshold to proceed to profiling, or by reamplification of partial/failed genotyping runs. In the context of the total dataset these multiple categorizations are not considered to substantially impact on the interpretation of profiling success statistics. Manually reviewing every record was outside the scope of this project.

Discussion

The analysis presented here of nearly 20 months of DNA sampling data, representing more than 36 000 individual exhibits, from the Queensland Police Service has revealed some interesting patterns that can inform operational procedures. Averaged over all items/surfaces, trace swabs recovered more full profiles than tapelifts; however, there was substantial variation noted among exhibit types, including many for which tapelifts were the more successful method of collection. Increasing the resolution of the analysis therefore provided a deeper insight into DNA profiling success among items and methods of collection. Interestingly, percentage profiling successes for swabs and tapelifts from porous and non-porous surfaces were highly similar, in apparent contradiction of

Table 3. Comparison of percentage success in DNA sampling between porous and non-porous items/surfaces from Table 2.

Surface	Collection method	Total results	Percentage suspect identification	Percentage full profile	Percentage partial/ mixed profile	Percentage no DNA
Non-porous	All trace	13290	9.15	5.83	11.58	85.98
	Swab	7243	7.17	5.16	8.61	88.30
	Tapelift	6047	11.17	6.51	14.60	83.62
Porous	All trace	2000	17.57	8.09	24.74	71.02
	Swab	97	16.27	7.21	24.77	70.25
	Tapelift	1903	18.54	8.75	24.73	71.60

conventional wisdom that swabs are more successful for non-porous surfaces whereas tapelifts are better for porous surfaces.

It is difficult to compare the data presented here with previous studies from other jurisdictions. The specifics of collection technique, consumables, DNA extraction and STR profiling procedures and kits between organizations and over time are likely to have significant influence on profiling success. In addition, there has been variation across studies in the exhibit categorization strategy used and hence granularity of data analysed. For example, some studies lump all clothing samples together [4,7,9], whereas others separate them into subcategories for specific clothing types [3,5,6]. Further, some studies were deliberately restricted to samples taken from volume crime scenes [8,9], whereas others either were from all crime scenes or did not specify [3–7]. This limits the ability to make truly like-for-like comparisons between studies. Nevertheless, some general trends deserve discussion.

Overall, full profile recovery from trace DNA samples was slightly lower in Queensland than reported from other jurisdictions compared here (Table 4). Interestingly, profiling success for many items included in the comparison was also poorer than that reported from other jurisdictions, despite the current use in Queensland of a more sensitive DNA profiling kit than that used in many of these previous studies. This increased sensitivity may have resulted in increased mixed profile recovery in Queensland. Alternatively, the observed differences could be because of different collection, storage, submission, triage or laboratory procedures in other regions, or a factor of analysing total sample data rather than smaller, selected subsets. For example, the dataset used here included both major and volume crime samples, which are treated in different ways both at collection (only one sample per volume crime occurrence is allowed to be submitted, whereas major crime samples are unlimited) and in the laboratory (major crime samples are automatically reworked if initial DNA profiling results are unsuccessful/incomplete, whereas volume crime samples are not). Such inconsistencies between datasets render the comparison indicative only. Nevertheless, trace DNA profile success was relatively high for items from cars (airbags, seatbelts), drinking straws, chewing gum, cartridge cases, underwear and waistbands, and bedding. The majority of comparisons with previous literature related to swabbed items (Table 4); however, tapelift sampling of many of these items in fact returned more full profiles than swabs (9 out of 19 items). Perhaps the most striking discrepancies were for swabs from hats/caps, inside of gloves, and collars compared with the results of Mapes et al [6]. Within the Queensland data, clear differences in profiling success were observed between collection methods which will contribute towards updated operational procedures.

These data provide valuable insight into DNA profiling success of one of Australia's largest police jurisdictions. Additional research is required to determine whether differences between Queensland and other published data stem from consumables used, collection technique, environmental effects (e.g. increased degradation), or some other factor. Some recent work has suggested that rayon swabs are not ideal for recovering maximum DNA from collected samples [10], although this appears to contradict other research that supports rayon as among the most effective swab materials [11,12]. Additional research is still required here to inform better consumables choice for forensic practitioners. Pleasingly, there is good support in the data presented here for the efficacy of forensic tapelifts, particularly in preference to swabs for many non-porous items. This accords with existing literature that supports tapelifting

Table 4. Comparison of Queensland DNA profiling success data for specific items against equivalent data from the literature.

		This study	Netherlands [6]	Singapore [7]	Switzerland [4]	Switzerland [9]	New Zealand [3]	New South Wales [8]
Exhibit category	Profile Collection	Full	Single	Single	Full/partial>5 loci	Single	Full	Full/partial>12 loci
Cigarette butt	Excised	54	84	81		70.6		
Hat/cap	Swab	3	42					
	Tapelift	8					25	
Collar	Swab	0*	34					
Glove (inside)	Swab	5	25a	11		18.8b		
	Tapelift	5					25	
Torch	Swab	12	27					
Drinking vessels	Swab	38	57	34		55.6	21c	
Knife handle	Swab	3*	19					
Lighter	Swab	2	17					
Firearm grip	Swab	5	6					
Firearms (other)	Swab	3*						15
Handle motorcycle	Swab	0*	9					
Cartridge cases	Swab	4*	6					
Tape	Swab	7	9	16				
Keys	Swab	1*	12					
Hair	Excised	31		21.1				
Drug apparatus	Swab	12		15			21c	
Thrown stones	Swab	0*			7	7.5		
Cables/power cords	Swab	0*			29	12.2		
Tools	Swab	5*d	5e	10	22			15
Clothing	Swab	8f		5		18.8b		
	Tapelift	9g					15h	
	Excised	32i			61			
Blood	Swab	71	68			87.5		
Dataset average	All trace	9j	25k	12		12k	16	14

*greater percentage full profiles from tapelifts where relevant
[a]combined here from latex & fabric glove results
[b]combined category clothing/gloves
[c]combined category drinking vessels/drug pipes
[d]averaged over all tools analysed in Table 2
[e]combined here from screwdriver/crowbar/hand-tools (other)
[f]averaged over hat/cap/underwear/waistband shorts/pants in Table 2
[g]averaged over beanie/balaclava/helmet/hat/cap/underwear/waistband shorts/pants in Table 2
[h]combined here from underwear/socks/upper garments results
[i]averaged over underwear/waistband shorts/pants in Table 2
[j]average profiling success for trace samples only (i.e. excludes biological fluids, hair, cigarette butts)
[k]included bloodstain profiling results

as a highly effective collection method [13,14], including for the specific tape product used by QPS forensic officers [15]. Future research and reporting by other agencies into their success statistics would benefit from a consistent approach to item and profile success categorization, to maximize comparability between studies. This study demonstrates that increasing the granularity of data captured can reveal important trends that can inform best practice at the crime scene and laboratory.

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Disclosure statement

The author declares no conflict of interest.

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References

1. Williamson AL. Touch DNA: forensic collection and application to investigations. J Assoc Crime Scene Reconstr. 2012;18(1):1–5.
2. van Oorschot RAH, Ballantyne KN, Mitchell RJ. Forensic trace DNA: a review. Investigative Gen. 2010;1(1):14. doi:10.1186/2041-2223-1-14
3. Harbison S, Fallow M, Bushell D. An analysis of the success rate of 908 trace DNA samples submitted to the crime sample database unit in New Zealand. Aust J Forensic Sci. 2008;14 (1):49–53. doi:10.1080/00450610802050774
4. Castella V, Mangin P. DNA profiling success and relevance of 1739 contact stains from caseworks. Forensic Sci Int-Gen Suppl Ser. 2008;1:405–407.
5. Dziak R, Peneder A, Buetter A, Hageman C. Trace DNA sampling success from evidence items commonly encountered in forensic casework. J Forensic Sci. 2018;63(3):835–841. doi:10.1111/1556-4029.13622
6. Mapes AA, Kloosterman AD, van Marion V, dePoot CJ. Knowledge on DNA success rates to optimize the DNA analysis process: from crime scene to laboratory. J Forensic Sci. 2016;61 (4):1055–1061. doi:10.1111/1556-4029.13102
7. Wong HY, Tan J, Lim ZG, Kwok R, Lim W, Syn -CK-C. DNA profiling success rates of commonly submitted crime scene items. Forensic Sci Int-Gen Suppl Ser. 2019. doi:10.1016/j.fsigss.2019.10.104
8. Raymond JJ, van Oorschot RAH, Gunn PR, Walsh SJ, Roux C. Trace DNA success rates relating to volume crime offences. Forensic Sci Int-Gen Suppl Ser. 2009;2:136–137.
9. Baechler S. Study of criteria influencing the success rate of DNA swabs in operational conditions: A contribution to an evidence-based approach to crime scene investigation and triage. Forensic Sci Int-Gen. 2016;20:130–139. doi:10.1016/j.fsigen.2015.10.009
10. Bruijns BB, Tiggelaar RM, Gardeniers H. The extraction and recovery efficiency of pure DNA for different types of swabs. J Forensic Sci. 2018;63(5):1492–1499. doi:10.1111/1556-4029.13837

11. Frippiat C, Noel F. Comparison of performance of genetics 4N6 FLOQSwabsTM with or without surfactant to rayon swabs. J Forensic Leg Med. 2016;42:96–99. doi:10.1016/j.jflm.2016.06.002
12. Verdon TJ, Mitchell RJ, van Oorschot RAH. Swabs as DNA collection devices for sampling different biological materials from different substrates. J Forensic Sci. 2014;59(4):1080–1089. doi:10.1111/1556-4029.12427
13. Verdon TJ, Mitchell RJ, van Oorschot RAH. Evaluation of tapelifting as a collection method for touch DNA. Forensic Sci Int-Gen. 2014;8(1):179–186. doi:10.1016/j.fsigen.2013.09.005
14. Gunnarsson J, Eriksson H, Ansell R. Success rate of a forensic tape-lift method for DNA recovery. Problems Forensic Sci. 2010;83:243–254.
15. Kanokwongnuwut P, Kirkbride P, Linacre A. Visualising latent DNA on tapes. Forensic Sci Int-Gen Suppl Ser. 2019. doi:10.1016/j.fsigss.2019.09.091