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An Investigation of Test Impression Methods to Accurately Reproduce Randomly Acquired Characteristics in Footwear Outsoles

Thesis Chair: Dr. Melissa M. Bailey

Abstract Approved: ____

The Scientific Working Group for Shoeprint and Tire Tread Evidence has published standards for making test impressions of footwear and tires using various methods; however, there is little published research on documenting randomly acquired characteristics (RACs) and studies comparing methods of documenting RACs. The purpose of this research was to calculate the statistical accuracy of various test impression methods of capturing randomly acquired characteristics, (such as nicks, scuffs, and cuts). This research focused on making 2D impressions of worn work boots, and sneakers with two methods: (1) the Identicator® inkless shoe print system, and (2) Handiprint® lifting material with black fingerprinting powder. For both methods, three different mechanisms were tested: (1) Dynamic step, (2) Static step, and (3) Rolled. This project was conducted in three phases. The first consisted of documenting the shoes and making the test impressions. The second phase included documenting the RACs that were reproduced on the impressions and identifying randomly acquired characteristics on the outsole of the shoes. The third, and final phase, was comprised of the statistical analysis and interpretation of the results. The statistical analyses concluded that the two techniques with the highest percentage of RACs transferred, Technique 1- Identicator® Dynamic step, and Technique 6- Handiprint® Rolled were statistically similar. The analyses also determined that Static step impressions resulted in a substantial reduction in capture efficacy. Overall, it was shown that the mechanism used to make an impression was of greater influence than the method used.

An Investigation of Test Impression Methods to Accurately Reproduce Randomly Acquired Characteristics in Footwear Outsoles

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A Thesis

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INTRODUCTION

Footwear evidence is often an under-utilized means of individualization, which occurs through the observation of randomly acquired characteristics on footwear outsoles. These characteristics, or RACs, are made during the everyday wear of footwear. They can be scratches, gouges, stone holds, holes etc. The Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD) names RACs as "essential for an identification of a particular item of footwear or tire as the source of an impression."[1] Footwear evidence requires adequate documentation, including photography, and collection of footwear impressions found at crime scenes, which are then submitted to a crime lab as unknown impressions. An impression is only fully scrutinized once shoes are submitted for comparison. Test impressions are then made from the submitted shoes, so as to compare 2D unknown impressions with 2D test impressions. As defined by SWGTREAD, a test impression is quite simply an impression made from footwear (or tires) used as an aid for comparison purposes.[1]

Test impressions can be made using any of several different methods. Early methods used talc powder and black carbon paper with newspapers as cushions.[2] SWGTREAD's Guide for the Preparation of Test Impressions from Footwear and Tires[3] describes several different methods. Several commonly used methods feature commercially available kits or individual products, while others use roller transport film or a clear adhesive sheet with black printing powder, or printing ink. For 3D impressions, SWGTREAD suggests the use of dental stone, or a silicone paste, both of which requires curing; Bio-Foam is another convenient method which has no down time.[3] The current study focused on two methods used to make 2D impressions: Handiprint® lifting material (HLM) coupled with black fingerprint powder and the Identicator®

inkless impression system.[3]

The resulting impressions produced by both methods are different, as is the cost. HLM is a vinyl-backed adhesive, which is covered with a clear plastic cover after the impression is made.[4] This product allows the user to ensure full contact between the outsole and adhesive backing; however, its use is generally limited to a lab setting due to the time involved and the need for a more controlled environment. Because black fingerprint powder is used, clean-up can be time consuming. The impressions made with this product cost about $1.31 each.

The Identicator® system is a self-contained folder-like kit. On one side there is the inkless coater pad, and on the other is the chemically reactive paper. These impressions tend to be much less expensive at approximately 78¢ per impression. This system is very simple, quick, and requires little clean-up. Problems can occur when new coater pads are used, which are so full of the inkless coater that it can overload the outsole. This can prevent the accurate transfer of the relevant details or completely obscure them.

Evidence-quality photography was used to document the outsole surfaces prior to making the test impressions, as is common practice in most crime labs. While photography of known shoes is rarely used for comparisons, it is common in the overall documentation of footwear. The photos also provide a reference for future use if the shoes are no longer available.

Footwear impressions collected from crime scenes may be found to be of poor quality, not revealing many individualizing characteristics of the footwear that created them, or they may not be a complete footwear impression. The unknown impression is only half of the information analyzed during a comparison; the other half is the test impression--the quality of which is well within the analyst's control. Therefore, in order to increase the chances of making an association or exclusion, the test impression must be an accurate representation of the known outsole. This means the test impression needs to capture as much fine detail on the outsole as possible. Two categories of footwear were used for this research: (1) work boots, described as having a tread with depth and an elevated heel with arch and ankle support, and (2) sneakers, described as having a tread that has depth, without an elevated heel, and with arch support. While there is no resolution recommendation for footwear photography, the Scientific Working Group of Imaging Technology (SWGIT) recommends 1,000 pixels per inch (ppi) for fingerprint photography.[6] This recommendation was tested as a possible standard for footwear photography.

This research was being carried out with two main objectives: (1) to calculate the statistical accuracy of the two test impression methods, (2) to determine which method produces the most accurate impression.

METHODS

Forty-two pairs of shoes were donated; of these, 8 pairs of work boots, and 8 pairs of sneakers were chosen for analysis. Several shoes were eliminated due to incorrect shoe type, such as sandals, cleats, or smooth-soled dress shoes. The shoes chosen were of the correct type, work boots and sneakers, and had several naturally-occurring RACs, based on a cursory visual examination. As the shoes had to be worn for impressions, shoes that were extremely dirty were eliminated. A total of six impressions were made from each shoe, using both methods--HLM and Identicator®--and three mechanisms--dynamic step, static step, and rolled.

Photography

Each shoe was photographed to scale, using oblique lighting from multiple directions (Figures 1-9) Next, mid-range (Figures 10 &11) and close up photos (Figures 12-16) were taken. All photos were taken using the following camera and equipment: Nikon® DSLR D7200 camera, Nikon® AF-S DX Micro NIKKOR 40mm f/2.8G lens, Nikon® MC-DC2 remote release cord, Manfrotto Tripod. The camera was set on aperture priority, with an aperture set between f13- f18. The close-up photos were taken with a minimum resolution of 1,000 pixels per inch (ppi), as recommended by SWGIT for latent print photography.[6] The high-resolution photos were then merged, using Photoshop®, to produce a high resolution photo of the entire outsole. Approximately 23 photos were taken of each shoe for documentation purposes, and no further analysis was performed at this time.

Collection of Test Impressions

Each method tested, HLM and Identicator®, was used to make three impressions using three different mechanisms. First, each shoe was individually rolled from heel to toe onto the impression medium (Figs 17 & 18). For the HLM, the analyst's hand was inserted into the shoe to apply even pressure across the insole, and the other hand ensured the material was fully adhered to the outsole as the shoe was slowly slid off the edge of a table. The rolled print for Identicator® was simple--the hand inside the shoe carried out the same function; however, the other hand applied pressure to the outer edges of the shoe, from the outside of the shoe. Dynamic step and static step impressions were made while the shoe was being worn, by a volunteer. Dynamic step impressions were made while taking a natural step (Figures 19 & 20) and static step impressions were made by placing the foot/shoe directly onto the impression media with minimal forward/backward or lateral movement and then removed by lifting the foot off (Fig 21 &22). The placement and removal of the shoe was as close to a 90° angle as possible to the impression surface. The Identicator® is specifically designed for making dynamic step impressions, while HLM has no specific impression designation. Each individual shoe was subjected to six total impressions, using the three mechanisms with each of the two methods.

Determination of RACs

Each impression was independently analyzed for RACs using a 5x magnification light. To avoid investigator bias (‘looking’ for specific RACs), impressions from multiple shoes were analyzed in groups, according to the mechanism used (static step, dynamic step, rolled). Each RAC found on the impression was marked with a fine-point black Sharpie®. Each shoe was then analyzed for RACs using the same magnification light as well as several additional light sources at varying angles and intensities. All RACs visualized on the outsole were then marked with a silver Sharpie® (Fig 23).

In a crime lab, if an analyst is not able to visualize specific RACs on the outsole, that appear in the unknown impression, he/she may not consider it for comparison--the analyst makes the decision to consider or disregard specific RACs. Using this knowledge, each impression was then compared to the shoe; any RACs marked on the impression but not the shoe, were then removed from consideration and further analysis. This measure is taken to prevent false RACs from being considered. False RACs may occur when particles or fibers become attached to the shoe during the making of the test impression, if the surface the impression was taken on had imperfections, or was not completely smooth.

Statistical Analyses

The total number of RACs possible (determined from the shoe itself) was used to determine the percentage of RACs found on each of the impressions generated by the techniques above. When discussing statistics, the term technique refers to the combination of the method with the mechanism used to produce each impression. The percentage of captured RACs was calculated for each impression. All data were analyzed using Statistical Analysis Software®, SAS. The first analysis was a one-way Analysis of Variance (ANOVA), which compared each technique's data set to determine if there was a significant difference between them. The second analysis was a two-factor experiment, with the factors being: (1) type of shoe (work boot or sneaker) and (2) the technique. This analysis used the data from each shoe as a replicate of the technique, to determine if the work boot and sneaker groups had results that differed from the overall results. The null hypothesis for both analyses was "There is no significant difference between the techniques." Tukey's Studentized Range Test was then carried out after each analysis to determine specific significant differences. An alpha value of 0.05 was used for the Tukey's Studentized Range Test. The alpha value determines the level of significance a test result will have and also represents the probability of the test results being incorrect--for instance an alpha value of 0.05 means there is a 5% chance the results are incorrect. The lower an alpha level is the less chance of a mistake; however, there is also a lower chance of finding statistically significant results. Conversely, higher alpha values have a high chance of error and a higher chance of finding statistically significant results.

RESULTS

The results from the two-factor analysis were in two sets. The first set sought to determine if the techniques were statistically similar, and if so, which ones were similar. The second set sought to determine if work boots and sneakers were statistically similar, when accounting for all the impressions.

The data from the first set indicated that the mechanism was a greater determinant of accuracy than the method (Table 1). Neither method was wholly better than the other; however, the rolled and dynamic step mechanisms clearly facilitated more accurate impressions, with significantly higher scores. The static step mechanism, due to its nature, captures a smaller percentage of the outsole, had the lowest average percentage of transferred RACs. The Identicator® had lower standard deviation scores suggesting that analyses using the Identicator® system may be more consistent than analyses using Handiprint® lifting material.

The Handiprint® system's averages had an 18-point range. The rolled mechanism had the highest percentage at 47%, followed by the dynamic step mechanism at 35%, and the static step mechanism at 29%. The Identicator® system had a much smaller range of averages spanning only 8 points. For this method, the most accurate mechanism was dynamic step at 41%, followed by the rolled mechanism at 34%, then the static step mechanism at 33%.

Figure 24 shows the interaction of the data according to technique type and shoe type. The technique types have similar ranges though occurring at different percentage ranges. The data points are colored according to shoe type, with Type 1 (blue) being work boots, and Type 2 (red) being sneakers. Figure 25 shows the distribution of the percentages with regard to technique type when the shoes types are disregarded.

Tukey's Studentized Range Test found three groups of no significant difference, or groups that have statistically similar results. Table 2 contains these results; techniques are listed in descending order of average percentage. Group 1 contains the Handiprint® rolled and Identicator® dynamic step impressions. These two techniques had the highest mean scores: 41% and 47% respectively. Group 2 contains Identicator® dynamic step, Handiprint® dynamic step, Identicator® rolled, and Identicator® static step. These techniques had averages between 33.65% and 41.26%. For this analysis, averages that fell within this range are statistically similar. Group 3 contains the four groups with the lowest average percentages--Handiprint® dynamic step, Identicator® rolled, Identicator® static step, and Handiprint® static step. The range for averages for this group is 29.83%-35.23%.

The second set of data pertaining to the difference in shoe type reveals that sneakers and work boots were not statistically similar data sets. Table 3 contains the averages for sneakers and work boots.

DISCUSSION

Footwear impression comparisons are by no means simple or completely objective--it does rely in part on the expertise of the analyst. Therefore, the best effort must be made to make conclusions with the strongest confidence possible. The quality of test impressions can impact the quality of the comparison, making the production of test impressions very important. During the data analysis portion of the current study, the researchers were surprised to discover that neither method was wholly better than the other and found some possible reasons for this. The first is the individual who was wearing the shoe when the RACs were made was not the individual wearing the shoe for the impression. This is very representative of how test impressions are made in crime labs. Analysts will usually make the impressions themselves or find another analyst to assist in the task. As gaits vary between individuals, there is the possibility that some contact between the outsole and impression media was not being made causing only a portion of the RACs to be transferred. Another factor affecting the test impressions may be a weight difference between the original wearer and the individual making the test impression. Weight differences would cause a different pressure which may cause some RACs to be obliterated or may cause others to appear larger or smaller than they are. A difference of shoe size between the shoe and wearer can also cause a different weight distribution on the outsole causing more or less of the outsole to be in contact with the impression media. If a shoe is slightly too small for the individual who is making the impression, then more of the toe and side portions of the outsole will be transferred. If the shoe is slightly too big, then portions of the outsole may not get accurately transferred, in particular the toe of the shoe.

Another interesting discovery was that the sneaker group had a significantly lower percentage of RACs found on the impressions compared to the work boots. This may be because of the conditions in which these shoes are typically worn. Work boots tend to be worn around construction, factory, farm or similar situations which usually have plenty of sharp objects, rough terrain, and construction waste to step on which may cause larger RACs that are more easily identified. Sneakers are usually worn on smoother terrain such as treadmills, sidewalks, and smooth flooring such as wood or tile, causing much smaller RACs which may be very difficult to see.

Finally, the last factor that almost assuredly played a role was the usage of the methods themselves. Identicator® is a very easy to use, quick process with very little cleanup or special treatment afterward. It’s almost foolproof, except for the occasional new coater pad which can overload the outsole obliterating the finer details. The simplicity and ease of use makes this a great system for on-scene work, such as collecting officers’ footwear exemplars. The Handiprint® lifting material requires much more user skill, to ensure an even application of powder. There is extensive cleanup because fingerprint powder is used to dust the outsole. Then, once the impression is made, it has to be immediately covered with the accompanying acrylic sheet and smoothed with a clean ink roller. This is a very inconvenient system for on-scene use as any wind can blow the fingerprint powder, and even worse, it can cause an impression to fold on itself, before being covered with the acrylic sheet. When the adhesive is unfolded, there is a mirror image of the impression on the folded area. This is very clearly meant to be used in the lab only.

CONCLUSION

In conclusion, neither method was more accurate across all mechanisms; instead, specific techniques proved to be superior. There was no significant difference between the Handiprint® rolled technique and the Identicator® dynamic Step technique, implying they are statistically indistinguishable. Of the three mechanisms, static step was clearly the least accurate. It seems common practice to take multiple test impressions prior to analysis. By preparing rolled and dynamic step impressions prior to footwear comparisons, the analyst can be sure he/she captured as many RACs as possible. This practice would allow the maximum number of possible points of comparison between unknown footwear impressions at a crime scene and test impressions made in the lab. Though RAC location was not recorded in this study, it has been observed that static step impressions may capture RACs in very small portions of the outsole that would not otherwise be captured in the dynamic step and rolled impressions--this may be due to the difference in weight distribution between impression techniques.

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5. Bodziak, W. J. Test Impressions of Known Shoes. In Footwear impression evidence: detection, recovery, and examination; CRC Press: Boca Raton, FL, 2000; pp 285–298.

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APPENDIX I: TABLES

Table 1: Average percentage according to impression technique

Technique	*Average Percentage*	*Standard Deviation*
Handiprint® Rolled	47.33%	41.92%
Handiprint® Dynamic Step	35.53%	42.27%
Handiprint® Static Step	29.83%	48.42%
Identicator® Rolled	34.04%	34.88%
Identicator® Dynamic Step	41.26%	36.62%
Identicator® Static Step	33.65%	35.41%

Table 2: Groupings According to Tukey's Studentized Range Test

Group 1	*Group 2*	*Group 3*
Handiprint® Rolled Identicator® Dynamic Step	Identicator® Dynamic step Handiprint® Dynamic Step Identicator® Rolled Identicator® Static Step	Handiprint® Dynamic Step Identicator® Rolled Identicator® Static Step Handiprint® Static Step

Table 3: Average percentage according to shoe type

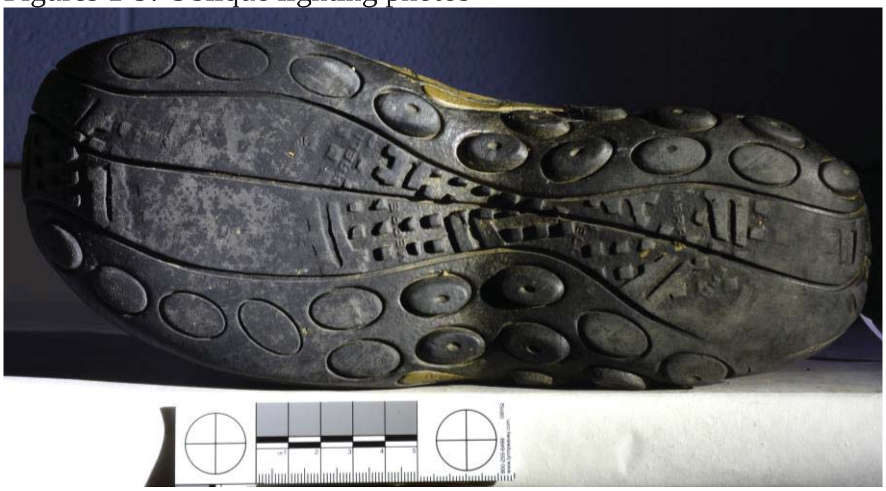
Shoe Type	*Average Percentage*	*Standard Deviation*
Work Boots	39.64	18.57
Sneakers	34.24	13.45

Table 4: Average Percentage per technique for each shoe type

Technique	*Sneaker Average*	*Work Boot Average*
Handiprint® Rolled	38.29 ± 12.19	37.82 ± 22.15
Handiprint® Dynamic Step	34.06 ± 13.86	26.94 ± 16.41
Handiprint® Static Step	28.09 ± 13.24	24.18 ± 15.79
Identicator® Rolled	28.94 ± 10.38	41.53 ± 11.41
Identicator® Dynamic Step	36.41 ± 11.42	29.73 ± 11.43
Identicator® Static Step	39.65 ± 16.34	42.86 ± 14.11

APPENDIX II: FIGURES

Figures 1-9: Oblique lighting photos



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9

Figures 1-9 are photos taken of SK-5-R using oblique lighting techniques, at a fairly low resolution.

Figures 10 and 11: Mid-range Photography

10

11

Figures 10 and 11 are photos taken of SK-5-R, using ambient lighting. The Mid-Range photos have a higher resolution than the Oblique lighting photos.

Figures 12-16: Close-Up Photography

12

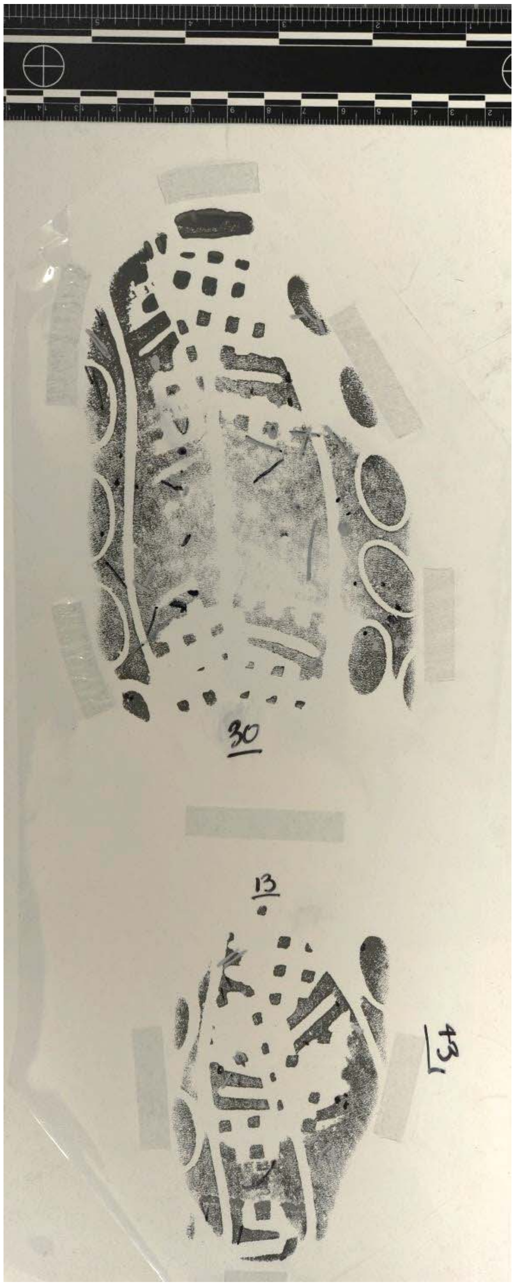
13

14

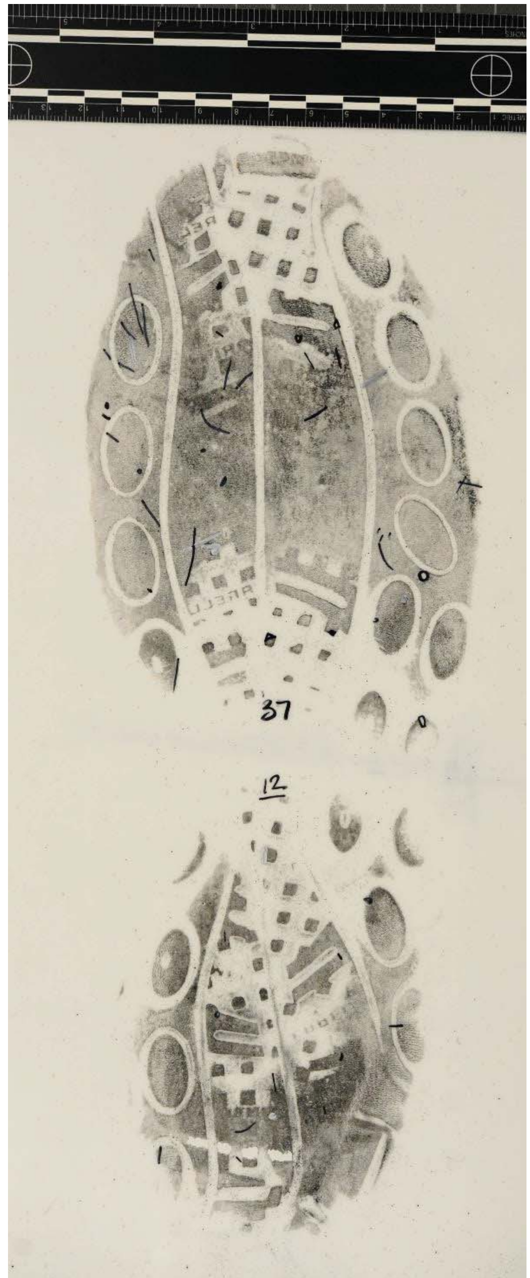
15

16
Figures 12-16 are photos taken of SK-5-R using ambient lighting. These photos have a minimum resolution of 1,00 pixels per inch.

Figures 17 and 18: Rolled Impressions



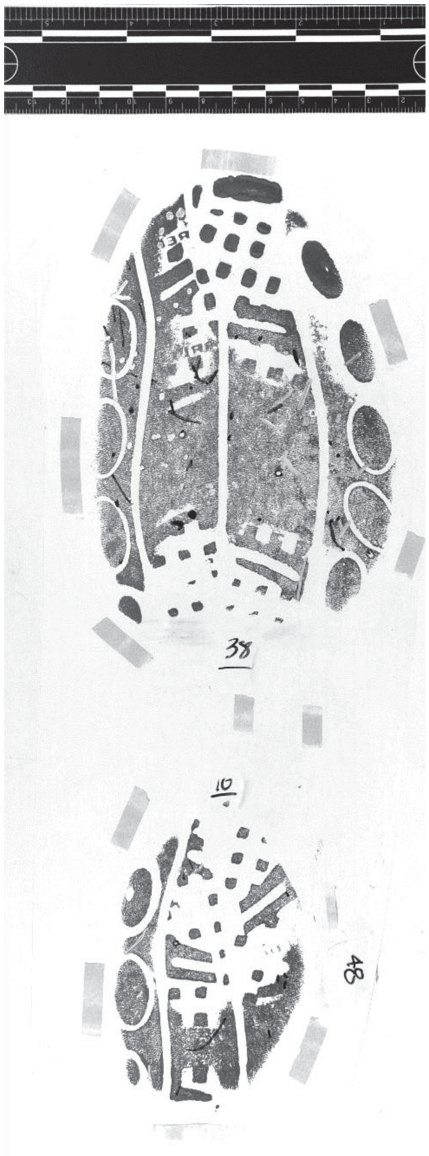
17



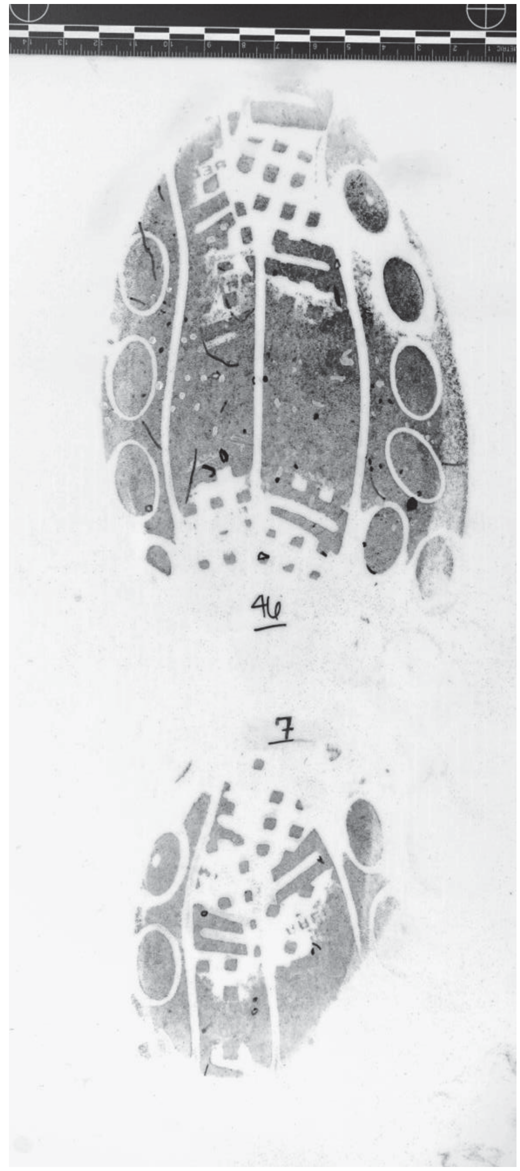
18

Figure 17 is a rolled impression using the Identicator® method. Figure 18 is a rolled impression using the Handiprint® and black fingerprint powder method.

Figures 19 and 20: Dynamic Step Impressions



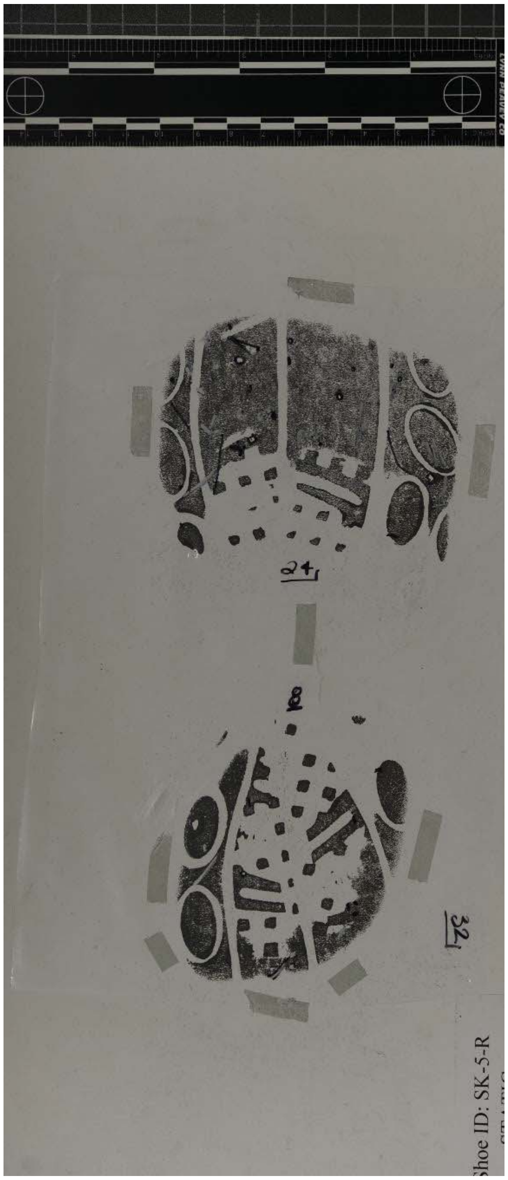
19



20

Figures 19 is a dynamic step impression using the Identicator® method. Figure 20 is a dynamic step impression using the Handiprint® and black fingerprint powder method.

Figures 21 and 22: Static Step Impressions



21

22

Figures 21 is a static step impression using the Identicator® method. Figure 22 is a static step impression using the Handiprint® and black fingerprint powder method.

Figures 23: Visualization of RACS with silver Sharpie®

23

Figure 23 displays how RACs were visualized, then marked for future comparison and verification of RACs on impressions. This photo has been flipped 180º across a vertical axis.

APPENDIX III: STATISTICAL ANALYSES

For all figures within this appendix, Method 1 is Identicator® Dynamic Step; Method 2 is Identicator® Static step; Method 3 Identicator® Rolled; Method 4 is Handiprint® Dynamic step; Method 5 is Handiprint® Static step; Method 6 is Handiprint® Rolled. Shoe Type 1 (blue) is work boots, and Shoe Type 2 (Red) is sneakers.

The GLM Procedure

Class Level Information

Class	Levels	Values
Methods	6	1, 2, 3, 4, 5, 6
Shoe Type	2	1, 2

Number of Observations Read	192
Number of Observations Used	192

Dependent Variable: y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	10280.12398	934.55673	4.47	<.0001
Error	180	37667.89789	209.26610		
Corrected Total	191	47948.02187			

R-Square	Coeff Var	Root MSE	y Mean
0.214401	39.16266	14.46603	36.93833

Source	DF	Type I SS	Mean Square	F Value	Pr > F
M	5	6344.672992	1268.934598	6.06	<.0001
Type	1	1398.060469	1398.060469	6.68	0.0105
M*Type	5	2537.390519	507.478104	2.43	0.0372

Source	DF	Type III SS	Mean Square	F Value	Pr > F
M	5	6344.672992	1268.934598	6.06	<.0001
Type	1	1398.060469	1398.060469	6.68	0.0105
M*Type	5	2537.390519	507.478104	2.43	0.0372

Figure 24: Interaction plot for y between techniques

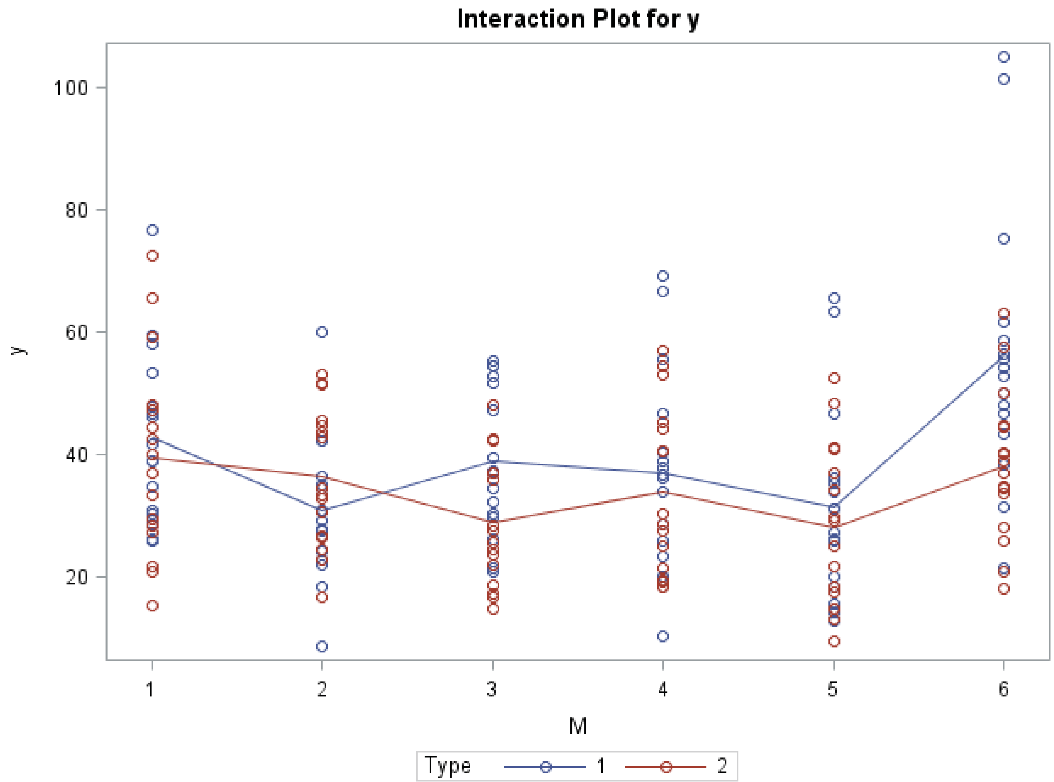


Figure 24. The plotted percentage of each shoe according to the technique. The interaction between the shoe types of each technique are also shown.

Figure 25: Distribution of y between techniques

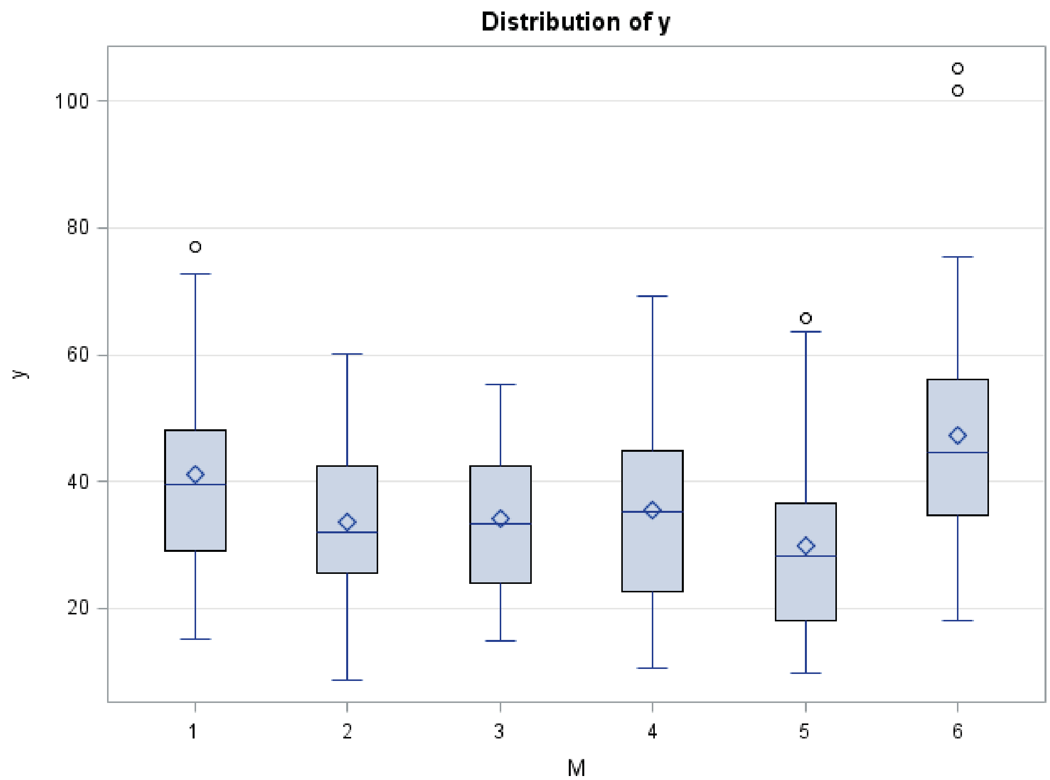


Figure 25. The distribution of percentages according to each impression technique.

Tukey's Studentized Range (HSD) Test for y

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	180
Error Mean Square	209.266 1
Critical Value of Studentized Range	4.07388
Minimum Significant Difference	10.418

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	M
	A	47.326	32	6
B	A	41.259	32	1
B	C	35.525	32	4
B	C	34.037	32	3
B	C	33.650	32	2
	C	29.834	32	5

Figure 26: Distribution of y between shoe types

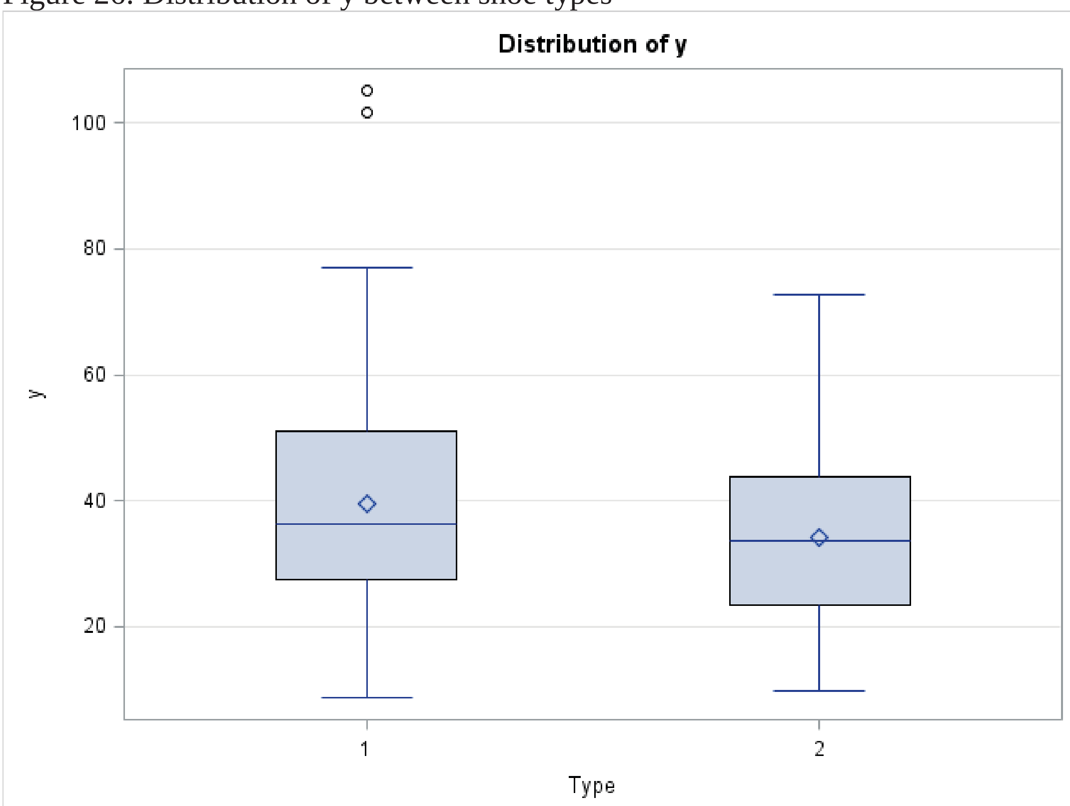


Figure 26.The distribution of percentages across the two shoe types using any impression technique.

Tukey's Studentized Range (HSD) Test for y

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	180
Error Mean Square	209.2661
Critical Value of Studentized Range	2.79057
Minimum Significant Difference	4.1201

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Type
A	39.637	96	1
B	34.240	96	2

Figure 27: Distribution of y between methods with regard to shoe type

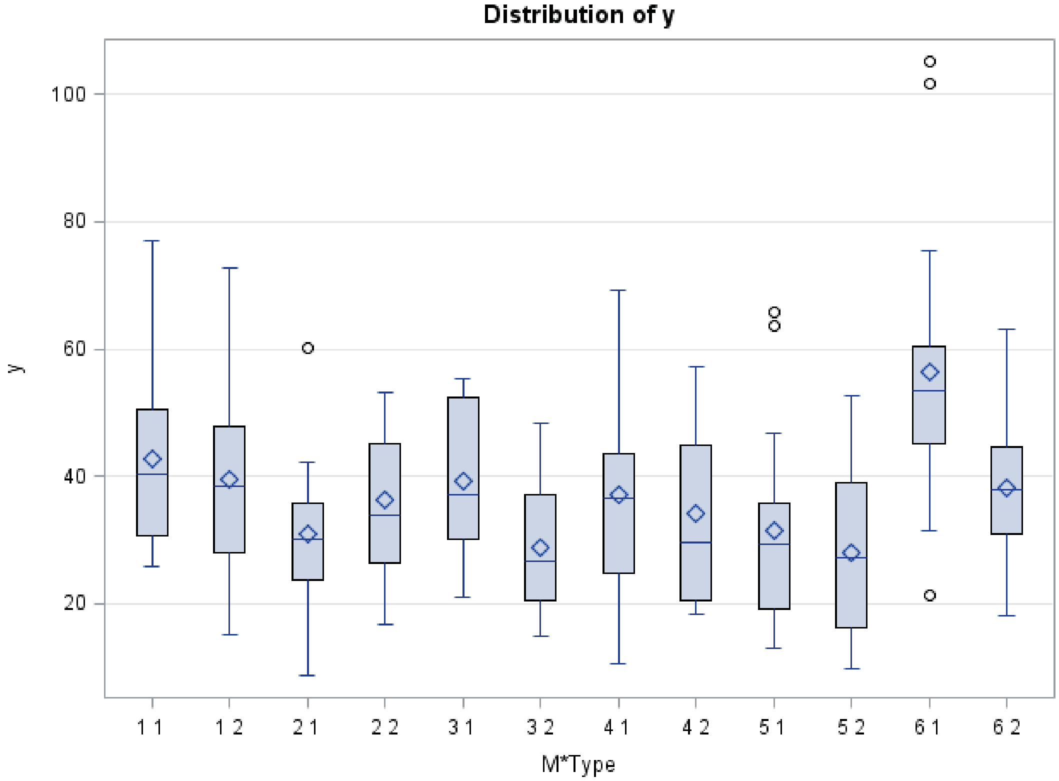


Figure 27.The distribution of percentages with regard to shoe type, and impression technique. The x-axis labels are read as method 1 shoe type 1; method 1 shoe type 2.

Level of M	Level of Type	N	Mean	Std. Dev
1	1	16	42.8637500	14.1082165
1	2	16	39.6537500	16.3437119
2	1	16	30.8925000	11.6120515
2	2	16	36.4068750	11.4170076
3	1	16	39.1356250	12.1088028
3	2	16	28.9381250	10.3822497
4	1	16	36.9862500	16.4118258
4	2	16	34.0631250	13.8574412
5	1	16	31.5825000	15.7900367
5	2	16	28.0856250	13.2431532
6	1	16	56.3600000	22.1544096
6	2	16	38.2918750	12.1873520

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An Investigation of Test Impression Methods to Accurately Reproduce Randomly Acquired Characteristics in Footwear Outsoles

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