# Degradation of the Soles of Shoes, and the Differentiable Prints That They Leave Over Time

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**Abstract:** Footwear impression evidence plays a significant role in criminal investigations and forensics. In almost all instances of crimes, the perpetrator is wearing footwear, and in many of these cases, trace impressions are left in the ground. The shoe prints left behind can either be in printing mediums such as dirt, or flat prints made up of blood or dust. These shoe prints can be photographed or cast and used as class evidence. Damage to the bottom of the shoe, the outsole, can lead to more individualized shoe prints. These damages occur at different rates depending on the physicality of the conditions that the outsoles are subject to. High intensity use of the shoes can lead to quicker individualized damages that can be observed and documented as evidence against the perpetrator. This paper describes the experiment used to measure the damages that occur to the outsole over time, and what activities will lead to higher rates of outsole individualization. This experiment used one pair of shoes specifically for walking only, and another used for rougher activities. The shoe prints made by these shoes were compared to see how the activities affected the outsole over a period of four weeks. The shoe designated for running degraded at a quicker rate and therefore left a more individualized print behind.

*Keywords: Impression evidence, shoe print, outsole, forensic trace evidence*

Shoe prints are an extremely important piece to crime scenes. Around 30% of cases have usable footwear impression evidence (Srihari 2011, Huynh et al. 2003). Most people walk around in shoes and each shoe has a very specific design or tread on the bottom of it. These designs are located on the outsole, the bottom of the shoe that touches the ground while walking. These markings can be imprinted onto soft surfaces like mud or sand, or they can be coated in substances like blood or dust and leave prints of the bottom of the shoe on the ground. Looking at these prints in the most basic way can be used as class evidence. Class evidence is evidence that can be used to broadly include or exclude suspects but cannot be used to identify a specific individual (Kiely 2001). When looking at a bloody print of a shoe on a tile, a defining mark representing a specific brand of shoe could indicate that someone wearing said brand was at the crime scene. Further, by looking at the print more precisely, the specific line of shoe could even be determined. This class evidence can help narrow down suspects (Naples and Miller 2004).

The outsoles of shoes are used constantly and subjected to wear; thus, by looking at shoe prints precisely, prints can be individualized. Little nicks and chips that don't seem to hold significance will be left as part of the pattern in the imprint in the ground. It is impossible to measure the probability of acquiring damages to the outsoles of shoes because damages are random events, but the more

individualized markings on an outsole decreases the chance of someone having an identical match (Adair et al. 2007, Hamburg and Banks). When looking at fingerprints, which are similar to shoeprints in their individualized nature, organizations like the FBI or INTERPOL require either a certain number of distinct points (minutiae) on the fingerprints or follow a nonnumeric holistic matching approach in order to create definitive matches (Ulery et al. 2014). This same method was used in this experiment, as a generic amount of distinct marks were looked for in order to determine individualization.

In order to control variables in the experiment, two pairs of shoes with outsoles made from the same rubber material were used. One pair of shoes was used for walking only, while the other was used for rougher experiences (running, climbing, playing sports). The present experiment analyzed the time it took for the outsole of a shoe to become individualized based on the roughness applied to the shoe. The experiment exists to determine an effective method to conduct this analysis. It was hypothesized that the shoe used for rougher materials would degrade faster than the other shoe, leaving behind a more distinct shoe print.

**Materials and Methods**

In this experiment, two pairs of shoes, men's sprint pro 3.5 (Head sport GmbH, Kennelbach, Austria) for running, and men's life racer (Adidas group, Herzogenaurach, Germany) were used for walking. Both were brand new and had rubber outsoles. Natural dirt was also used as a medium for making prints. Besides materials used to clean the bottom of the shoes in between prints, and a iPhone 13 camera (Apple, Cupertino, CA) that took pictures of the shoes, those were the only materials used in the experiment. First, in order to see what the new shoe print looked like, a print was made of each right shoe in the dirt. Next, a clear photo was taken of each print. Each pair of the shoes was used for a specific purpose, in order to observe the effects that this caused. One pair of shoes was labeled to be used solely for walking around. The other pair of shoes was used for more athletic activities, like running and playing sports such as tennis and soccer. Therefore, one of the shoes went through much rougher experiences than the other. After each week of use, the prints were created and photographed again. This was repeated over a four-week period. After photographing and documenting each print, the prints were analyzed for their unique features. It is impossible to measure the probability of someone's unique shoe print matching another because the damages to the bottom of the shoe are random. Thus, the shoes were marked on how many different unique traits were present on the bottom of them. This was similar to how the FBI deals with fingerprints, by looking for an amount of differing or matching minutiae in order to describe the fingerprints as unique. After the four-week period was over, the shoes were printed one final time, and the prints were compared to see the rates at which each shoe diversified itself from the other in the printing medium.

**Results**

The print made from the right shoe of each shoe type was photographed every week for four weeks. The initial week one print was photographed, and then the following weeks were photographed for 3 consecutive weeks. The shoes designated for walking and running were both photographed and can be seen in Figures 1-8.

**Commented [EW1]:** Do you remember the brand of shoe?

**Commented [EW2]:** What brand of camera?

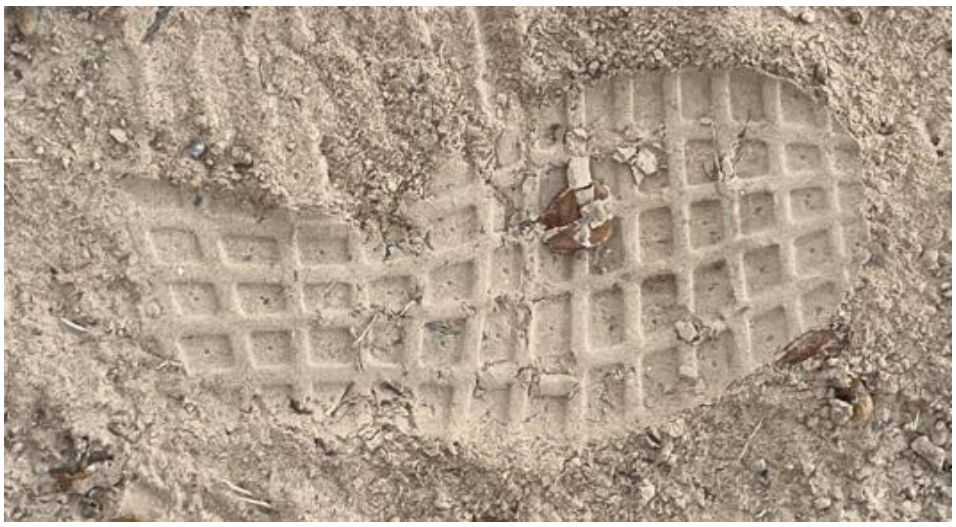

**Fig. 1.** Initial photograph of the print created by the walking shoe.

**Fig. 2.** Photograph from the print created by the walking shoes on the second week.

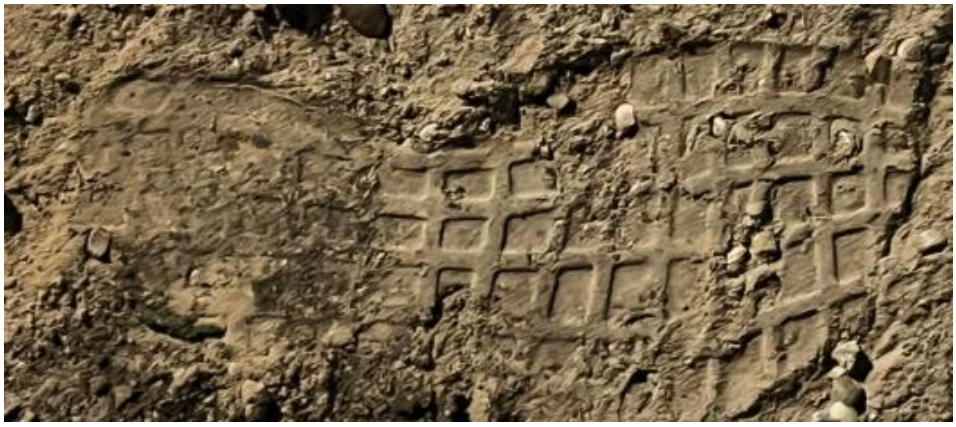

**Fig. 3.** Photograph from the print created by the walking shoes on the third week.

**Fig. 4.** Photograph from the print created by the walking shoes on the fourth week.

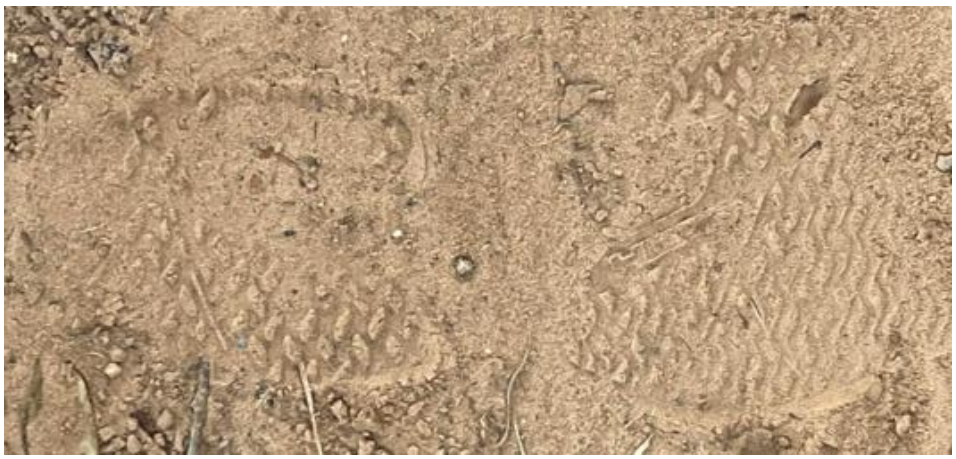

**Fig. 5** Initial photograph of the print created by the running shoe.

**Fig. 6.** Photograph from the print created by the running shoes on the second week.

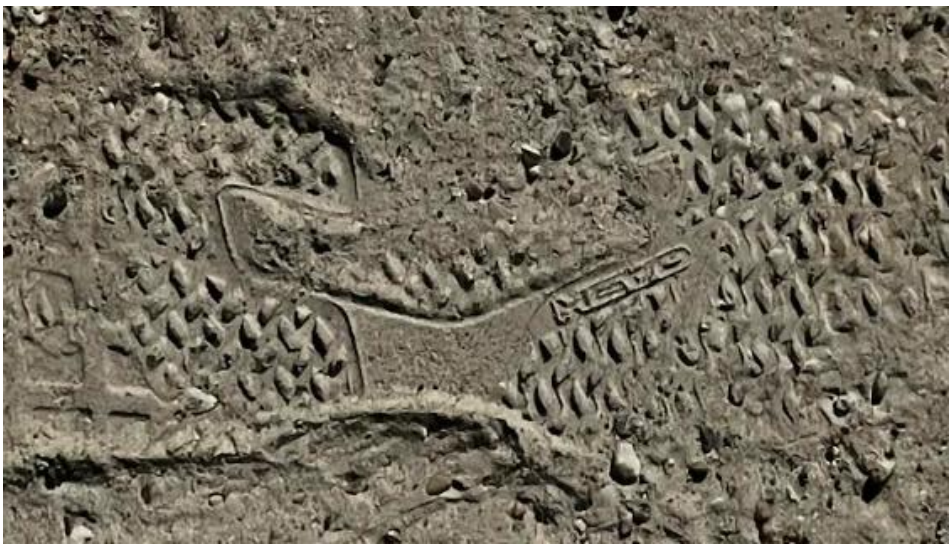

**Fig. 7.** Photograph from the print created by the running shoes on the third week.

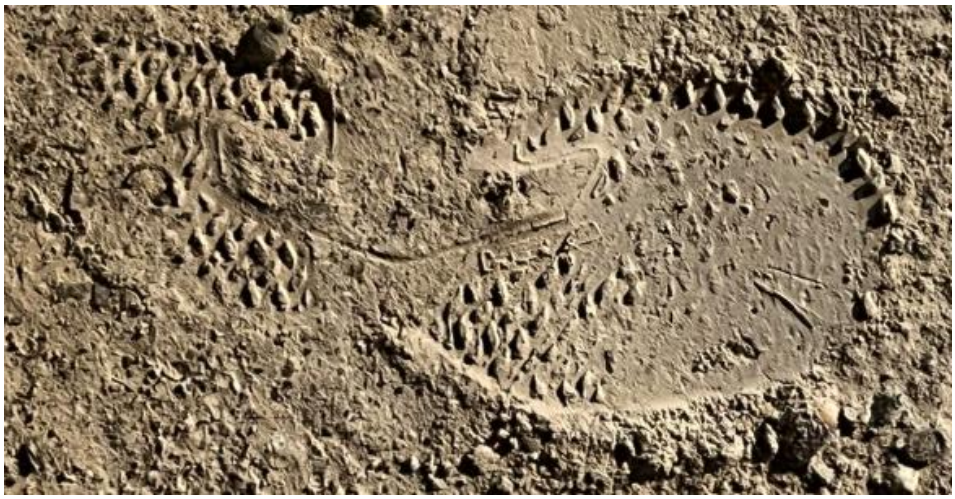

**Fig. 8.** Photograph from the print created by the running shoes on the fourth week.

Looking at the prints made from the shoe designated for walking first, not many differences were created during the time period. Looking at Figure 1, small dots can be observed in the upper squares on the grid left in the print. These dots were small bumps

on the bottom of the shoe, but they were worn down quickly and do not appear in any of the prints left by the shoe in the following weeks (Figures 2-4). One other measurable change that can be viewed by looking at the initial print compared to the final print is the depth of the squares. The shoe designated for walking has a grid pattern that leaves squares in the ground. Looking at the initial print (Figure 1), the squares are very defined and deep. Compared to the final print (Figure 4), these squares seem much more shallow.

Looking at the other shoe prints, made from the shoe designated for running, more degradation can be noticed. Looking at the prints from the early weeks (Figures 5 and 6), Distinct triangle shaped ridges can be seen on the top half of the print. In the later weeks they are shaved down and much less distinct (Figure 7). In the print made in the last week (Figure 8), many of the bumps have been degraded completely flat and the top half of the shoe made a smooth print in the dirt. There are also many notches made in the top of that shoe that could help individualize it from other prints made by similar shoes.

**Discussion**

Analyzing the data from this experiment helped prove the hypothesis. In the prints created by the shoes designated for running, significantly more degradation can be seen across the weeks it was used as compared to the shoes designated for walking. In addition to shaving down and smoothing out the outsole, many individualized markings are noticeable in the print. These minutiae can individualize this print to a high degree of certainty because of the number of marks. The shoe designated for walking, though, doesn't show enough individualized damage to be used as anything other than class evidence. This experiment shows that shoes collect damage over time that can help individualize them, but 4 weeks of only walking in a pair of shoes was not enough to individualize the prints it left.

The shoe's sole changes bring up a limitation of this experiment. While the imprint does seem to lose a considerable amount of depth as the weeks progress, because active wear shaves the outsole down (Gupta et al. 2023), this is hard to measure from a picture alone. Making casts of the footwear impressions as opposed to photos would have given more accurate and measurable data to be interpreted (Snyder 2016). Shoe prints in mediums such as dirt or mud tend to be cast in the field, but prints created out of dust or blood cannot be cast, which shows how there is still importance in viewing individualized images of shoe prints (Kaur et al. 2021).

Similar to issues faced while viewing the photographs of the prints made by the shoe designated for walking, depth is hard to accurately measure in a photograph; therefore, this experiment was limited by using photographs instead of casts of the print. Another limitation that affected this experiment was the amount of time our experiment was performed under. If the experiment had been done over a longer period, the results would have produced more individualizing characteristics in both pairs of shoes and determined a more accurate estimate of the time it takes for a shoe print to become individualized. However, because of the short period of time our experiment was preformed, it was discovered that it takes longer for shoes used solely for walking to develop enough minutiae to individualize it.

One possible confounding variable in this experiment was the fact that the two shoes were of different make. This did not have much effect on this experiment, though, because the outsoles of both shoes, whilst different shapes, were made of the same material, rubber.

Building off our research we have learned that shoe soles do show individualization after a period of wear and tear. In the future our research can be used to repeat this experiment with a much larger pool of photos regarding a longer time frame, and the use of casts to better analyze a soles individuality. In the future the data collected could be used in case profiling of suspects, and potential evidence in a case.

**References Cited**


**Adair, T. W., Lemay, J., McDonald, A., Shaw, R., Tewes, R. 2007.** The Mount Bierstadt Study: an experiment in unique damage formation in footwear. *Journal of Forensic Identification.* 57(2): 199-205.

**Gupta, S., Chatterjee, S., Malviya, A. 2023.** Effect of shoe outsole wear on friction during dry and wet slips: a multiscale experimental and computational study. *Multiscale Sci. Eng.* 5:62-76.

**Hamburg, C., Banks, R.** Evaluation of the random nature of acquired marks on footwear outsoles. https://archive.gfjc.fiu.edu/ipes/presentations/Hamburg_random-acquired-marks.pdf

**Huynh, C., de Chazal, P., McErlean, D., Reilly, R., Hannigan, T. J., Fleury, L. M. 2003.** Automatic classification of shoeprints for use in forensic science based on the Fourier transform. *International Conference on Image Processing*. 3:569-72.

**Kaur, A., Jamal, F., Shikha, Ramesh, A., Sojan, A., Dileep, D. 2021.** Collection, preservation, and packaging: forensic evidence management, pp. 51- 105. *In* J. Singh and N. R. Sharma (eds.), Crime scene management within forensic science. Springer, Singapore.

**Kiely, F. 2001.** Forensic evidence: science and the criminal law. CRC Press LLC, Boca Raton, Fl.

**Naples, V., and Miller, J. 2004.** Making tracks: the forensic analysis of footprints and footwear impressions. https://anatomypubs.onlinelibrary.wiley.com/doi/pdf/10.1002/ar.b.20025

**Snyder, C. 2016.** A comparison of photography and casting methods of footwear impressions in different sandy soil substrates. *Journal of Forensic Identification.* 66(1): 37-58.

**Srihari, S. 2011.** Analysis of footwear impression evidence: final technical report. https://www.ojp.gov/pdffiles1/nij/grants/233981.pdf

**Ulery, B., Hicklin, R. A., Roberts, M., Buscaglia, J., 2014.** Measuring what latent fingerprint examiners consider sufficient information for individualization determinations. *PLoS ONE.* 9(11): e110179.