B1_146_PF: AN INVESTIGATION INTO THE CORRELATION BETWEEN THE SHAPE OF THE BLOODSTAIN AND THE BLOOD SOURCE VELOCITY

Ruamsiri Songsaeng,[1,*] Ratchapak Chitaree,[2]
[1]Forensic Science Graduate Programme, Faculty of Science, Mahidol University, Thailand
[2]Department of Physics, Faculty of Science, Mahidol University, Thailand
*e-mail: ruamsiri_s@outlook.com

Abstract: Bloodstain pattern analysis is a topic in forensic science discipline that analyzes the characteristics of bloodstain at a crime scene. The patterns indicate what actions or series of the events might occurr at the scene, known as crime scene reconstruction. Free falling of the blood droplet from the blood source, for example wound and bloody object, results in a circular shape of the bloodstain. In case of having horizontal velocity such as walking and running, it causes the change in shape of bloodstain and spine formation. Knowing the correlation between the shape of bloodstain and the horizontal velocity helps the investigator to have more information to estimate the action that might occur at the crime scene. This gives an evidence-based clue to the investigators to answer a question such as 'Are these actions consistent or conflicted to the testimony?' So, the aim of this study is to investigate the correlation between the blood source velocity and the shape of bloodstain including the spine formation. The method of this study is that a bloody weapon, knife, was fixed stationary at a specific height and the surface was moved, relative to the knife, with different velocities. To create the moving surface, a belt conveyor was constructed. The size of horizontal bloodstain was recorded at each velocity. The result shows an obvious correlation between the shape of a bloodstain and the blood source velocity. The ratio between length and width of bloodstain increased as the blood source velocity increased. The advantages of this study are that we can estimate the range of the blood source velocity from observed bloodstains. This clearly helps the investigators to reconstruct the crime.

Introduction: Bloodstain pattern analysis (BPA) is an important topic in forensic science. The knowledge obtained from BPA can be used to reconstruct the actions and series of events that occurred at a crime scene. BPA is the analysis of the characteristics of bloodstain such as the shape, size and the patterns for the interpretation of the actions that resulted in those bloodstains. Apart from the DNA analysis that can answer the question 'who' which becomes valuable scientific evidence in the court, BPA is also helpful to the court in order to answer the question, what action was done by the person. The answer of the question leads to a significant concern whether the person is guilty or not.

The sources of bloodstain come from many types of actions such as the contact between the blood source and the surface resulting in a transfer stain. The other case, for example, is the blood droplet that leaves from a blood source, trajects through the air and impacts upon to the surface causing a bloodstain. The shape of the bloodstain largely depends on the angle of impact. The blood droplet that impacts perpendicular to the surface results in a circular shape of the bloodstain. The action causing the circular bloodstain is a free-falling or passive drop from a stationary blood source which can be from both injured person and bloody object. The falling blood droplet is considered to be due to only the gravity while the air resistance can be neglected due to a small size of the blood droplet. There are many research that study the correlation between the characteristics of circular bloodstains and the physical condition of blood source such as the height of the blood source and types of the objects[1,2]. The studies showed the correlation among these characteristics, for example the types of the objects correlate to the size of the droplet in which a blunt object gives larger droplets than the ones obtained from the sharp object. The size of the blood droplet correlates to the impact velocity which also relates to the height of the blood source[2]. These studies can be applied to the investigation to estimate the height and the types of the blood source. Although the correlation found did not lead to an exact event reconstruction, this information can be a guideline for narrowing the possibility of the event regarding the blood source.

Not always that the blood source has been stationary in a real situation, it has the motion of the blood source, for example the injured person runs and the person holds a bloody object and walks. The study of only the passive drop is not enough to cover all actions in the real situations. This prompts the authors to investigate how a blood source moving with a horizontal velocity affects the characteristics of the bloodstain. Theoretically, as the blood droplet leaves from the horizontal moving blood source due to the gravity, the dimensional motion makes the blood droplet to fall along a curved path to the surface. Each trajectory corresponds to a specific angle of impact. So, the shape of bloodstain changes from circular (perpendicular impact) to more elliptical shape[3] (angled impact) and has the spine formation[4]. In this study, the correlation between the characteristics of the bloodstain that resulted from blood dripping from the blood source and the blood source velocity was investigated to categorize the range of velocity causing the change of the bloodstain and the spine formation. The blood source in this study was chosen to be a bloody weapon imitating the situation of a person holding the weapon and was at a slow pace.

Methodology: An appropriate arrangement to create a moving blood source was done by fixing the blood source stationary and creating the moving surface. This arrangement was more convenient to control the velocity and the dripping of the blood than creating a moving blood source. The velocities of the surface were varied to investigate the correlation of the characteristics of bloodstain in terms of the length, width, a number of the spines, a number of satellite and the satellite distance from its parent stain.

Belt conveyor: To create the moving surface, the belt conveyor was constructed as shown in **Figure 1**. The distance of the belt for this experiment was 1.3 m and the width of the belt was 6.35 cm. The belt was made from the polyvinyl chloride material and covered the surface with the calculator paper. The motor could be adjusted for a selected relative motion between the blood source and surface.

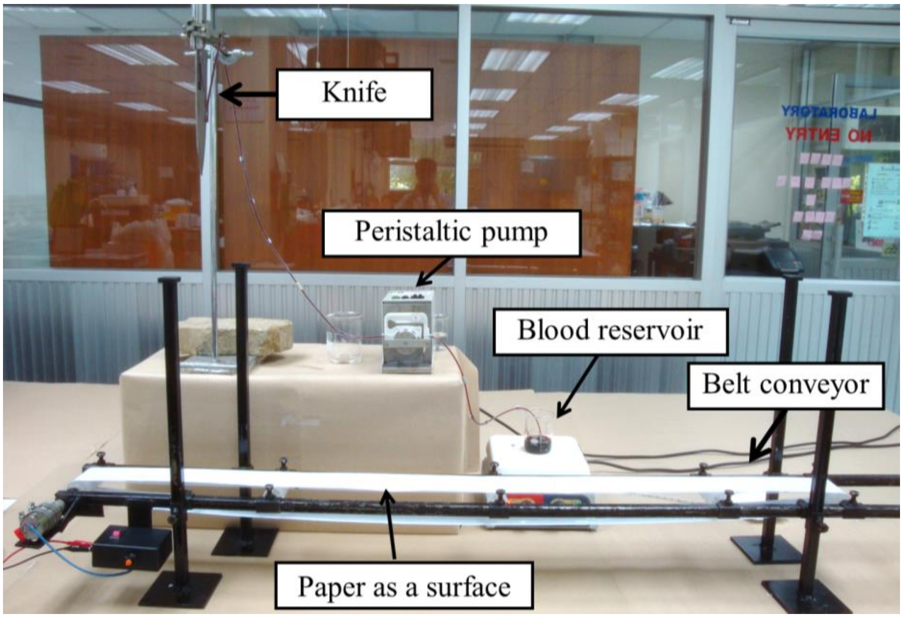

Figure 1. The experimental set up for this study.

Dripping part: The kitchen knife was chosen as a weapon for this experiment. This is because it was easily found in household and commonly used to commit a crime[5]. The kitchen knife is a single bevel as shown in **Figure 2**. To create blood droplets from the tip of the knife, the peristaltic pump was used to draw the blood from the reservoir to the blade and let it flow to the knife tip. The peristaltic pump was used in order to constantly control the blood dripping rate. The blood was warmed at 37 °c throughout the experiment in order to mimic the human body temperature. The tip of the knife was 50 cm above the surface. This is the height averaged from the tip of the blade to the ground obtained from thirty samples of Thai men aged between 21 – 35 years old grabbed the knife and stood up straight.

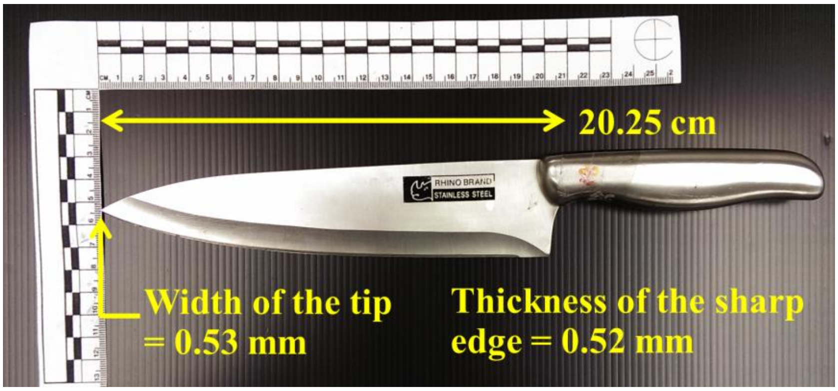

Figure 2 The picture of kitchen knife used in this study

The porcine blood was used as a replacement of the human blood due to the concerns of the hazard and difficult handling of the human blood. In fact, the porcine blood has the similar physical properties to the human blood and it is easy to obtain[6]. The velocities of the belt were varied within a selected range to see the differences and the correlation between the velocities and the characteristics (in **Figure 3**) of the bloodstain in terms of the width and length of the bloodstain, a number of spine formation and a number of satellite stains.

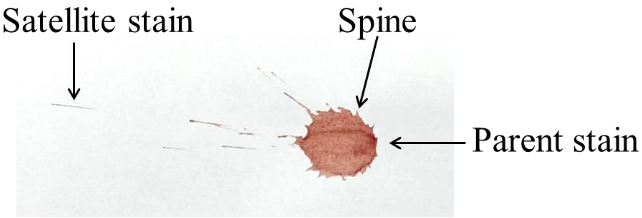

Figure 3. The characteristics of spatter bloodstain on a surface moving relative to the blood source.

Results and Discussion:

The shape of the bloodstain: there was an observable correlation between the shape of bloodstain and the blood source velocity. The increase of the velocity resulted in the increase of ratio between the length and the width of bloodstain as shown in **Figure 5**. The increase of the ratio indicated the change of bloodstain shape from circular to more elliptical shape as shown in **Figure 4.** This suggests that the ratio between the length and the width can be used to estimate the range of blood source velocity. The precision of the size of the bloodstain in the velocity was good and the error of both the length and the width were less than 0.05 cm.

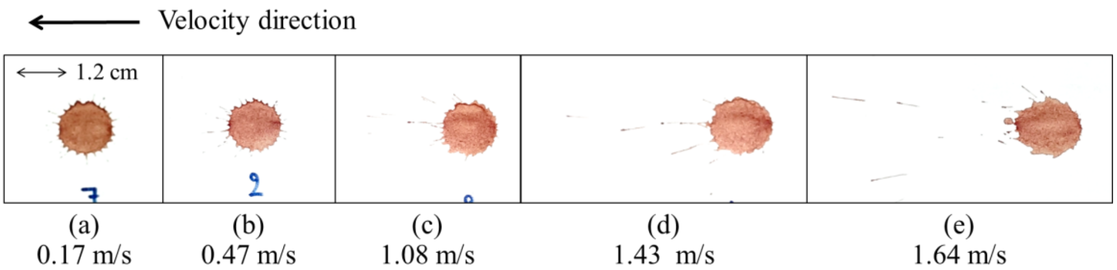

Figure 4. The characteristics of bloodstains impacted to the surface at different velocities, 0.17 (a), 0.47 (b), 1.08 (c), 1.43 (d) and 1.64 (e) m/s.

Number of the spine: The number of the spine of the bloodstain tends to decrease as the velocity was increased as shown in **Figure 6**. This information may be used to estimate the range of the blood source velocity. This is because some velocities had the number of spine overlay to each other, so the estimation of the exact number could be incorrect. At the low velocity which was 0.17±0.01 m/s, the spine around the bloodstain distributed equally whereas at higher velocities started at 0.47 ±0.02 m/s, the amount of spine at the same direction as the velocity were greater than the backward direction in **Figure 4**. The advantage of this appearance is that it can be used to determine the directionality of the blood source motion.

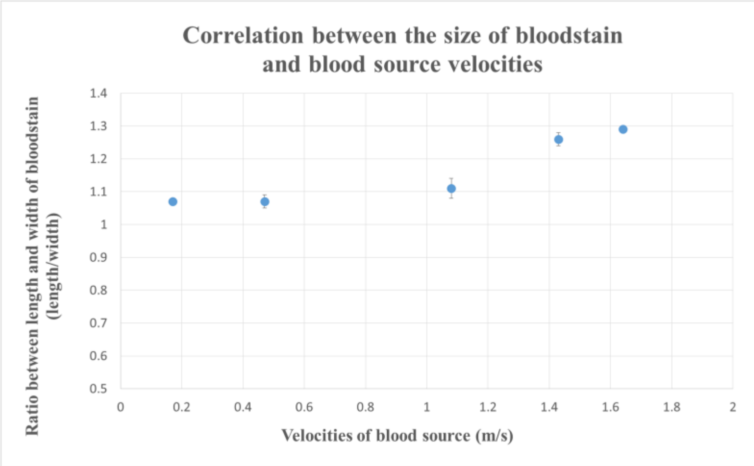

Figure 5. The correlation between the size of bloodstain as a ratio between the length (cm) and width (cm) and the blood source velocities (m/s).

Number of satellite stain: The number of satellite stain tends to increase as the velocity increase, however, there was a wide range of the error in all velocity as shown in **Figure 7**. As a result from the large uncertainty, the number of satellite stain is not an appropriate parameter to estimate the velocity of the blood source. The limitation of this experiment was that the width of the belt was restricted according to the size of the calculator paper and, therefore, not large enough to accommodate all satellite stains generated. The directionality of the motion of the blood source can be estimated in a similar way as discussed in the section of the number of spines. That is a higher number of spine found in the same direction as the velocity as shown in **Figure 4**.

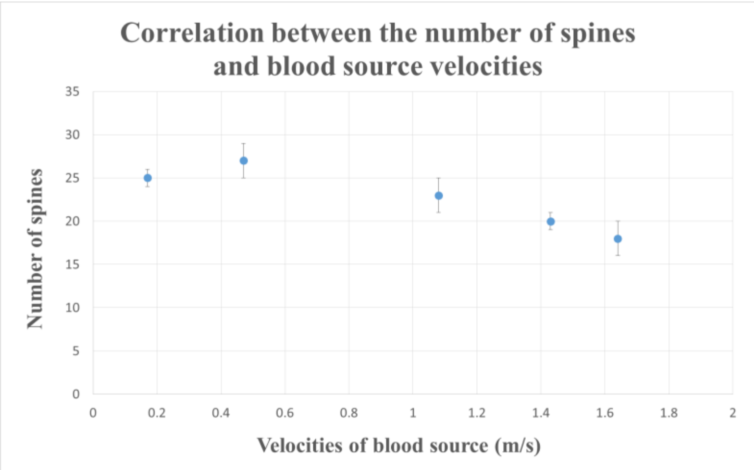

Figure 6. The correlation between the numbers of spines and the blood source velocities (m/s).

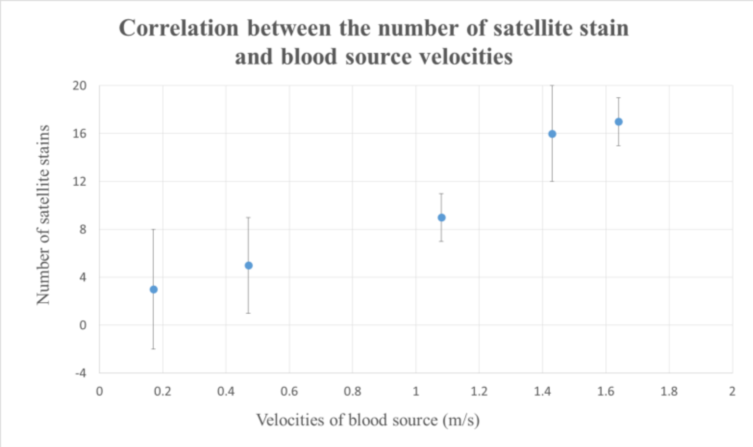

Figure 7. The correlation between the number of satellite stains and the blood source velocities (m/s).

All correlations observed could be used as a guideline for the investigators to estimate the range of the blood source velocity and the directionality of the motion although this study had the limitation that it was fixed to only one condition. Other parameters should be investigated in order to see the variation of the parameters such as the types of the surfaces, types of the weapons and the height of the blood source. As the correlation of the shape of bloodstain and the blood source velocity was investigated, further study may lead to an exact velocity that causes the shape of bloodstain to shift from circular to the elliptical shape and the extension of the velocity range to cover the motion in a real situation.

Conclusion: The correlation between the characteristics of bloodstain and the blood source velocity were investigated. The shape of bloodstain and the number of spines is observed to be correlated to the velocity which can be used to estimate the range of velocity of the blood source. Additionally, the spine and the satellite stain can be used to evaluate the directionality of the motion. This should be noted that the experimental data observed and collected were under controllable conditions laboratory. Further studies may include other factors that affect the characteristics of bloodstain such as surface and aging of blood.

Acknowledgements: Financial support from Forensic Science Graduate Programme, Faculty of Science, Mahidol University is gratefully acknowledged. The author also thanks, Dr. Chutchai Pawong for this assistance in the construction of belt conveyor apparatus.
a

References:
1. Hulse-Smith L, Mehdizadeh ZN, Chandra S. J Forensic Sci. 2005;50:54-63.
2. Kabaliuk N, Jermy MC, Mprison K, et al. Forensic Science International. 2013; 228:75-82.
3. Pizzola AP, Roth S, De Forest RP. J Forensic Sci. 1986;31:50-64.
4. Adam DC. Forensic Science International. 2012; 219:76-87.
5. Kellermann L, Westphal L, Fischer L, Harvard B. JAMA. 1996;273:1759-1762.
6. Raymond MA, Smith ER, Liesegang J. Science & Justice. 1996;36:153-160.