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Vacuum Cupping Under Various Negative Pressures: An Experimental Investigation

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***Abstract*—In this study, a simulated vacuum chamber was designed to investigate the cupping effects of vacuum pressure. The results showed that finger tip temperature was increased as the vacuum pressure was increased. When the vacuum pressure was -60mmHg, the peak finger tip temperature was 34°C, which was 6.7°C or 24.5% higher than before vacuum pumping began. The results also indicated a linear relationship between the suction height and the vacuum pressure. The mathematical representation of this relationship can be expressed as $H=0.1|P_v|$, where H and P_v are measured in mm and mmHg, respectively.**

Keywords—cupping; vacuum pressure; finger tip temperature; suction height

I. INTRODUCTION

Cupping refers to a form of traditional Chinese medicine therapy in which a cup is applied to the skin and the pressure in the cup is reduced via a change in heat or by suctioning out the air inside the cup, so that the skin and superficial muscle layer are drawn into and held in the cup [1,2]. Cupping is applied by practitioners to certain acupuncture points, as well as to regions of the body that are affected by pain where the pain is deeper than the tissues to be pulled. Generally, the cup is left in place for about 10 minutes, with the typical range of placement times being from 5-15 minutes. During this time, the skin becomes reddened due to the congestion of blood flow. Cupping therapy is a process of suctioning or vacuuming sections of the body's meridian system for the purposes of drawing out toxins, pain management, increasing blood flow, and promoting a healthier flow of chi energies [3].

Traditional cupping, which involves the use of heated cups, also has some similarity to moxibustion therapy. In traditional cupping, heating of the cups was the method used to obtain suction. More specifically, the hot air in a cup has a low density and, as the cup cools with the opening sealed by the skin, the pressure within the cup declines, causing the skin to be sucked into the cup. With this approach, the cups are hot and have a stimulating effect similar to that of burning moxa wool.

Most Chinese medicine clinics now use vacuum cupping for their convenience and to avoid the possibility of burns [4,5]. By extracting the air from the cup, it can adhere to the skin surface; these cups are easy to use, convenient, and safe. Vacuum cupping cups have a vent and check valve. The cup is held over the patient and the pistol grip pump or piston is used to extract the air, making the cup interior a vacuum. After the air is removed, the check valve remains tight so that the skin is pulled inside the cup. There are two methods for vacuum cupping. The first is electric cupping that uses a vacuum pressure of 76mmHg for one minute; the second is manual cupping that uses a vacuum pressure of 45-60mmHg for five minutes. The average manual cupping pump trigger can pull back 40mm, creating 35-85kPa of negative pressure. The largest negative pressure that can be maintained for 30 minutes is ≥25kPa [6].

Modern medicine asserts that vacuum cupping breaks cutaneous and subcutaeous capillaries, clearing the meridians and collaterals and eradicating disease. As cupping is proven to benefit health, many scholars have begun to research this field [7-9]. A literature review revealed that the effects of vacuum pressure have yet to be investigated for either electric or manual cupping. Therefore, this study focused on vacuum pressure and integrated modern technologies to improve the treatment efficacy of this traditional method of healing.

II. Materials and Methods

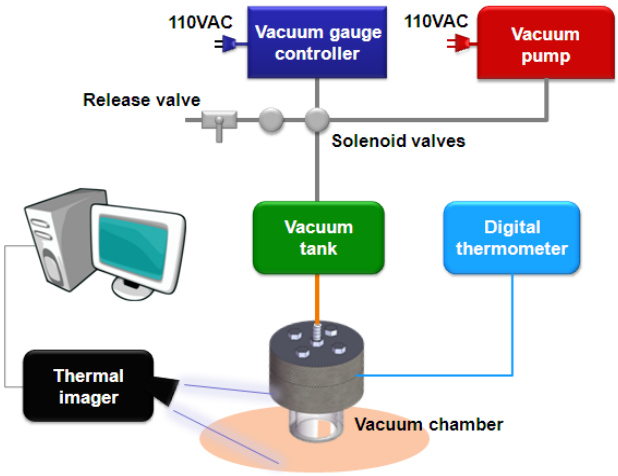
Most vacuum cupping cups are made of glass or transparent plastic and are bell shaped; smaller cups have a volume of approximately 30-60ml and larger cups have a volume of 60ml. Vacuum cupping sets include several plastic cups and a pistol grip pump. Some sets also include a rubber tube used to connect the pump to the cup for cupping certain portions of the body.

In traditional fire cupping, the atmospheric pressure inside the cup drops after the air inside the cup has been burned away, creating a negative gage pressure. The following equation describes the relationship between absolute pressure (P_{abs}), atmosphere pressure (P_{atm}), and vacuum pressure (P_v).

$$P_{abs}=P_{atm}+P_v \quad (1)$$

Figure 1 shows the test device used in this study; a vacuum pump was used to remove the air within the cup. A vacuum gauge controller with an LED digital

display and an operating pressure range of 0.001-1000 mmHg was used. The vacuum system included a release valve and a solenoid valve for safety and a vacuum tank to maintain vacuum stability. The upper portion of the cupping simulator vacuum chamber was made of stainless steel (AISI304), and the lower portion was made of transparent acrylic. The vacuum chamber used this transparent material to echo the core four types of examinations in Chinese medicine (inspection, listening and smelling, inquiry, and palpation). A ruler was etched into the side to observe how far the surface of the skin was raised, and a laser pointer was also used to record the suction height. A thermal imager was used to capture and record changes in the surface temperature of the area near the cupping site. The thermal images can serve as an automatic continuous monitoring system capable of observing a large area of surface temperatures at a distance. The images can also be used to analyze the effects that changes in vacuum pressure have on the treatment efficacy of vacuum cupping.



(a) schematic diagram

(b) photo diagram

Figure 1 - Experimental setup.

Normal human body temperature is not exactly 37°C [10]; that value represents the average of a range that varies depending on gender, age, time, and activity. This study measured the finger tip temperature (FTT) before and after therapy in order to investigate the topic at hand. Just as the meridians and collaterals in traditional Chinese medicine correspond to blood vessels and nerves in Western medicine, the FTT directly reflects the blood flow in peripheral blood vessels. Thus, as cupping claims to promote the flow of blood and qi, in reality, it helps clear blood vessels and nerve pathways. The FTT values measured in this experimental study were taken on the distal phalanx of the left index finger for all participants. To measure FTT, a thermocouple was held against the distal phalanx via breathable medical tape to prevent it from shifting position and to reduce any influence from the ambient temperature. The tape was adhered lengthwise along the finger rather than being wrapped around the finger so as to not restrict blood flow in the distal phalanx. A K-type thermocouple and digital thermometer were used to retrieve temperature readings.

III. Results and Discussion

The change in suction height (H) along with vacuum pressure (P_v) was investigated first. The vacuum pressure ranged from -10 to -60mmHg and the vacuum pump ran for 180 seconds. The measurement data for the four participants (coded F1, F2, M1, and M2) is shown in Figure 2. The data distribution indicated that suction height rose as vacuum pressure increased. The linear increase had an average slope approaching 0.1mm/mmHg. This relationship is shown in the following equation:

$$H=0.1\,|\,P_v\,|$$

Suction height was measured in mm and vacuum pressure was measured in mmHg. The largest standard deviation for all data shown in Figure 2 was 0.1mm.

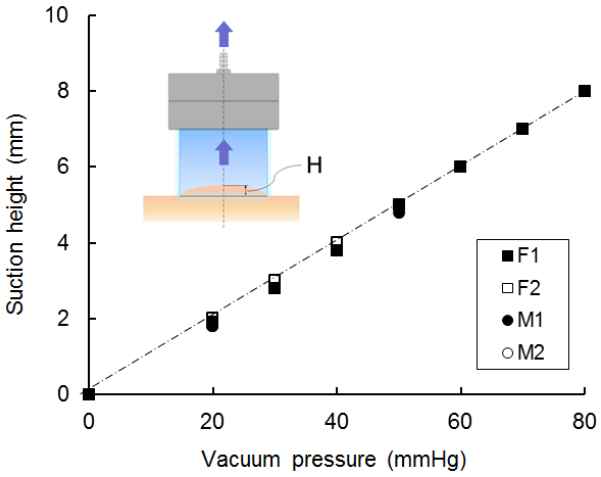


Figure 2 - Suction height (H) vs. vacuum pressure (P_v).

Figure 3 shows the non-dimensional FTT ($\overline{T}_f$) as the treatment time increased for vacuum pressures of -30 and -60mmHg. As ambient temperature influences the surface temperature, non-dimensional FTT was used to show the percentage increase in FTT relative to the ambient temperature and was defined as $(T_f-T_a)/T_a$. The results show that during the vacuum pumping time ($0\le t\le 180$s), non-dimensional FTT ($\overline{T}_f$)

increased and continued to increase after air stopped being pumped. The data presented in Figure 3 is based on the negative pressure Pv=-60mmHg. The highest non-dimensional FTT was $\overline{T}_f$ =1.95 and actual FTT was 34°C, 6.7°C or 24.5% higher than when vacuum pumping began.

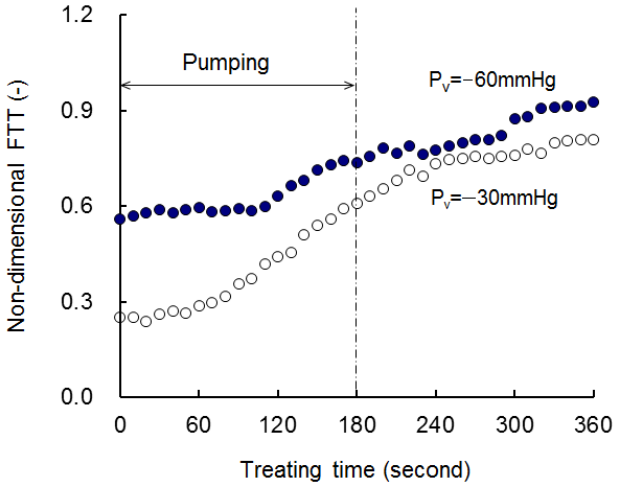
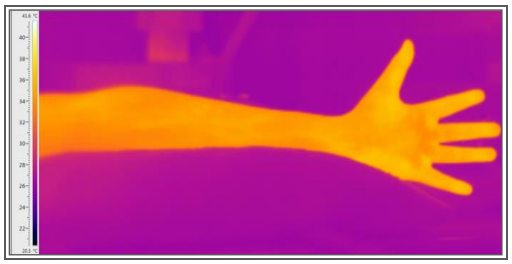


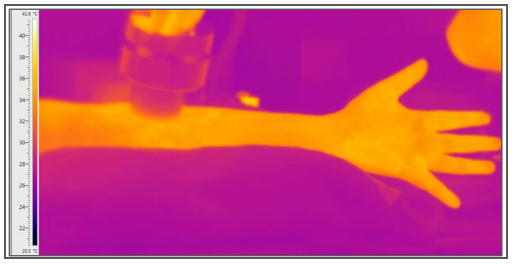
Figure 3 - Variation of non-dimensional finger tip temperature over treatment time.

As the thermal imager was more sensitive to temperature variations, it was used for the vacuum pressures -10 and -20mmHg. As cupping began, images were taken of the cupping site, forearm and palm (Figure 4). A temperature color scale is provided on the left of the images where temperature increased as the coloration faded to white. The images indicate that the palm temperature was noticeably higher and FTT was higher than the palm temperature. A vacuum pressure of -10mmHg was used during cupping on the forearm; the temperature ranged from 20.3°C to 41.6°C. Figure 4 shows that the temperature of the entire imaged area underwent change. The surface temperature near the test site increased immediately as did the palm temperature; however, the FTT values for the five fingers were decreased. This indicates that the negative pressure from cupping raises the skin and the suction draws up the blood inside the capillaries, restricting the peripheral blood flow and causing the FTT to drop.

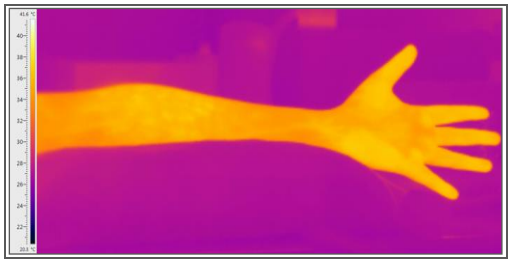
If cupping was continued for a long period of time, the increased temperature at the cupping site would gradually diffuse to the rest of the body, increasing the temperature of the entire arm, including the FTT values. At 180 seconds (Figure 4), participants had burning sensations; thus the vacuum pressure was released and the cup removed. Sixty seconds after the cup was removed, the temperature of the entire arm continued to rise; the increases in each FTT were particularly apparent. Figure 4 also shows that round marks appeared on the skin at the cupping site that grew and became more prominent with time. The temperature of the entire arm continued to increase, particularly the finger tips. This indicates that cupping improves blood circulation and remedies cold sensation in the extremities.



(a) t=0s



(b) t=180s

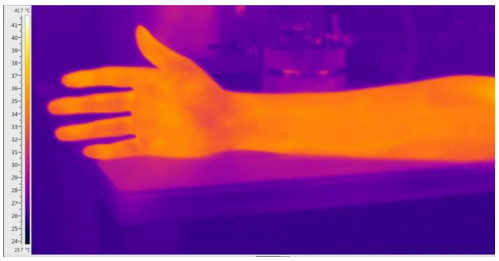


(c) t=360s

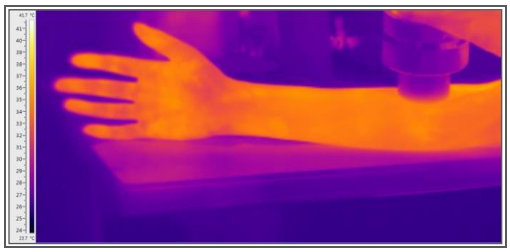
Figure 4 - Thermal images at different time points under P_v=-10 mmHg.

The vacuum pressure was then adjusted to -20mmHg to test cupping on participants' right arms. The thermal imager temperature color scale was set to automatic mode, so the scale ranged from 23.7°C to 41.7°C. The color contrast in the images in Figure 5 makes it easier to visualize the temperature differences. Figure 5 indicates that before cupping began, palm temperature was relatively high at approximately 35-37°C, whereas the FTT was approximately 33-35°C. The highest temperature on the entire arm was found on the medial forearm. From the start of cupping to 180 seconds, the skin temperature around the vacuum chamber was reduced by 1.5-2.0°C. After the vacuum chamber was removed and time reached 360 seconds, the temperature increase spread out and the temperature at the center of where the vacuum chamber was reached 39.5-40°C.

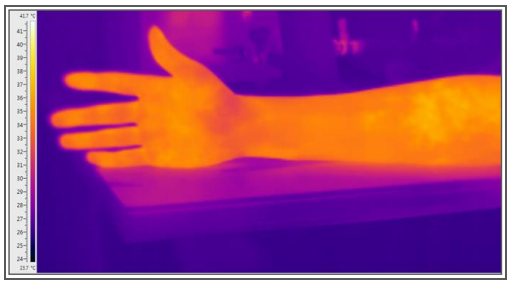
A comparison of the thermal images after cupping is shown in Figure 6. This shows that forearm and palm temperatures were higher before cupping began. After cupping, the area of the forearm that had a higher temperature moved to a more proximal location and increased in size and temperature. The temperature of the palm also increased.



(a) t=0s



(b) t=180s



(c) t=360s

Figure 5 - Thermal images at different time points under P_v=-20 mmHg.

Figure 6 - Before and after thermal images for cupping therapy.

IV. Conclusions

This study used experimental methods to investigate how the vacuum pressure inside the cup affected the therapeutic efficacy of modern vacuum cupping. The experimental tests used a custom made vacuum chamber along with pressure and temperature sensors to determine the correlation between vacuum pressure and the height to which the surface of the skin was raised and FTT. A thermal imager was also used to photograph physiological changes due to vacuum pressure.

The results of this study indicate that the suction height increases linearly along with vacuum pressure. The mathematical representation of this relationship can be expressed as $H=0.1|P_v|$, where H and P_v are measured in mm and mmHg, respectively. In terms of quantitative analysis, after cupping therapy, FTT rises markedly. When the vacuum pressure was -60mmHg, the peak non-dimensional FTT was $\overline{T}_f$ =1.95 and the actual FTT was 34°C, which was 6.7°C or 24.5% higher than before vacuum pumping began.

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