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BURNING INJURY IN THE CUPPING THERAPY: A THEORETICAL INVESTIGATION

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ABSTRACT

This study applied a numerical approach to analyze heat transfer in traditional Chinese medicine cupping and to examine whether cupping therapy causes skin burning injury. This study suggested that cupping creates a closed space with adiabatic conditions. The factors considered included the suction temperature when cups were placed onto the skin immediately after fire was applied to them. A higher-order color-coded isothermal chart was used to demonstrate the heat transfer that occurs inside cups. The numerical results showed that the heat inside cups quickly transfers to the skin and dissipates into the external environment. The decrease in the skin's temperature gradually slowed down, with the rate of decrease becoming almost flat after approximately 158 seconds (at which point the rate of temperature decrease was 0.02℃/s). With regard to concerns regarding whether the cupping therapy can cause burns, the numerical results showed that in cases when a suction temperature of 75℃, 100℃, 125℃, and 150℃ were applied, a temperature of 44℃, at which skin could be burnt, was maintained for 150~300 seconds. Thus, preventive measures against burns must be taken when conducting cupping therapy.Cupping is an external therapy in traditional Chinese medicine that is mainly based on heat. However, during treatment, its duration and temperature cannot be effectively controlled, which can cause burning injury. Inconveniences and risks of traditional cupping therapy have resulted in its reduced application. This aspect of traditional medicine is at risk of being lost to future generations, which has become a large concern.

KEYWORDS: Cupping, Heat Transfer, Burning Injury, Suction Temperature, Skin Temperature

INTRODUCTION

Chinese medicine traditionally uses heat in various therapies, but there have been few academic analyses of heat as used in traditional Chinese medicine (TCM), including analyses of the thermal effectiveness of cutaneous devices or the thermal responses of skin tissue. Maintaining the human body temperature is a complicated process that requires consideration of blood flow and metabolic heat generation. An analysis of the thermal responses of cellular tissue thus poses many difficulties. However, a number of different models for physiological heat transfer have been proposed (Khaled &Vafai, 2003). Heat is commonly used in medical practice (Okajima, Maruyama, Takeda, &Komiya, 2009); various heat therapies use temperature changes to soothe and repair cellular tissue. Among the heat therapies, the most commonly applied therapy is cupping therapy, which originated in traditional Asian medicine and involves the heating of certain spots of the human body with the use of open cups(Shen*et al.*, 2006).

Other names for "cupping" in Chinese include "horn cupping," "flash-fire cupping," "suction tube therapy," "bamboo tube therapy," and "cupping glass therapy." In practice, cupping uses flames, heat, or air exhaustion to create negative pressure inside a cup which is then placed directly on the skin to induce passive hyperemia and thus achieve treatment objectives (Al-Rubaye, 2012; Cao *et al.*, 2010; Chen, Li, Liu, Guo, & Chen, 2015; Huang & Cao, 2006; Huang, Choong, & Li, 2013; Lee, Kim, & Ernst, 2011;Liu, Piao, Meng, & Wei, 2013;Mehta &Dhapte, 2015; Pringle, 2007; Xu, Cui, Derrik, Xu, &Leang, 2014). This is the most commonly used method in folk medicine. The local suction created during cupping causes passive hyperemia (more commonly known as congestion) within the superficial tissue to help it heal or improve circulation, thus promoting metabolism.

Cupping is a safe and convenient therapy and health care option. However, due to the absence of any restrictions on the cupping procedures used, there are concerns that it can lead to burns. Modern cupping has mostly moved away from the use of heat and instead shifted toward the use of vacuum cups (Duh &Chiu, 2015), an approach which has changed the nature of cupping therapy. Medical treatments using heat-related technologies are already relatively advanced, and recent studies on heat transfer in cupping (Duh, 2015; Duh, Chen, &Yu,2016; Duh, Yu, &Chen, 2015) have been successful in developing medical cupping equipment (Duh, 2016). However, during treatment, the amount of heat used to best meet the patient's needs is still mainly determined by the physician's experience.

Cupping is a form of thermal stimulation, in which a certain amount of heat must be achieved, such that performing the treatment haphazardly could render it ineffective. At the same time, excessive or improper use of heat may cause serious burns. In particular, the flash-fire cupping method often uses alcohol lamps with flame temperatures of up to 463℃ as a heat source. After being heated by the flame, the cup is immediately placed on the treatment area, where burns may occur shortly after the cup comes in contact with the skin.

RESEARCH PURPOSE

Although cupping is closely associated with heat, there has been a lack of studies regarding the use of heat in cupping. Bodily functions generally benefit from heat, but heat can cause irreparable damage to the human body if inappropriately used or overused. Heat can penetrate the skin and raise the tissue temperature to 42°C, causing the natural death of cells. Jiang,Ma, Li, and Zhang(2002) discussed the effect of the thermal properties and physical dimensions of skin on burns and determined that thermal injury occurs in skin tissue at 44°C and above. Apart from temperature, the duration of thermal therapy is an important factor that can cause thermal injury. Moreover, due to the fact that cellular tissue can endure temperatures of up to 58°C for only three minutes, prolonged thermal therapy can damage the lipid layer of the cell membrane and cause changes to the proteins in cells, which will lead to coagulation necrosis (Huang, Gervais, &Muellerm, 2001) in cells.

The study of the skin's biological heat mechanism is an interdisciplinary area that includes research on biological thermal conduction, biomechanics, neurophysiology, and heat injury. Thermal stress produced by collagen heat denaturation in the heating process leads to substantial shrinking. Thus, stress, strain, temperature, and thermal injury are related and their changes occur together. Xu, Lu, and Seffen(2008) developed a numerical method to analyze the heat transfer process and responses caused by heat; the results are applicable in clinical research. In the single-layer skin model, accurate temperature data regarding thermal injury and thermal stress can be derived under different boundary conditions. However, in the multi-layer skin model, the application of the finite difference method (FDM) and finite element method (FEM) is required to obtain accurate data. Research results showed that heat transfer in skin is a complicated process, that it has a minor effect on thermal injury and blood perfusion, but that it greatly affects the distribution of skin temperature, particularly, in the very thin stratum corneum. Therefore, accurate numerical simulation of skin thermal stress is crucial in the evaluation of non-uniform temperature distribution and thermal injury.

Limited by current conditions, the practice of cupping has gradually declined and is even facing the threat of extinction. Therefore, to preserve the value of TCM, this study effectively addressed practical issues relating to long-practiced traditional cupping methods, and applied numerical analysis to look at the prevention of thermal injuries caused by traditional cupping therapy. In the theoretical analysis in this study, any "thermal injury" was referred to as a "burning injury."

MATERIALS AND METHODS

This study analyzed heat transfer in the cups used in cupping therapy. ANSYS software was used to execute the numerical methods used in this study, and the methods did not require the use of complex governing equations. Appropriate boundary conditions were set so that changes in the temperature field were used to investigate the heat transfer during cupping. To simplify the mathematical model and facilitate theoretical analysis, this study made the following assumptions:

1. The skin area was isotropic and homogenous.
2. Thermal physical properties of the air and skin were not related to temperature.
3. The effects of thermal radiation and thermal convection were not considered.
4. The area around the cups was designated as an adiabatic zone.

In the numerical analysis in this study, a geometric model was built based on the type of cup used in traditional cupping, as shown in Figure 1. The geometrical dimensions of the cups were as follows: internal diameter D=50 mm, height H=80 mm, wall thickness c=5 mm. Cups had a cylindrical shape. The aspect ratio (AR), that is the ratio of height H and internal diameter D, was equal to $AR=H/D$=1.6. The geometrical model used for numerical calculations was a circular cylinder (r,θ,z) with an axially symmetric cup so that the azimuth angle θ can be ignored and the equation can be simplified using the coordinates (r,z). The cup heat equation is given below:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(k_a r\frac{\partial T_a}{\partial r}\right)+\frac{\partial}{\partial z}\left(k_a\frac{\partial T_a}{\partial z}\right)+\dot{q}=\rho_a c \quad (1)$$

where k_a, ρ_a, and c_a are thermal conductivity coefficient, density, and specific heat of air, respectively. $\dot{q}$is the heat generation rate of the heating source inside a cup and was set to 0 because no heating source was installed inside cups in this study.

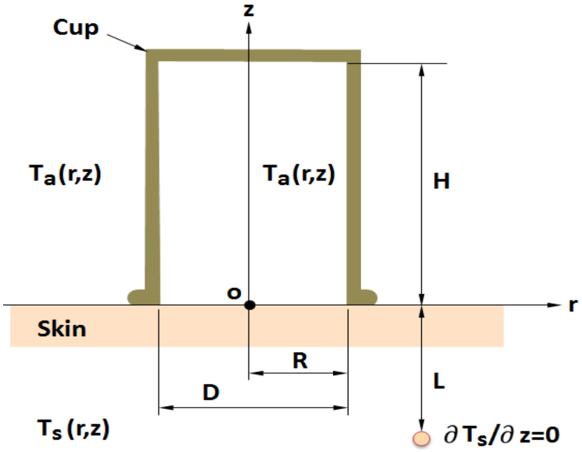

Figure1,Geometric model of cups

The geometric model illustrated in Figure 1 can also be applied with regard to the skin. The two-dimensional heat equation was used to calculate heat transfer in the skin. Its mathematical model was similar to that for the air inside the cup. The two-dimensional heat equation is given below:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(k_s r\frac{\partial T_s}{\partial r}\right)+\frac{\partial}{\partial z}\left(k_s\frac{\partial T_s}{\partial z}\right)+\dot{q}_s= \quad (2)$$

Where , , and are thermal conductivity coefficient, density, and specific heat of skin, respectively. A different component of this equation (compared to the cup heat equation) is the metabolic heat generation rate of skin, which is an important factor in maintaining body temperature at approximately 37o^{C}

The thermal equations for the air inside the cup and the skin were transient; therefore, the initial conditions were set as follows:

$$T_a(r,z,0) \qquad \text{for } t=0, z>0, r=R$$

$$T_s(r,z,0) = \qquad \text{for } t=0, z$$

The initial air temperature inside the cup was equal to the temperature of a lit alcohol lamp (t) and was designated in this study as the suction temperature. The initial skin temperature (t) was assumed to be 37 .

With these given parameters, the skin temperature (t) can be found using the boundary conditions and equations (1) and (2). Boundary conditions are required in numerical analysis. Boundary conditions for cups are described using cylindrical coordinates (*r*,*z*) (Figure 1). The boundary conditions for the area around the cups (*r*=*R* and *z*=*H*) were assumed to be adiabatic. Therefore, radial heat transfer at the cup walls was zero, implying that heat flux (z) was zero. Thus, the air inside the cup and at the skin surface and the skin must be in thermal equilibrium:

$$\frac{\partial T_a(r,z,t)}{\partial z} \qquad \text{for } z \qquad (5)$$

$$k_a\frac{\partial T_a}{\partial z}\Big|_{z=0^+}=k_s\frac{\partial T_s}{\partial z}\Big| \qquad (6)$$

$$\frac{\partial T_a(r,z,t)}{\partial r} \qquad \text{for } r=R \qquad (7)$$

The skin layer will maintain thermal equilibrium with both the air inside the cup and the air outside the cup.

The deepest point of skin (*L*) was fixed at ,

where the $\partial T_s/\partial z$ depth, i.e. the *L* value, was obtained using a trial and error method.

$$k_s\frac{\partial T_s}{\partial z}\Big|_{z=0^-}=h_a A(T_s-T_a)\Big|_{z=0^+}$$

$$\text{for } z=0,\ r>R \qquad (8)$$

$$\frac{\partial T_s}{\partial z}\Big|_{z=L}=0 \quad \text{for } z=L \qquad (9)$$

This study used ANSYS software to analyze(2) heat transfer inside the cups and thermal injury from cupping therapy under appropriate boundary conditions. In numerical analysis, all thermal physical properties of air were assumed to be constant values. Thermal conductivity, density, and specific heat of air were $k_a = 0.0257$ W/m · K, $\rho_a = 1.205\ kg/m^3$, and $c_a = 1005$ J/kg · K, respectively. All thermal physical properties of skin tissue were assumed to be fixed values. Thermal conductivity, density, specific heat, and metabolic heat of skin were $k_s = 0.45$ W/m · K, $\rho_s = 1200\ kg/m^3$, (3) $c_s = 3300$ J/kg · K(Jiang*et al.*, 2002; Lv&Liu, 2007; (4) Okajima*et al.*, 2009), and $\dot{q}_s = 1378.3\ W/m^3$.

All calculations in this study were performed using a numerical analysis method. Areas of numerical analysis included air at the skin surface inside the cups and the skin layer under the skin surface inside the cups.

RESULTS AND DISCUSSION

The numerical analysis in this study focused on calculating heat transfer in cupping therapy and on analyzing the changes in temperature near the skin after the air inside the cups was heated and they were placed on the skin ($t>0$). The temperature inside the cups is normally 80~140℃; to analyze heat transfer inside the cup, this study therefore selected four different values for the suction temperature (T_o) inside the cup, namely, 75℃, 100℃, 125℃, and 150℃. This study used ANSYS software to build a numerical model and used a color-coded isothermal contour method to illustrate temperature changes inside the cup. A color-coded demonstration of air inside the cup helped to analyze the research issue by providing a visualization of heat transfer inside the cup. Colors were determined by suction temperature, ranging between 20~150℃. Since the temperatures that deserved attention ranged between 35℃ and 50℃, this method allowed for the observation of transient states when the temperature inside the cup changed.

Figure 2 shows changes to the temperature inside the cup and at the skin surface (T_s at $z=0$, $r=0$) after the air inside the cup was heated and the cup was placed on the skin. The temperature distribution curve shows that as the initial skin temperature ($T_{s,i}$) was set at 37℃, the heat inside the cup quickly transferred to the body; the decrease in temperature is particularly evident in the first 55 seconds. The decrease in the skin's temperature gradually slowed down, with the rate of decrease becoming almost flat after approximately 158 seconds (at which point the rate of temperature decrease was 0.02℃/s).

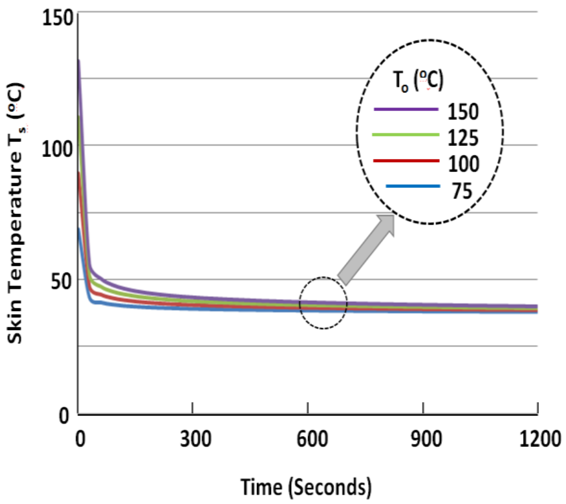

Figure 2, Temperature at the skin surface inside the cup

Figures 3 and 4 show the distribution of temperature at the skin surface (z=0) inside the cup (r=0) at earlier (t<150 s) and later (t>300 s) stages of the cupping therapy. Each figure includes four thermal distribution curves corresponding to suction temperatures of 75, 100, 125, and 150 . As mentioned earlier, according to Jiang *et al.* (2002), the temperature at which skin tissue can burn is 44 and above (Jiang*et al.*, 2002). As shown in Figure 3, which showed the changes in temperature after the cup was placed on skin, the suction temperature was 75 ; at t=30 s, the temperature affecting the skin decreased to below 44 . At t=150 s, a temperature of =100 was observed and the temperature affecting the skin was below 44 .

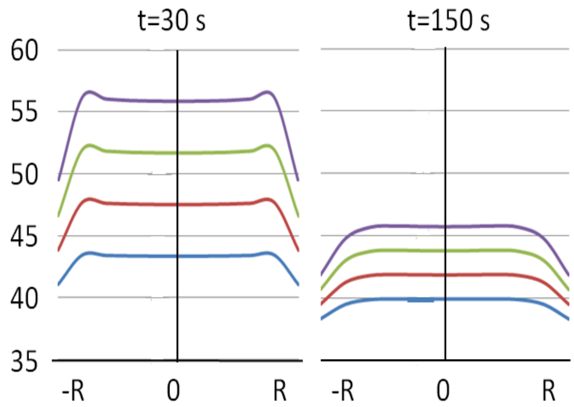

Figure3, Thermal distribution at the skin surface at the earlier stage of the therapy

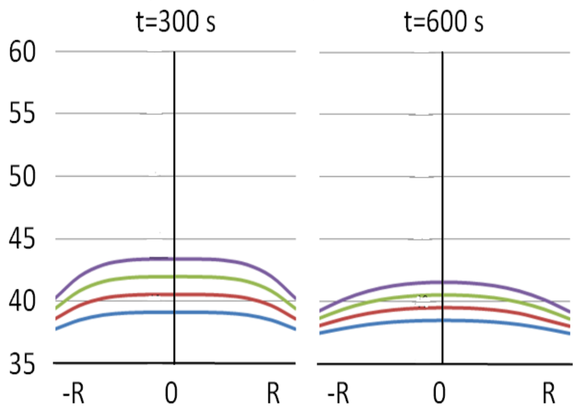

Figure 4, Later stage of the therapy

Figure 4 shows that after 300 seconds (t=300 s), the final suction temperature was T_o=125℃ and 150℃ and its effect on the skin remained below 44℃. This indicates that in cases when the suction temperature of 125℃ and 150℃ was applied, the temperature of 44℃, at which skin could be burnt, was maintained for 150~300 seconds. Thus, preventive measures against burns must be taken during cupping therapy. According to Huang *et al.*(2001), thermal injury or coagulation necrosis of cellular tissue can be observed when it is kept at 58°C over 180 seconds and longer. Thus, when the suction temperature of 150°C is applied, cups cannot cause thermal injury or coagulation necrosis to cellular tissue.

In order to analyze whether higher suction temperatures cause thermal injury to the skin, this study examined suction temperature equal to 150°C. Figure 5 shows changes to the temperature inside the cup when the suction temperature was 150°C. Cups can cause skin burns, particularly in the earlier stages of the therapy when air inside the cup is heated and the cup is then immediately placed on the skin. Therefore, changes in temperature were examined at t=30 s and t=60 s to investigate heat transfer inside the cup. Traditional cupping often uses natural bamboo cups, which lower the likelihood of the user getting burnt and possess a lower thermal conductivity coefficient (which in turn make them more effective in terms of preserving heat).

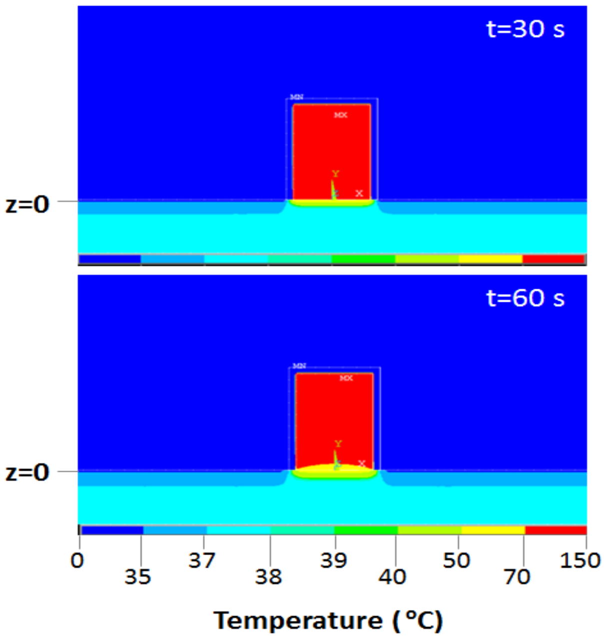

Figure5, Changes in temperature inside the cup at the earlier stages of the therapy

After the cup was heated, the temperature inside the cup rapidly increased to the initial suction temperature. Afterward, the cup was immediately placed on the treatment area. Figure 5 shows changes in temperature inside the cup at the earlier stages of the therapy. In this calculation example, the external temperature (T_a) is 20°C and body core temperature is 37°C. Therefore, the heat inside the cup can transfer into the human body through the skin. In the beginning after the cup was placed on the skin surface (t=0), the high temperature state marked in red was observed inside the cup. As shown in Figure 5, after 30 seconds, the skin surface temperature near the cup fell to the yellow/green-temperature range. Due to the difference in temperature, heat transfer was observed in adjacent areas of skin and air outside the cup and the temperature of the skin surface was no longer equal to the core temperature. As the cupping continued, the temperature changed as marked by the gradual increase in yellow/green areas in the isothermal chart at 60 seconds. As seen from the figure, the thermal contours formed a convex oval shape. The medium inside the cup was air and the main heat transfer mechanism was thermal convection. Therefore, thermal contours of the air inside the cup are more prominent.

Figure 6 shows changes in temperature inside the cup at the later stages of the therapy. The green and yellow areas at the binding surface between the cup bottom and the skin surface expanded upward and downward. The yellow areas that expanded upward inside the cup continued to form a convex oval shape, while the green areas expanded downward inside the skin and formed an oblate elliptic shape. The medium for heat transfer in the skin was solid tissue and the main heat transfer mechanism was thermal conduction. This led to uniformity of thermal contours inside the cup. As shown in Figure 6, after 600 seconds, the temperature inside the cup was entirely marked in green/yellow and ranged between 40~70°C. At the same time, dissipation of heat in the external environment led to the expansion of the skin surface area that had a temperature below the core temperature (37°C). The skin surface (z=0) was marked with light green color and its temperature ranged between 40~50°C.

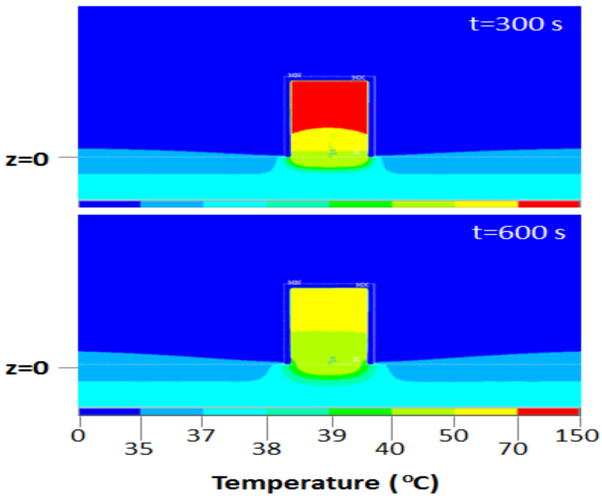

Figure 6, Later stages of the therapy

CONCLUSION

This study used ANSYS software for numerical analysis and investigated the effects of the traditional cupping therapy by examining the heat transfer inside the cup based on the determined temperature conditions. The aspect ratio used in this study was *AR=H/D*=1.6,the numerical results showed that in cases when a suction temperature of 75℃, 100℃, 125℃, and 150℃ were applied. This study focused on using the two-dimensional heat equation and setting boundary conditions for the traditional cupping process to examine heat transfer between the cup and skin tissue. The main method employed in this study was heat transfer analysis based on the distribution of temperature inside the cup and skin tissue.

Numerical results showed that heat inside the cup quickly transferred to the body; the decrease in temperature was particularly evident in the first 55 seconds. The decrease in the skin's temperature gradually slowed down, with the rate of decrease becoming almost flat after approximately 158 seconds (at which point the rate of temperature decrease was 0.02℃/s). With regard to the question of whether the cupping therapy can cause burns, the numerical results showed that in cases when suction temperatures of 125℃ and 150℃ were applied, a temperature of 44℃ (at which skin could be burnt) was maintained for 150~300 seconds. Thus, preventive measures against burns must be taken during cupping therapy. With regard to whether cupping can cause severe burns, the numerical results indicated that when a suction temperature of 150℃ was applied, the cups could not cause thermal injury to or coagulation necrosis in cellular tissue.
The medium inside the cup was air and the main heat transfer mechanism was thus thermal convection. Therefore, thermal contours of the air inside the cup are more prominent and the thermal contours inside the cup formed a convex oval shape. Furthermore, solid tissue served as the skin's heat transfer medium and the main heat transfer mechanism was thermal conduction. This led to thermal contours inside the cup forming a uniform oblate elliptic shape.

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REFERENCES

Al-Rubaye K.Q.A. (2012). The clinical and histological skin changes after the cupping therapy (Al-Hijamah). *Journal of the Turkish Academy of Dermatology*, 6(1), 1-7.

Cao H., Han M., Li X.,Dong S., Shang Y., Wang Q., Xu S., &Liu J. (2010). Clinical research evidence of cupping therapy in China: A systematic literature review. *BMC Complementary and Alternative Medicine*, 10, 70-80.

Chen B., Li M.Y., Liu P.D., Guo Y., & Chen Z.L. (2015). Alternative medicine: An update on cupping therapy. *The Quarterly Journal of Medicine*, 108(7), 523-525.

Duh F.C. (2015). Application of heat transfer to thermal therapy using electro-moxibustion cup. *Journal of the Chinese Institute of Engineers*, 38(2), 232-237.

Duh F.C. (2016).Development of an innovative medical cupping device. *American Journal of Engineering Research*, 5(10), 53-58.

Duh F.C., Chen C.H., & Yu Z.Y. (2016).A qualitative research on the heat transfer of cupping therapy. *Journal of Multidisciplinary Engineering Science and Technology*, 3(7), 5177-5180.

Duh F.C. & Chiu Y.H. (2015).Vacuum cupping under various negative pressures: An experimental investigation. *Journal of Multidisciplinary Engineering Science and Technology*, 2(7), 1907-1911.

Duh F.C., Yu Z.Y., & Chen C.H. (2015).A study on avoiding burn injuries when treating patients with needle cupping. *Journal of Multidisciplinary Engineering Science and Technology*, 2(6), 1484-1489.

Huang C.Y., Choong M.Y., and Li, T.S. (2013). Effectiveness of cupping therapy for low back pain: A systematic review. *Acupuncture in Medicine*, 31(3), 336-337.

Huang S. & Cao Y. (2006).Cupping therapy. J*ournal of Chinese Medicine*, 82, 52-57.

Huang J.S., Gervais D.A., & Muellerm P.R. (2001). Radiofrequency ablation: Review of mechanism, indications, technique, and results. *Chinese journal of Radiology*, 26, 119-134.

Jiang S.C., Ma N., Li H.J., & Zhang X.X. (2002).Effects of thermal properties and geometrical dimensions on skin burn injuries. *Burns*, 28, 713-717.

Khaled A.R.A.&Vafai K. (2003).The role of porous media in modeling flow and heat transfer in biological tissues. *International Journal of Heat and Mass Transfer*, 46(26), 4989-5003.

Lee M.S., Kim J.I., & Ernst E. (2011). Is cupping an effective treatment? An overview of systematic reviews. *Journal of Acupuncture and Meridian Studies*, 4(1), 1-4.

Liu W., Piao S.A., Meng X.W., & Wei L. (2013). Effects of cupping on blood flow under skin of back in healthy human.*World Journal of Acupuncture-Moxibustion*, 23(3), 50-52.

Lv Y.G.&d LiuJ. (2007).Effect of transient temperature on thermoreceptor response thermal sensation. *Building and Environment*, 42(2), 656-664.
Mehta P. & Dhapte V. (2015).Cupping therapy: A prudent remedy for a plethora of medical ailments. *Journal of Traditional and Complementary Medicine*, 5(3), 127-134.

Pringle M. (2007).Some thoughts on fire cupping, *Journal of Chinese Medicine*, 83, 46-49.

Okajima J., Maruyama S., Takeda H., & Komiya A. (2009). Dimensionless solutions and general characteristics of bio heat transfer during thermal therapy. *Journal of Thermal Biology*, 34, 377-384.

Shen X., Ding G., Wei J., Zhao L., Zhou Y., Deng H., & Lao L. (2006).An infrared radiation study of the biophysical characteristics of traditional moxibustion. *Complementary Therapies in Medicine*,14, 213-219.

Xu P.C., Cui S.L., Derrik A.C.W., Xu S., &Leang L.T.(2014).Preliminary observation on effect of cupping on the skin surface temperature of patients with back pain. *World Journal of Acupuncture-Moxibustion*, 24(4), 59-61.

Xu F., Lu T.J., &Seffen K.A. (2008). Biothermomechanics of skin tissues. *Journal of the Mechanics and Physics of Solids*, 56, 1852-1884.