Change of Skin Blood Flow at Lower Limb under External Pressure

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Abstract: It has been reported that external pressure exerted on lower limbs helps to accelerate blood flow during doing exercise or playing sports and thus improving sports performance. In this paper, the pressure effect on skin blood flow was investigated. Pressures of various magnitudes were exerted on ankles and calves respectively by using a sphygmomanometer, under which the skin blood flow change was observed. The results showed that the skin blood flow increased when pressure of certain level was loaded at ankle or calf; however, as the pressure magnitude exceeding certain value, it turned to decrease. Moreover, ankles seemed to bear much higher pressure than calves. The mechanism of skin blood flow responding to external pressure was also discussed.

Keywords: external pressure, skin blood flow, lower limb

1. Introduction

The influence of external pressure on human physiological systems has attracted wide attention from many areas: clothing science, sports physiology, and clinical practice as well. Many researchers have reported that garment pressure had influence on blood pressure, heart rate, respiration, digestion, and other physiological systems [1-3]. External pressure has been used in compression therapy in clinical area. To treat various venous diseases of lower limbs, compression stockings and bandages were used to exert pressure on lower limbs, to enhance venous return, reduce venous distension and prevent stasis [4-7]. It has also been reported that external pressure exerted on lower limbs helps to accelerate blood flow during doing exercise or playing sports and thus improving sports performance.

Since human body is soft and flexible, the external pressure has complicated influence on the micro blood circulation of the soft tissue. Some researchers have reported the effect of pressure exerted at different lower limb parts on the distal skin blood flow [8, 9]; the difference made by the size of the compressing regions has also been investigated [8]. Fromy et al. [10] investigated the change of blood flow of the finger skin undergoing pressure, the blood flow increased under pressure of low level, it turned to decrease as the pressure increasing to an absolute pressure value close to the one classically reported as the “capillary closing pressure” (around 32mmHg). Liu et al. also tried to find out the physiological response under compression hosiery [11]. However, still few reports are available about how the external pressure influences on the underlying skin blood flow, and further on the blood circulation at lower limbs. In this paper, the pressure effect on underlying skin blood flow was investigated in terms of different magnitudes, loading position and time period of pressure exerted on lower limb

2. Methods

Five undergraduate students denoted as S1-S5 volunteered to participate in this study. Their ages, statures and weights were 23±1yrs, 156±2cm, and 48±2kg respectively. They had refrained from heavy exercise for 24h and had not consumed salty food, alcohol or caffeine for 17h before entering the laboratory. The experiments were carried out in a chamber of constant temperature (20±2°C) and humidity (65±5%), the air velocity was less than 1m/s. The experiments were started at the same time of each day during May and June 2008. The subjects were asked to wear loose trousers. To avoid the influence of human hydrostatic pressure on the results, the subjects were asked to lie as supine posture.

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The skin blood flow was observed by using the Advance Laser blood Flowmeter, ALF21R(Advance Co. Ltd. Japan). Three parameters of blood flow can be obtained simultaneously: “flow”, “velocity”, and “mass” . Here, “flow” denotes the total blood volume of entering the skin soft tissue of 100g per minute; “velocity” is the equivalent velocity of all the capillary flows within the measured skin region; “mass” corresponds to the mass of blood of the measured skin area at a time. “Velocity” and “mass” can be obtained directly, “flow” is expressed in terms of the product of the two parameters. At the same time, pressure was measured by using air-pack pressure sensors(AMI Co. Ltd, Japan).

To control the pressure magnitude easily, a sphygmomanometer was used to compress a region of 14cm width on lower limb. Pressures of three magnitudes 20, 30 and 40mmHg were loaded on ankles and calves respectively. Figure 1 showed the measured positions at the right leg. To investigate the effect of difference time periods of pressure loading, two protocols were applied in this study, as shown in Figure 2 The change of skin blood flow along with exerted pressure was recorded.

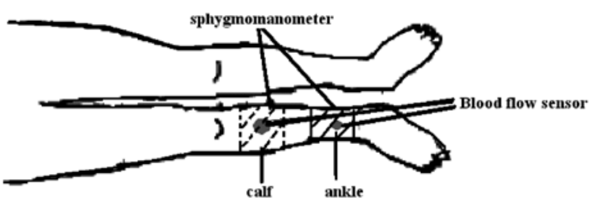
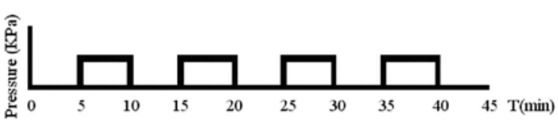
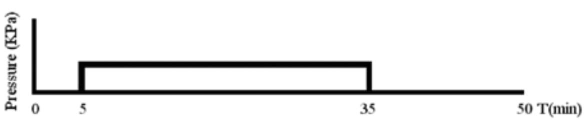


Figure 1 Measured positions on the right leg



(a) Protoco1 1



(b) Protocol 2

Figure 2 Experimental protocols of pressure loaded

The Wilcoxon signed ranks test for comparison of two-related-samples within the subjects was carried out to by using the SPSS package to evaluate the change of skin blood flow between pressure loaded and pressure removed. Significant statistical differences were defined as $p < 0.05$.

3. Results and Discussion

3.1 Effect of Pressures of Different Magnitudes

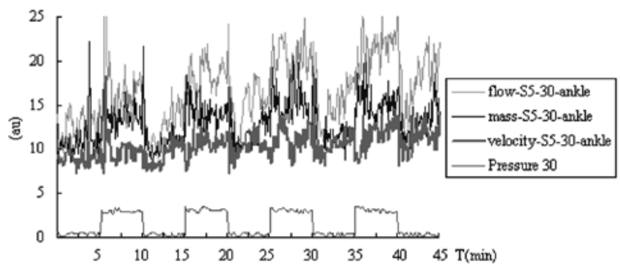


Figure 3 Skin blood flow change of S5 along with pressure of 30mmHg exerted on ankle

Figure 3 showed skin blood flow change of the subject S5 along with pressure of 30mmHg exerted on ankle. “Mass” showed obvious increase as pressure loaded, and return as pressure removed. There was no clear trend of “velocity” change with the pressure observed. Since “flow” was calculated from the product of “mass ” and “velocity”, it showed same change with “mass”. Therefore, in this study, “mass” was focused to reflect the skin blood flow response to external pressure.

Figure 4 showed “mass” changes of all subjects with pressure loaded by Protocol 1, Figure 5 was the mean value of “mass” with the pressure loaded (wp) on lower limbs or not (np), and Table 1 is the result of the statistic analysis carried out on these data. Whether the pressure of 20mmHg was exerted on ankles or calves, as shown in the left column of Figure 4, “mass” changes of all subjects showed same trend: increased to some extent with pressure loaded, and returned rapidly with pressure removed ($p=0.000$). When the pressure increased to 30mmHg, “mass” changes were similar to those of the cases of 20mmHg ($p=0.000$). As shown in the right column of Figure 4, when the pressure was of 40 mmHg, the skin blood flow showed complicated change. When pressure being exerted on calves, “mass” of all subjects decreased with pressure loaded, and recovered quickly with pressure removed ($p=0.000$).