Design and Evaluation of the System Device for Mitigation of the Low Back Pain Among Veterinarians

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Abstract. This Study proposes an innovative auxiliary device to solve the low back pain (LBP) caused by veterinarian's poor work posture. In recent years, with the heightened status of pets in people's lives, the demand in animal hospitals has increased significantly, and the occupational hazards of veterinarians have also emerged gradually. Veterinary work environment is complex and diverse, and working hours are overly long, which can easily cause the issue of the LBP. Among the patients with the LBP, many people are classified as non-specific low back pain (NSLBP). This means that there is no known pathological anatomy for the LBP itself, and its principle is strongly related to the compressive load of the spine. NSLBP should be considered as a change in the structure of the whole body's spine. Poor posture can lead to imbalance of curvature of the spine and damage to soft tissues. This Study begins with the posture state of the veterinary surgery, where biomechanics and physiological anatomy are used to target the interaction of the lower back and shoulder flexion angles during the operation of the veterinarian, and to consider the results of the blood flow when the muscles are tight. This Study will design an auxiliary device for the veterinary surgery to effectively reduce the mechanical load on the spine, overstretch the muscles and promote blood circulation, thereby improving the fluency of the veterinary surgery and slowing the veterinarian's NSLBP.

Keywords: Veterinary · Non-specific low back pain · Assistive device

1 Introduction

The high suicide risk among doctors and veterinarians has been widely documented due to the overly long man-hours and dramatic changes in work patterns [1]. Fritschi [39] and Platt et al. [40] point out that veterinarians have a three-fold higher risk of suicide than normal people, and the proportion of veterinarians committing suicide is higher than that of pharmacists, dentists, and other medical practitioners [2], mainly because of the complicated working environment and long working hours, coupled with social pressure, sense of incompetence/helplessness and mistakes, etc., which leads to the relatively complex occupational risk factors faced by veterinarians [3].

This Study hopes to find the best way and design elements to systematically integrate the veterinary surgical posture, so as to create an improved design of device to

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tackle with the non-specific low back pain (NSLBP) suffered by the veterinarian and to promote the efficiency and quality of the veterinarian. The background and purpose of this study will be detailed below.

1.1 Background

Studies indicate that 50% of veterinarians in New Zealand suffer from chronic musculoskeletal problems, mainly because of the long hours of work. In recent years, musculoskeletal discomfort (MSD) has become a disease in the veterinary industry [4]. However, Fritschi et al. do not define the MSD among the veterinarians and the details of the MSD in relation to their body parts, so follow-up studies conduct a more indepth investigation of veterinarians in different parts of New Zealand and find that 96% of veterinarians have encountered the MSD-related issues, where 67% says their life is affected and 18% can no longer work, and the most affected part of the body is the lower back, accounting for 73% of the entire population in this study [5].

According to the occupational injury system records managed by the Ministry of Labor in Taiwan from 2008 to 2013, 3477 occupational diseases were reported, of which 873 were related to lumbar vertebrae, and the number of cases related to the low back pain (LBP) was also increasing year by year [6]. However, although the work-related musculoskeletal disorder will not cause harm immediately, long-term accumulation will make it a major cause of disability in a veterinarian, which can then lead to more diseases, the most common of which is the LBP. In the United States, the lifetime prevalence of the LBP is 60–85% [7], costing about $100 billion [8].

LBP is just a symptom, not a disease. It can be caused by multiple causes [9]. Common causes include soft tissue damage or inflammation of the back fascia, including the back muscles, ligaments, tendons, acute and chronic strains, sprains, contusions, and the risk of the head's lifting posture and waist and back injuries are also focused on in many studies [10]. Thus, it is known that the LBP is not just a single disease, but a symptom caused by multiple causes [11]. The most common form of the LBP is the NSLBP, which means that the LBP itself does not have a known cause from the perspective of pathological anatomy. Thus, approximately 85% of cases are classified as the NSLBP [12]. As a result, the doctor's diagnosis process or the patient's testing process will cause a large medical cost. NSLBP should be regarded as a change in the structure of the whole body's spine. Poor posture can lead to pathological changes between the bones of the spine and soft tissues, so the analysis cannot be restricted to the lumbar region [13].

1.2 Purpose

Poor posture among veterinarians during prolonged surgery can easily cause the NSLBP. This Study will learn how to maintain the correct posture and improve the joint mobility during the veterinary surgery from Literature Review to improve the issue of the NSLBP among veterinarians. An innovative assessment method will be produced to consider the spine angle and blood flow during the veterinary surgery, and summarize those factors during the procedure of surgery into a posture classification system. The posture classification system can be used as a tool to assess posture stress and prevent the NSLBP among veterinarians, including the hands, arms, neck and lower back, as well as the time period of remaining in the posture. Based on biomechanics and physiological anatomy, the posture state can be used to explain the interaction between the lower back and shoulder flexion angle and the mechanics during the operation, and the result of blood flow when the muscle is tight will be considered as well. Minimizing discomfort can help to reduce the risk of the LBP [14] among veterinarians.

The purpose of this study will be summarized into the following four points:

1. Maintain or control joint movements and reduce the problem of slouching due to overly reliance on the vision.
2. Provide an upward moment that supports the torso, and reduce the angle of the spine and the mechanical load, thus reducing the force on the lower back and neck.
3. Promote blood circulation in the hands of the veterinarian during the surgery to help reduce excessive muscle tension and improve mobility of the shoulder joints compared to that in the general state.
4. Improve the quality and efficiency of veterinary work, increase work comfort and slow down the occurrence of the NSLBP.

2 Literature Review

Nowadays, most of the research and design for mitigation of the LBP are based on drug therapy and physical stimulation. There is no discussion about the physiological mechanisms and correlations of factors that may induce the LBP. Therefore, this study will re-examine the influence of trunk changes on the severity of NSLBP, which is briefly described as follows:

2.1 Spinal Changes

The NSLBP is not just a symptom. There are many possible reasons, like the psychological factors [15], biomechanical factors [16] and many others. Studies in the human body have found that the magnitude of compression loads on spine is strongly correlated with the injury caused by the LBP among the patients [17].

The spine will absorb or transfer the force between the upper and lower limbs when the body is in a certain posture, and the proper dynamic balance will be maintained in combination with appropriate visual motion control [18, 19]. The functional unit of the spine contains two adjacent vertebrae and soft tissues in between, and the vertebral body is the structure mainly subjected to the compressive load (Fig. 1). Some studies have also linked the flexion posture to the underlying mechanisms of the LBP. As the flexion posture can change the passive mechanical properties of the trunk and weakens the trunk's proprioception [20, 21], it can damage the active neuromuscular control of the spine. These changes may cause the spine to become overloaded and unstable, thus increasing the risk of lumbar injury [22].

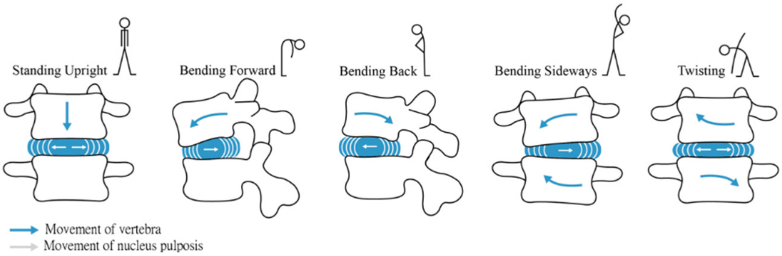


Fig. 1. Different positions may damage your spine. (Sequence Olgakabel [42]-Reorganized by this Study)

There are quite a lot of research literatures on the biomechanical model of the lower back. The biomechanical law uses the mechanical model to estimate the stress on the lower back and joints. This way, the force on each part can be clearly known, and the patterns related to the lower back mainly include the biomechanical model proposed by Chaffin in 1969, which divided the main body into seven links. Without considering the influence of inertia, the angle of each joint is taken by photography to calculate the force on the spine. The principle of force and moment balance, where torque equals force times distance (T = F * L) and Mmuscle = Fmuscle * d, is adopted to compare the calculated value at L5/S1 and verify the result of joint reaction and torque [23]. The study conducted by the National Institute for Occupational Safety and Health (NIOSH) also points out that if the force on the L5/S1 intervertebral disc exceeds the action limit by 3400 Newtons, it will increase the risk of injury caused by the LBP [24]. It can be seen that the factors inducing the NSLBP are no longer limited to the lesions in the lumbar spine, but are more related to the curvature of the spine and the changes in the trunk [25], The more curved position requires more muscle strength to offset the moment about the lower back, so how to reduce the moment about the lower back through analysis of the posture structure of different parts of the trunk, thus reducing the total compressive stress acting on the spine (Fig. 2) will be the focus of this study.

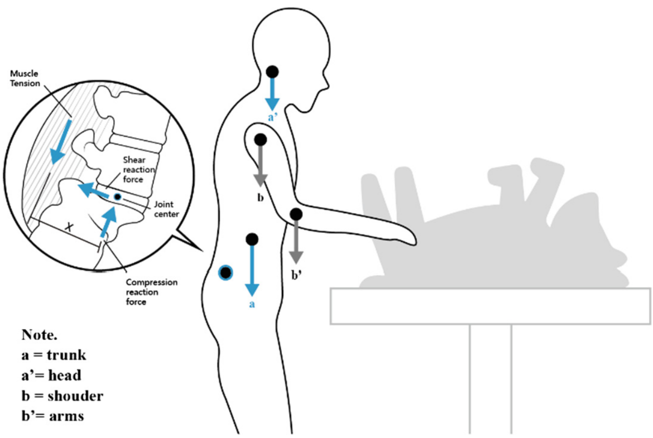


Fig. 2. The biomechanics of the human spine

2.2 Soft Tissue Changes

Experts point out that prolonged spinal flexion can lead to back muscle fatigue, and studies have shown that in this position, the torso extensor muscles will creep. The back muscles also reflexively contract to limit the angle of the spine, thus protecting the spine from injury [26]. Under the high static load for a long period, ischemia and hypoxia will cause energy loss and pain in muscles or tendons [27]. And if the work involves fine hand movements, the pain should be related to the vasodilation of the trapezius muscle [28].

In recent years, studies have delved into the relationship between the angle of the back, the degree of shoulder flexion and different levels of discomfort for different muscle groups. It has been found that the angle of shoulder flexion and the angle of elbow flexion has a significant influence on the level of discomfort for different muscle groups [29]. Therefore, the design must consider how to reduce the interaction between the MSDs, so as to reduce the risk effect.

Through the concept of back extensions, we can understand the relationship between muscles (Fig. 3) and locations. It is found that when there is a change in the muscles of the hand, it actually affects the muscle groups in charge of the shoulders and lower back. If the relationship between the trapezius muscle and the shoulder angle is discussed, as the shoulder angle and the height of the arm increase, the trapezius muscle will be overactive, resulting in a decrease in the blood flow [30]. If the trunk is in a tight, stressed state for a long time, the state of poor blood circulation will be extended to the whole body. If the nerves between the cervical vertebrae are pressed again, the muscles will be tense, the shoulders and necks will be sore, and the headache and arm numbness will be indirectly caused. Studies have shown that skin temperature contributes to thermal comfort and autoregulatory response throughout the body [31]. In a low temperature environment, maintaining a stable hand and body temperature above a certain level is an important key to maintain operational ability [32]. Studies have also pointed out that the standing posture can affect the muscles and blood flow, so the interaction of the shoulder flexion angle, elbow flexion angle and back angle should be considered. It has an important impact on the stability of the spine [30].

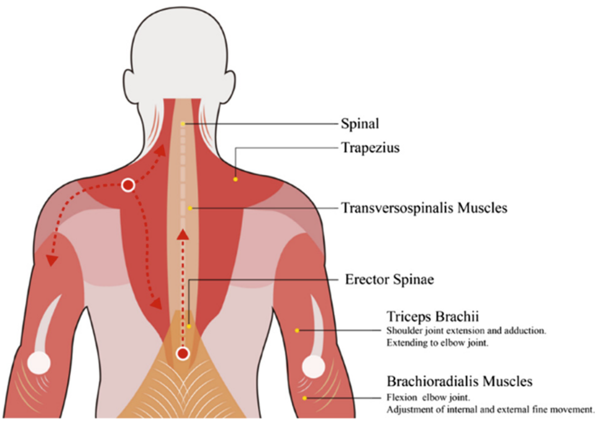


Fig. 3. Back muscle anatomy

Bru, Svebak, Mykletun & Gitlesen also suggested that in order to reduce the back pain of the medical staff, attention should be paid not only to the source of external physical load, but also how to relieve neck and shoulder pain. Studies on the LBP should not only start with the waist, but combine the biomechanics principles of the back with the physiological concepts to maintain normal body temperature regulation and thermal comfort in order to control the blood flow between muscles and achieve homeostasis.

2.3 Postural Control

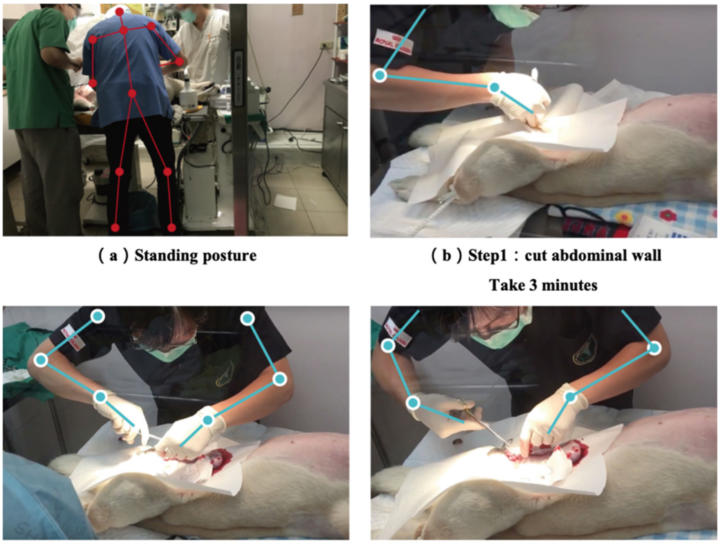
Existing research shows that the NSLBP can affect the capabilities in postural control, emphasizing that motion control can affect a person's ability to proces postural control, and the LBP patients are prone to damage to their central nervous system [33]. The stability in the posture of the NSLBP patients will be worse than that of healthy subjects. Postural Control reduces the coordination of the back muscles and overstretches the muscles [34]. Therefore, maintaining a balance between static and dynamic postures in any work activity can prevent the LBP problem from occurring. In addition, the veterinarian will inevitably maintain the surgical posture to some extent. As the shoulders are shrunk for a long time, and the trunk is not used to support the body, the core mucles can be debilitated to cause muscle paralysis and reduced shoulder mobility. Core mucles activey has been recognized as a way to reduce damage and increase tissue health [35].

Many designs that address the LBP will lead to compensatory patterns [36]. As the movement of any segment of the spine is limited, other segments may suffer damages. Meanwhile, most of the existing products do not consider the correlation between lumbar motion and the whole body. As the job task involves exercise of the whole body, it is necessary to analyze the influence of spinal exercise on the lower back during work. The Swiss neuroscientist, Brügger [41], uses the gear mechanism to illustrate the chain reaction caused by the spine posture, which is also known as the Brugger Sitting Posture. In the past, we used to see only the relevant areas or nearby tissues upon occurrence of the pain and disease. However, the body is actually working as a whole and each part will affect another. Therefore, Brugger divides the spine into several parts, using a simple gear rotation mechanism to illustrate the chain reaction caused by the spine posture, where the cervical vertebrae, thoracic vertebrae and lumbar vertebrae are considered a coherent system, where changes to one part can affect the overall alignment of the spine.

3 Methods

3.1 Veterinary Hospital Observation

Through interviews and observations with veterinarians, it is easy to understand that veterinarians are prone to changes in lumbar curvature and soft tissues due to the poor surgical posture. The influencing factors include the actual operations of the veterinarian, environmental design and conditions of the equipment in use (Fig. 4). Regarding the follow-up observations and step analysis of the veterinary procedure for ovario-hysterectomy (OHE) of animals, the following shows the results of observation and analysis: (a) un-balanced standing posture, indentation and lifting of the shoulders; (b) Step 1: Use tweezers and the scalpel to cut the abdominal wall layer by layer. (c) Step 2: Use the hook to find the uterus and ovary and take them out. (d) Step 3: Use the needle to suture the wound.



(a) Standing posture

(b) Step1 : cut abdominal wall
Take 3 minutes

(c) Step2 : Take out the uterus and ovaries
Take 15 minutes

(d) Step3 : stitch up the wound
Take 10 minutes

Fig. 4. Analysis of the OHE posture and process

3.2 Expert Interview

The influence of the spine curvature, soft tissue status, and visual angle on the basic operating mechanism of the NSLBP and the impact and limitations of spine research are established based on the advice obtained from interviewing a physiotherapist in National Cheng Kung University. Also, through Literature Review, the direction of this study is clearly defined. Expert Interview also helps clarify whether NSLBP among veterinarians is caused by the poor posture that skews the curvature of the spine and damages the soft tissues. Veterinarians will also increase the load on the lower back due to the long period of suspending the hands in the air. Design which is commonly seen only addresses the compensatory patterns or the inability to cure over the part of the lumbar spine. The above interviews will provide details and be used as the focus in the follow-up design and experiment of this Study.

3.3 A New Assistive Design for the Thermal Comfort

Through Literature Review, it is found that maintaining a stable hand and body temperature above a certain level is an important key to maintaining operational ability Through evaluation of the skin temperature, we can understand the thermal comfort relationship between the human body and the environment [37]. In the initial stage of veterinary hospital observation, it was found that the ambient temperature in the operating room was low, which may cause the veterinarian's hand fluency to decrease during the surgery and make the posture more flexed during operation. However, in the initial observation, we can only understand the problem of posture buckling during the veterinary surgery, but we cannot explore in depth the association between the skin temperature and thermal comfort, so this Study will design a assistive device to evaluate the veterinary surgery and the relationship between the skin temperature and the Blood Flow and discuss whether the balance in the skin temperature can promote blood circulation and mitigate muscle tensions.

Participants

This experiment mainly simulates the posture of the veterinarian during the veterinary surgery. Therefore, the subjects will mainly be students aged between 22 and 25, and there will be 5 participants in the Evaluation Experiment. The subjects suffer no other obstacles to their actions and they take no muscle relaxation drugs (such as NSAID) that can affect their central nervous systems.

Site Planning

The experimental site is set in the Ergonomics and Interaction Design Lab under department of industrial design National Cheng Kung University, where the environment is deemed as a control factor (with the ambient temperature maintained at 20–24°, the ambient humidity maintained at 50–60%, and lighting) to achieve a unified status for simulation of the surgery for the subjects.

Evaluation Model

This Study is aimed at veterinarians in Taiwan who show changes in the curvature of the trunk posture and the state of soft tissues during the surgery. After the observation and interview in the veterinary hospital, the OHE in the surgical content will be the Evaluation Model. As the OHE is relatively standardized and highly frequent in Taiwan, the veterinary hospital with a large number of visitors may arrange a series of operations in a day, which may take a longer time than other diagnostic and surgical operations.

Evaluation Equipment

This study utilizes the Human Computer Interaction Method, where the temperature sensors are combined with the carbon fiber heating sheets through Arduino (Fig. 5), to make a wearable device that can evaluate whether the skin temperature of the hand is maintained at the normal temperature or 32° [38]. If the skin temperature of the hand is lower than the normal temperature, the heat generating sheet will be utilized to make the temperature reach equilibrium based on the concept of thermal comfort, so that the skin temperature can be maintained within the normal range (Fig. 6). Making the temperature sensor based on Arduino can also allow us to have a better understanding of the human body at low temperatures, as well as the changes in the values of the skin temperature and the relevant status. Afterwards, the Bi-Directional Pocket Doppler with the LCD Display (Model: ES-100 V3, HADECO, JAPAN) is used for measurement and evaluation of the blood flow status.

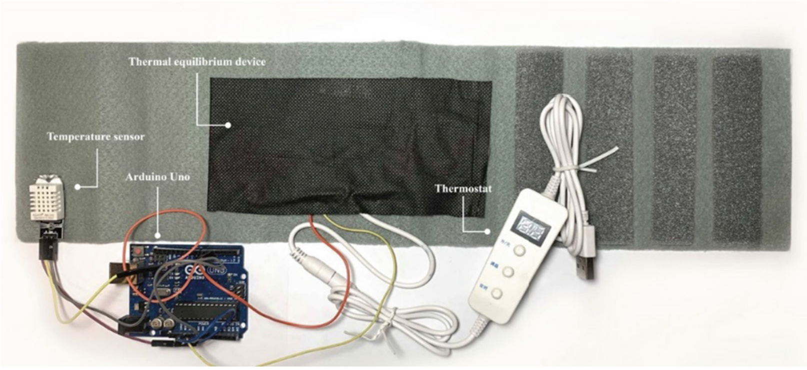


Fig. 5. Wearable thermal comfort assistive device

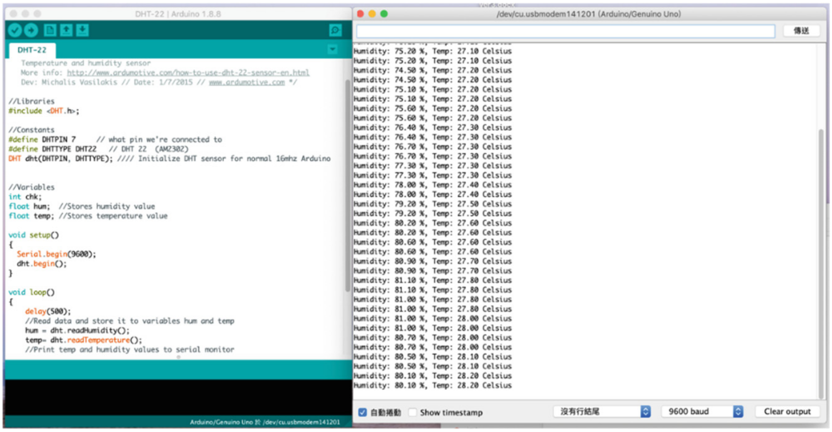


Fig. 6. Temperature control data

Evaluation Process

With the previous understanding of the concept of back muscle extension, in this Study, the subjects will simulate the OHE on the animal models, and each process will take 30 min, with the interval of 10 min for resting. This Study will test (1) New Type 1: no device intervention; (2) New Type 2: the thermal comfort device worn in the position of triceps brachii (TB, inside the upper arm) (Fig. 7a); and (3) New Type 3: the thermal comfort device worn in the position of brachioradialis (BH, inside the forearm) (Fig. 7b) to assess the effect of intervention or no intervention with the device on blood circulation in the hands. The subjects wear the designated clothes, which is convenient to wear and photograph, and starts the simulation of the OHE within the specified time limit. Afterwards, an evaluation of the blood flow status is conducted on the brachial artery to compare whether the intervention of the wearable thermal comfort device can adjust the skin temperature, maintain body temperatures within the normal range and control the blood flow between muscles to achieve homeostasis.

Fig. 7. a: Worn in the position of TB, b: Worn in the position of BH

4 Results

4.1 Variations in the Blood Flow

Design and analysis are performed based on the Blood Flow obtained from the Evaluation Experiment, as well as discussion with experts and observations. Based on the concept of thermal comfort, we find the main muscle location that may affect the blood circulation, and the parts with larger changes in values as the main stimulation site in the future measurement to improve blood circulation. This Study aims to conduct statistical analysis on (1) New Type 1: no device intervention; (2) New Type 2: the thermal comfort device worn in the position of TB; and (3) New Type 3: the thermal comfort device worn in the position of BH. One-way ANOVA is conducted on the above 3 categories (Table 1) to analyze the significant difference between the mean blood flow rate and mean blood flow volume. The results show that there are significant differences with $P < 0.05$, thus rejecting the null hypothesis. The evaluation device proves that compared with the situation where there is no intervention of any device, wearing the device designed by this Study can help maintain the skin temperature and thermal comfort and bring about significant benefits to the blood flow status.

Table 1. Evaluation - Pre-test result

		Sum of squares	df	Mean square	F	Sig.
MN	Between groups	39.232	2	19.616	9.819	.003
	Within groups	23.972	12	1.998		
	Total	63.204	14			
MN’	Between groups	135.525	2	67.763	9.366	.003
	Within groups	84.412	12	7.034		
	Total	219.937	14			

Note. MN: Mean of velocity (cm/s); MN’: Mean of volume flow (ml/s); Pre-MN: Previous mean of velocity (cm/s); Post-MN’: Post mean of volume flow (ml/s).
*The mean difference is significant at the 0.05 level.

Therefore, this Study goes further for post-hoc verification and uses Multiple Comparison Analysis Testing to understand significant differences exist between which groups when there is a significant difference in the mean numbers of multiple sets of samples. Table 2 shows the blood flow data in different states. It can be found from the data in the table that there is a positive relationship between the mean blood flow rate and the mean blood volume, and the data obtained from the thermal comfort device worn in the position of TB exhibit more significant differences than that obtained from the thermal comfort device worn in the position of BH. This study proves that the wearable device worn in the position of TB can more significantly promote blood circulation than that worn in the position of BH. This is also consistent with the findings proposed by Hellig [30] and Frank et al. [31] previously, where excessive muscle stretching will cause the blood flow status to decrease, but if thermal comfort is maintained for the hands, it will promote blood circulation and improve the operational competence of the hands.

Table 2. Multiple comparisons

Dependent variable	(I) Phase	(J) Phase	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
						Lower bound	Upper bound
MN (cm/s)	1.00	2.00	−3.76	0.8939	0.004	−6.252	−1.268
		3.00	−2.96	0.8939	0.02	−5.452	−0.468
MN’ (ml/min)	1.00	2.00	−6.96	1.6774	0.005	−11.636	−2.284
		3.00	−5.56	1.6774	0.02	−10.236	−0.884

Note. MN: Mean of velocity (cm/s); MN’: Mean of volume flow (ml/s); Pre-MN: Previous mean of velocity (cm/s); Post-MN’: Post mean of volume flow (ml/s).
*1.00 = Non-thermal comfort; 2.00 = Thermal comfort TB; 3.00 = Thermal comfort BH.
*The mean difference is significant at the 0.05 level.

5 Discussion

This Study creates a new assessment method that considers the spine angle and blood flow during the veterinary surgery, and summarizes those factors during the procedure of surgery into a posture classification system. Through analysis in the Evaluation Experiment, it is proved that maintaining the skin temperature and thermal comfort of the hands can effectively improve blood circulation, and that the wearable device worn in the position of TB can more significantly promote blood circulation than that worn in the position of B. This could be caused by the fact that TB is a bridge between the shoulder muscles and the elbows, so the effect on blood flow status is more obvious. This is also consistent with the findings proposed by Hellig and Frank et al. (2018; 2009) previously, where excessive muscle stretching will cause the blood flow status to decrease, but if thermal comfort is maintained for the hands, it will promote blood circulation and improve the operational competence of the hands.

This study needs further data collection and observation to understand the effects of the NSLBP among veterinarians on the biomechanics changes of the trunk and the state of blood circulation. This Study analyzes the existing LBP assistive devices and factors that may influence the NSLBP. Design guidelines are thus established, and the Focus Group is implemented to allow participation of experts in biomechanics and anatomy, so that the follow-up design proposals can be made to select appropriate device designs and soothing means.

6 Conclusion

This Study achieves blood flow status boost to the lower back muscles by maintaining thermal comfort of TB. This study will subsequently evaluate the biomechanical rule for the veterinary surgical posture, and use the motion capture system to assess the stress and angle of posture. In this study, we explore the principles, combine the concepts of biomechanics and physiological anatomy, and use innovative aids to solve the issue of NSLBP among veterinarians.

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