Mechanical structure design of a modularized vertebral detection and therapy instrument

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Abstract. Compared with traditional hands-free massage therapy, vertebral detection and therapy instrument has shown good performance in improving therapeutic effect and safety. At present, foreign vertebral detection and therapy instrument have complete functions. However the cost of the instrument is expensive. Domestic vertebral detection and therapy instruments are cheaper, but the function of detecting muscle hardness is lack. In this paper, the mechanical system of a modularized vertebral detection and therapy instrument is designed. The mechanical part of the instrument is composed of three separable working modules. It has the function of detection and treatment with low cost. The modular design of the instrument solves the problem of overheating during operation, and makes it show some advantages in maintainability, expansibility and other aspects.

1. Introduction

With the widespread popularity of electronic products such as mobile phones and computers, the incidence of spine-related diseases continues to increase, and the equipment required to detect and treat these diseases has become an important research direction. Traditional sEMG and MRI[1,2] instruments required for detecting muscle stiffness have a long detection time and high use cost. Tuina robots with multi-degree-of-freedom manipulators as the main body[3, 4] can use a variety of massage techniques on patients with muscle stiffness, but its larger size limits its application environment. It uses a built-in sensor to evaluate the stiffness of the patient's muscles, and uses high-frequency pulse force to impact the human body to cause resonance to treat the stiffness of the body's muscle tissue. At present, the domestic detection and treatment instruments can be divided into pneumatic type[5], electromagnetic coil type[6], eccentric wheel type[7], etc. according to their working principles. These detection and treatment instruments are portable and low-cost, but lack the detection function. The American PulStar G3 detection and treatment instrument[8], which has both detection and treatment functions, is costly. Therefore, it is necessary to balance the relationship between a portable, economical, and both detection and treatment instrument. At the same time, it is also an urgent problem to prevent the high temperature generated by the vertebral detection and therapy instrument from affecting its work durability.

This paper designs the mechanical system of a modularized vertebral detection and therapy instrument. The mechanical structure of the vertebral detection and therapy instrument is designed into different working modules according to the functional requirements and characteristics of sensors and electromagnets. While ensuring portability, parts can be assembled and replaced freely according to treatment requirements.
2. Modular mechanical structure design

In order to achieve detection and treatment functions, the mechanical structure of the vertebral detection and therapy instrument uses sensors and electromagnets as core working elements, which are used to detect preload force, detect muscle stiffness, and apply impulse force. The vertebral detection and therapy instrument is assembled by three modules with different functions. The overheating problem caused by long-time work is solved by replacing the modules.

The schematic diagram of the working principle of the vertebral detection and therapy instrument is shown in figure 1. When not working, the electromagnet is powered off, sensor 2 is not stressed, and sensor 1 is pre-compressed. When detecting a patient, the massage head of the treatment device presses the part of the patient to be detected, and the internal components and the outer casing relative displacement and slide the sensor 1 to the left. When the force received by the sensor 1 reaches a predetermined value, the electromagnet generates a pulse force to hit the human body part. Depending on the degree of stiffness of the body part, the peak value of the reaction force received by the sensor 2 is different, thereby determining whether the part needs treatment. During the treatment of the patient, when the preload force received by the sensor 1 reaches a predetermined value, the electromagnet pushes the massage head to hit the diseased part at a predetermined frequency and number of times, and the pulse force triggers resonance of the human tissue to achieve the therapeutic effect.

![Figure 1. The working principle diagram of the spine detection and treatment instrument.](image)

Figure 2(a) is the actual assembly diagram of the vertebral detection and therapy instrument. When in use, the three modules are assembled into a vertebral detection and therapy instrument with complete functions. Each module is circled with a dotted frame. Figure 2(b) is a cross-sectional view of the connecting part of the rear module and the middle module, in which the slider slides into the slot under the push of the spring to connect the middle module and the rear module. Figure 2(c) is a cross-sectional view of the connection between the middle module and the front module. The two modules are connected by threads. The stop part is used to avoid the thread looseness caused by vibration and improve the reliability of the connection.
2.1. Front sensor module

The function of the front sensor is to judge the stiffness of the patient's muscles by reading the value of the sensor 2 during detection. In figure 3(a), the thread of the front sensor outer casing is used to connect with the middle module, and the center hole is used to pass the iron core that applies impulse force. The two symmetrically arranged synapses are the circuit connection points between the front module and the middle module. In figure 3(b), when treating a patient, the iron core of the middle module hits the central slider and the sensor, and the central slider transmits the pulse force $F_1$ to the human body, triggering the resonance of the human tissue to achieve the therapeutic effect. In figure 3(c), when detecting a patient, the right end of the center slider is close to the patient through the massage head. When the iron core hits the center slider, the center slider slides to the right under the impact force $F_2$. The resultant force generated by the body tissue and the compression force of the spring form a resultant force $F_3$, which forces the central slider to slow down. Sensor 2 judges the stiffness of the patient's muscles by detecting the high and low strength caused by the deceleration of the center slider. The appearance and dimensions of each part are shown in figure 3(d).
2.2. Middle work module

The design purpose of the middle working module is to provide the impulse force required by the treatment device when working, and to connect the front module and the rear module. In figure 4(a), the bracket is subjected to the rightward thrust $F$ exerted by the rear module during assembly, and this force cooperates with the limit slot to maintain the bracket at the right end of the middle module in the non-working state. Therefore, the electromagnet in the stent will be in the same initial position before each operation, which can provide a stable initial condition for subsequent detection or treatment. The pulse force required in the process of detection and treatment is generated by the frequent on and off of the electromagnet. In Figure 4 (b), the right end of the middle module is connected to the front sensor through threads. The middle module will produce high-frequency vibration when it is working. The stop part is used to prevent the loosening of the thread caused by vibration and improve the stability of the connection. In figure 4(c), the appearance of the left end of the middle module is shown in the figure, and the central hole is used to pass through the Putter of the rear module. In the natural state, the slider is stretched out by the spring, which hinders the installation of the rear module, and the contraction of the slider needs to be controlled by a button. In figure 4(d), before the middle module is assembled, press the buttons on both sides, the slider is squeezed to slide to both sides and shrink under the outer casing, and the rear module extends from the central rectangular area. In figure 4(e), after the rear module is assembled in place, the button is released, and the slider rebounds to the initial position by the action of the spring and extends into the slot of the rear module to fix the two modules.
2.3. Rear sensor module

The rear sensor module is used to detect the preload force exerted on the patient. In figure 5(a), the rear module is connected to the middle module by the cooperation of the slot and the slider. When assembling, the sliding block at the tail of the middle module extends into the slot to fix the relative position of the middle module and the rear module. In figure 5(b), the spring is pre-compressed during the assembly process of the rear module. At this time, the force detected by the sensor 1 is the pre-compression force $F_1$. In figure 5(c), when detecting a patient, the Putter is forced to move to the left to squeeze the sensor 1. At this time, the detected force $F_2$ minus the pre-compression force $F_1$ is the pre-load force applied to the patient. The appearance and dimensions of each part are shown in figure 5(d).

Figure 5. Rear sensor module. (a) Overall appearance drawing. (b) Sectional view of assembly force. (c) Sectional view of applying preload. (d) Exploded view.
3. Summary
This paper designs a modularized mechanical system of the vertebral detection and therapy instrument. The mechanical structure of the vertebral detection and therapy instrument relies on applying an impact force to the patient and detecting the reaction force generated by the human body to detect muscle stiffness. And by transmitting the pulse force generated by the electromagnet to the human body to generate resonance to achieve the purpose of treatment. The mechanical part of the detection and treatment instrument adopts a modular structure. By replacing the module, the problem of sensor and other sensitive components failure in a high-heat environment is solved, and it is suitable for use in an environment with long working hours and high working intensity.

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