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ARTICLE

Development and Evaluation of a Coir-Fiber-Based Lumbar Support Pillow Incorporating Acupoint Stimulation for Sedentary Individuals with Low Back Pain

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Abstract

Low back pain is a prevalent issue among sedentary individuals due to prolonged sitting postures, often leading to physical discomfort and psychological distress. This study proposes a coir-fiber-based lumbar support pillow (CLP) incorporating traditional Chinese medicine acupoint massage principles to alleviate low back pain in sedentary individuals. The CLP was designed based on human-machine interaction parameters and acupoint locations, integrating coir-fiber-based massage balls (CMBs) to optimize acupoint stimulation. A user evaluation involving 20 participants assessed acupoint stimulation, elastic modulus distribution, and physiotherapy effects. Results demonstrated that the stimulation pressure varied significantly depending on acupoint location, with the right lumbar side 16.57% higher than the left and lower lumbar acupoints 67.45% higher than upper ones. Elastic modulus tests showed a positive correlation with stimulation levels, confirming that CMBs provide effective acupoint stimulation. Physiotherapy tests indicated significant reductions in systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR), with respective decreases of 9.8%, 7.2%, and 37.4%. Additionally, the use of CLP led to notable reductions in fatigue (VAS) and anxiety (STAI). The CLP successfully integrated acupoint massage principles, demonstrating effective lumbar support and physiotherapy benefits. The combination of coir fiber elasticity and acupoint stimulation improved comfort, reduced back fatigue, and enhanced circulation. These findings suggest the potential of coir fiber-based products incorporating traditional Chinese medicine in mitigating sedentary-related discomfort.

Keywords: Lumbar support pillow, Coir fiber, Low back pain, Acupoint stimulation, Sedentary individuals

1. Introduction

Low back pain is prevalent among sedentary individuals, often due to prolonged maintenance of a sitting posture characterized by an upright spine, forward-leaning body, and unsupported lumbar region. In addition to physical discomfort, psychological symptoms such as anxiety and irritability may also accompany these issues (Mahdavi et al. 2021, Hu et al. 2022). A lumbar support pillow can effectively alleviate these discomforts by providing appropriate support to the lumbar area, thereby stabilizing the body (Gao et al. 2022).

Research on lumbar support pillows has primarily focused on structural design and filling materials. Structural studies aim to enhance comfort through improved support mechanisms. For instance, Guo et al. (Guo, Dong, and Yuan 2022) found that seats with lumbar support significantly reduced muscle fatigue under vibration conditions. Gao et al. (Gao et al. 2022) demonstrated that maintaining a backrest tilt angle of 29-33° and a seat cushion angle of 10° minimized lumbar load. Research on cushion filling materials has increasingly emphasized renewable resources. Yu et al. (Yu et al. 2023) developed a modular seat cushion using waste bamboo fiber based on pressure distribution analysis, which significantly enhanced user comfort. Saengwong-ngam et al. (Saengwong-ngam et al. 2023) created a cushion from natural rubber latex and bamboo leaf fiber, achieving performance comparable to commercial polyethylene foam cushions.

Coir fiber, as a renewable bio-material, exhibits significant potential for use in lumbar support pillows. Coir fiber can deform up to 4-6 times more than other natural fibers, making it one of the strongest natural fibers (Ali et al. 2022). Its structure, composed of parallel single-cell tubular fibers, provides lightweight, sound-absorbing, thermally insulating, and cushioning properties (Mahmud et al. 2023). Additionally, Costa et al. (Costa, Faria, and Dantas 2014) found that coir fiber, as a cushion material, offered better injury prevention during transportation compared to wood. These characteristics indicate that coir fiber is an ideal elastic filling material for lumbar support pillows. Moreover, coir fiber can be processed into composites with superior performance when combined with other materials. Joy et al. (Joy et al. 2023) developed a latex-coir composite sheet, demonstrating a 47% improvement in strength and drainage performance compared to nonwoven coir felt and woven coir geotextile when comprising 50% latex with a density of 800g/M^2.

To further enhance the efficacy of lumbar support pillows in alleviating low back pain, integrating traditional Chinese medicine physiotherapy methods such as acupuncture, massage, and acupoint drug administration could be effective (Kim et al. 2023, Xie et al. 2020). Lin et al. (Lin et al. 2023) showed that massage significantly mitigated symptoms including headaches and lumbar pain. Additionally, acupoint application can stimulate and regulate specific points, promoting the regulation of Qi and blood. Purepong et al. (Purepong et al. 2015) discovered that an acupressure-based backrest provided superior relief for low back pain compared to conventional pillows. Additionally, numerous studies have indicated that appropriate acupoint stimulation can promote blood circulation, dredge meridians, and relieve fatigue and stress (Li et al. 2023, He and Zhao 2019).

Therefore, this study aims to develop a lumbar support pillow using coir fiber as the raw material to improve low back pain among sedentary individuals by incorporating traditional Chinese medicine principles. Specifically, a coir-fiber-based lumbar support pillow (CLP) incorporating acupoint massage of traditional Chinese medicine was proposed, encompassing its design, preparation, and evaluation. The relationship between the elasticity modulus of coir-fiber-based massage balls (CMBs) in the CLP and the acupoint stimulation levels, as well as the impact of CMB distribution on the physiotherapy effects of CLP, were analyzed.

2. Materials and Methods

2.1 Structural Design of CLP

The structural design of CLP primarily involves parameters such as width, height, thickness, and the contact angle between the human body and the lumbar support pillow. Based on the Chinese standard GB/T 10000-2023, dimensions corresponding to the 50th percentile of Chinese adults were selected for the design, setting the external dimensions of the CLP at 340 mm in width, 300 mm in height, and a minimum thickness of 60 mm. To ensure optimal comfort, a contact angle of 50° was chosen (Dimitrijevic et al. 2022).

Following the research by Kim et al. (Kim et al. 2023), the most commonly used acupoints for treating low back pain were identified. And their coordinates were established based on the intersection points between the human-machine contact surface and the midline of the human spine, as illustrated in Fig. 1a. According to these acupoint coordinates, a series of CMBs were strategically placed at each coordinate (Fig. 1b). The overall structural design of the CLP is presented in Fig. 1c.

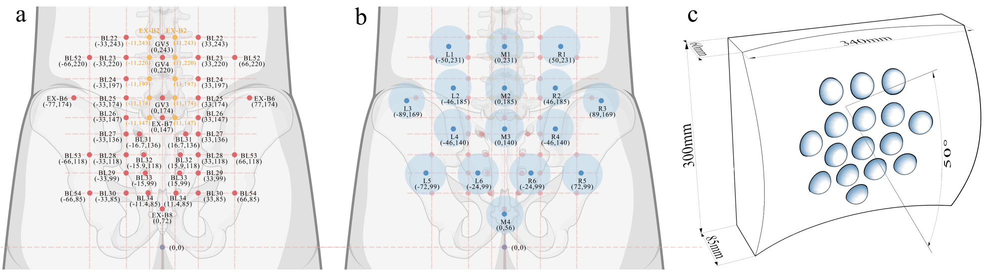

Figure 1. Acupoint coordinates (a), arrangement scheme of CMBs (b) and structural design of CLP (c)

2.2 Preparation of CMBs and CLPs

The coir fiber was supplied by Zhilan Trade Company in Jiande, China. The ethylene-propylene fibers were sourced from Yufang New Material Technology Co., Ltd. in Jiangsu, China. Initially, the coir fibers were dried for 24 hours at 108 ± 2°C. Subsequently, the dried coir fibers were mixed with relaxed ethylene-propylene fibers in proportions of 50%, 55%, 60%, 65%, and 70%. The mixed fibers were then placed into a spherical metal mold with a diameter of 36 mm and heated at 150°C for 50 minutes. Through quality control, CMBs with densities of 0.08 g/cm^3, 0.10 g/cm^3, 0.12 g/cm^3, 0.14 g/cm^3, and 0.16 g/cm^3 were produced.

The CLP consists of a CLP base and CMBs. The CLP base was prepared using a similar process as the CMBs, with a coir fiber proportion of 50% and a density of 0.10 g/cm^3, which is a common density for lumbar support pillows on the market. The coir fibers and ethylene-propylene fibers were evenly mixed and placed into a curved metal mold measuring 340 mm × 300 mm × 60 mm, then heated at 150°C for 50 minutes. After cooling and demolding, a CLP base without CMB installation holes, designated as CLP0 (Fig. 2a), was produced. Following the acupoint coordinates displayed in Fig. 1b, protruding spheres corresponding to the CMB installation holes were set up in the metal mold. By repeating the CLP0 preparation process, a CLP base with CMB installation holes was obtained. Finally, the CLP was assembled by installing the CMBs into the CLP base (Fig. 2b).

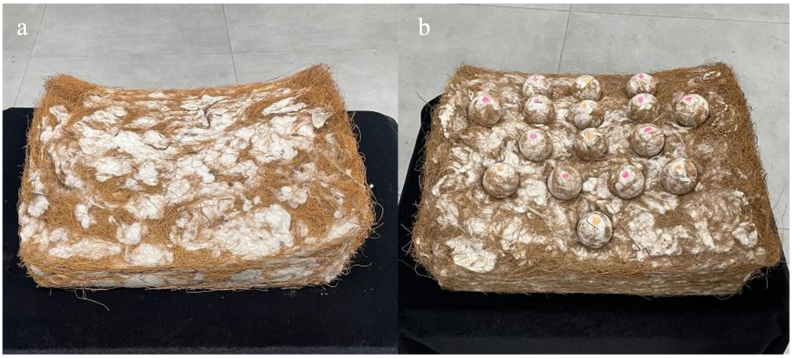

Figure 2. Images of CLP0 (a) and CLP (b)

2.3 Evaluation of CLP

2.3.1 Participants

Twenty students from Zhejiang Sci-Tech University, who frequently engage in sedentary office work and suffer from low back pain, were selected as participants. The participants included 10 males with heights ranging from 172 to 176 cm and 10 females with heights between 158 and 162 cm. All participants were in good health. To minimize interference, participants were instructed to avoid intense physical activities before the experiment. Meanwhile, informed consent for participation in the study was obtained from each participant.

Given that individuals habitually transition from an upright sitting posture to a slumped sitting posture over time and tend to rest their upper bodies on the table, a slumped sitting posture was defined as the test posture for evaluating the CLP (Fig. 3a). During the test, the office chair was fixed in an appropriate position to prevent rotation or movement. Besides, participants were asked to maintain a 90° angle at both hips and knees, with feet shoulder-width apart, and to keep their upper bodies naturally leaning forward. Additionally, participants were instructed to look straight ahead while performing typing exercises during the test. The CLP was installed on each office chair, ensuring that each CMB stimulated the lumbar region (Fig. 3b).

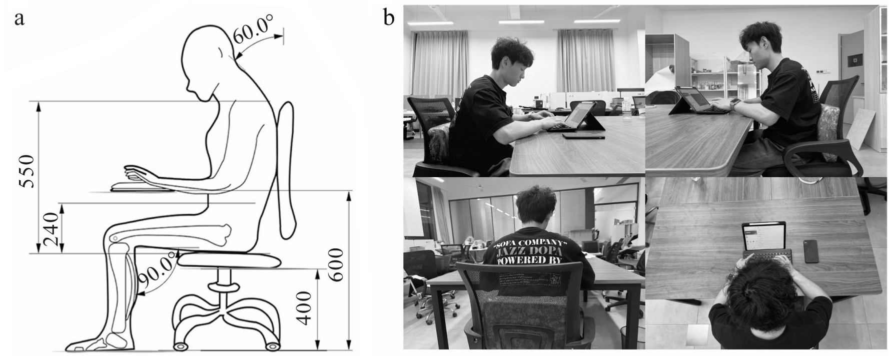

Figure 3. Sitting posture of CLP evaluation

2.3.2 Acupoint stimulation

Quantitative analysis of acupoint stimulation, including stimulation pressure and sensation, was conducted using the MASS scale (Chao et al. 2022) and a 10-point visual analogue scale (Sun et al. 2012). The stimulation pressure at 16 CMB positions as shown in Fig. 1b were measured using a push-pull gauge (HP-200, Yueqing Aidebao Instrument Co., Ltd., China). The instrument was set to peak pressure test mode with a pressing head featuring a flat circular surface of 1.5 cm in diameter. The stimulation pressure was applied to each position, and its value when the participant felt the stimulation sensation was recorded. Three measurements were taken for each acupoint. The stimulation sensation was assessed on a 10-point scale, focusing on sensations of soreness, numbness, swelling, and heaviness. When the average score of these four sensations was between 3 and 5 points, it indicated that the stimulation sensation was generated upon pressing the acupoint (Hu et al. 2019). The stimulation sensation scoring results were categorized as follows: level III for scores between 3.0 and 3.5, level IV for scores between 3.5 and 4.5, and level V for scores between 4.5 and 5.0.

2.3.3 Elastic modulus

The elastic modulus was tested in accordance with EN 1957-2012 standards. A universal mechanical testing machine (Shanghai Yiheng Co., Ltd., Shanghai, China) was used to test cubic samples (60 mm edge length) made of coir fiber with the same proportion and density as the CMBs. The compression speed was set at 1 mm/min, the maximum load was set at 250 N, and six samples were tested. The CMBs were divided into 12 levels based on their elastic modulus values, with each level differentiated by 0.1 MPa increments.

2.3.4 Physiotherapy effects

Acupoint stimulation can improve various physiological parameters, such as systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and blood oxygen saturation (SpO_2) (Dakic et al. 2023). Therefore, the physiotherapy effects of the CLP could be evaluated by changes in these physiological parameters before and after using the CLP. Initially, the baseline values of SBP, DBP, HR, and SpO_2 were collected from each participant. Additionally, the initial levels of lumbar fatigue and anxiety were recorded using a visual analog scale (VAS) with a score range of 0-10 and the State-Trait Anxiety Inventory (STAI), respectively. Subsequently, participants underwent a one-hour slumped sitting test using the CLP and the control group CLP0. After the experiment, the aforementioned parameters were measured and recorded again to calculate the differences. The average values were calculated by removing the two highest and two lowest values from each data set. SpO_2 was measured using a Medisana pulse oximeter (Medisana GmbH, Neuss, Germany), while SBP and DBP were measured using a Yuwell blood pressure monitor (Yuwell Medical Equipment and Supply Co., Ltd., Jiangsu, China).

3. Results and discussion

3.1 Acupoint stimulation

Table 1 shows the acupoint stimulation scores for soreness, numbness, swelling, and heaviness at the 16 CMB positions. The average scores for heaviness (4.86 ± 0.76) and swelling (4.65 ±

0.78) are similar across all CMB positions and slightly higher than those for soreness (3.53 ± 0.59) and numbness (2.86 ± 0.56). With increasing acupoint stimulation levels, the stimulation pressure value at the same CMB position gradually increases. Even at the same acupoint stimulation level, the stimulation pressure values vary between different acupoints. Notably, the stimulation pressure values at the CMB positions on the right side of the lumbar region (R1–R6) are higher than those on the left side (L1–L6), with an average increase of 16.57%. Along the spine midline, the stimulation pressure values at the lower locations (M3 and M4) are significantly higher than those at the upper locations (M1 and M2), showing an average increase of 67.45%. This was due to the uneven distribution of muscle and bone tissues in the human lumbar region and their varying sensitivity at each acupoint. Moreover, typical office seating posture, often involving right-hand mouse usage, led to more body weight being shifted to the left side, making the left side of the lumbar region more sensitive to stimulation pressure (Xia et al. 2023). Additionally, along the spine midline, the lumbar spine was more sensitive to pressure due to the greater number of small joints (Tran et al. 2024).

Table 1. Matching results between stimulate levels and elastic modulus levels of CMBs

CMB	Acupoint stimulation scores				Total	Stimulation	Stimulate
Position	Soreness	Swelling	Numbness	Heaviness	score	Level	Pressure (N)
L1	2.95±0.74	2.15±0.73	3.50±0.74	3.70±0.56	3.08±0.55	III	44.32±7.21
	3.30±0.78	2.60±0.80	4.65±0.57	5.50±0.67	4.01±0.43	IV	50.59±6.97
	4.30±0.64	3.40±0.58	5.35±0.73	5.60±0.80	4.66±0.47	V	57.17±6.63
L2	2.90±0.54	2.10±0.62	3.60±0.80	3.75±0.54	3.09±0.46	III	43.52±3.73
	3.05±0.38	2.80±0.51	4.90±0.54	5.00±0.89	3.94±0.33	IV	47.19±4.16
	4.25±0.62	3.40±0.66	5.50±0.59	5.75±0.70	4.73±0.36	V	52.33±4.44
L3	3.00±0.55	2.25±0.74	3.75±0.70	3.90±0.44	3.23±0.39	III	46.77±4.38
	3.70±0.64	2.95±0.80	5.05±0.38	5.15±0.79	4.21±0.25	IV	52.24±3.96
	4.35±0.65	3.70±0.78	5.65±0.57	5.70±0.84	4.85±0.29	V	57.91±4.22
L4	2.80±0.60	2.05±0.59	3.50±0.74	3.65±0.54	3.00±0.44	III	45.72±5.29
	3.00±0.55	2.70±0.46	4.80±0.60	4.75±0.70	3.81±0.30	IV	51.48±5.02
	4.20±0.60	3.30±0.56	5.35±0.48	5.60±0.73	4.61±0.32	V	55.37±5.76
L5	3.15±0.48	2.25±0.83	3.85±0.57	3.90±0.54	3.11±0.43	III	68.29±7.39
	3.90±0.62	3.25±0.70	5.05±0.50	5.10±0.77	3.84±0.31	IV	74.60±8.01
	4.35±0.57	3.70±0.78	5.55±0.59	5.80±0.93	4.56±0.41	V	81.35±7.68
L6	2.75±0.54	2.40±0.73	3.50±0.74	3.80±0.60	3.11±0.43	III	59.14±6.64
	3.10±0.62	2.75±0.54	4.75±0.54	4.75±0.83	3.84±0.31	IV	64.72±6.93
	4.30±0.56	3.40±0.58	5.15±0.65	5.40±0.80	4.56±0.41	V	71.18±6.04
R1	2.75±0.54	2.20±0.51	3.75±0.70	4.20±0.75	3.23±0.41	III	49.83±6.38
	3.15±0.65	2.80±0.75	4.70±0.78	4.85±0.91	3.88±0.46	IV	53.78±6.69
	4.15±0.79	3.35±0.85	5.30±0.71	5.55±0.80	4.59±0.61	V	58.66±6.24
R2	2.95±0.86	2.30±0.78	3.40±0.66	3.90±0.70	3.14±0.59	III	47.74±6.09
	3.50±0.80	2.70±0.78	4.40±0.66	5.40±0.73	4.00±0.34	IV	52.82±6.14
	4.20±0.68	3.45±0.59	5.45±0.80	5.65±0.85	4.69±0.52	V	57.64±5.78
R3	2.85±0.57	2.05±0.74	3.50±0.87	3.65±0.48	3.01±0.52	III	51.36±6.73
	3.10±0.44	2.55±0.59	4.95±0.50	5.10±0.77	3.93±0.28	IV	57.53±7.16
	4.00±0.71	3.35±0.73	5.55±0.59	5.65±0.73	4.64±0.28	V	62.28±6.83
R4	3.00±0.55	2.25±0.74	3.75±0.70	3.90±0.44	3.23±0.39	III	48.52±3.94
	3.70±0.64	2.95±0.80	5.05±0.38	5.15±0.79	4.21±0.25	IV	54.39±4.26
	4.35±0.65	3.70±0.78	5.65±0.57	5.70±0.84	4.85±0.29	V	58.16±4.41
R5	2.55±0.59	2.05±0.67	3.75±0.62	4.10±0.70	3.11±0.38	III	74.87±7.18
	3.25±0.70	2.90±0.77	4.80±0.51	4.80±0.81	3.94±0.39	IV	79.22±7.39
	4.10±0.83	3.60±0.80	5.40±0.66	5.60±0.73	4.68±0.57	V	87.33±8.04
R6	3.10±0.44	2.55±0.92	3.85±0.57	3.90±0.62	3.35±0.20	III	61.31±5.77

CMB Position	Acupoint stimulation scores Soreness	Swelling	Numbness	Heaviness	Total score	Stimulation Level	Stimulate Pressure (N)
	3.85±0.73	3.10±0.70	5.00±0.55	5.10±0.70	4.26±0.22	IV	66.62±5.94
	4.30±0.56	3.85±0.73	5.50±0.59	5.75±0.70	4.85±0.24	V	73.34±6.17
M1	3.05±0.59	2.25±0.75	3.70±0.78	3.90±0.54	3.23±0.50	III	49.83±6.38
	3.15±0.57	2.85±0.57	4.85±0.48	5.10±0.77	3.99±0.37	IV	53.78±6.69
	4.20±0.60	3.35±0.57	5.45±0.50	5.55±0.74	4.64±0.41	V	58.66±6.24
M2	2.80±0.81	2.20±0.75	3.25±0.70	3.80±0.75	3.01±0.58	III	47.74±6.09
	3.35±0.57	2.65±0.73	4.40±0.58	5.20±0.81	3.90±0.28	IV	52.82±6.14
	4.40±0.66	3.40±0.73	5.50±0.81	5.85±0.73	4.79±0.46	V	57.64±5.78
M3	3.05±0.50	2.30±0.71	3.90±0.62	4.00±0.45	3.31±0.30	III	51.36±6.73
	3.85±0.57	3.10±0.83	5.15±0.48	5.05±0.86	4.29±0.28	IV	57.53±7.16
	4.45±0.59	3.85±0.85	5.70±0.56	5.80±0.87	4.95±0.28	V	62.28±6.83
M4	2.90±0.54	2.10±0.77	3.60±0.73	3.70±0.56	3.08±0.40	III	48.52±3.94
	3.65±0.65	2.75±0.89	4.90±0.44	4.85±0.85	4.04±0.36	IV	54.39±4.26
	4.25±0.70	3.40±0.86	5.50±0.59	5.55±0.80	4.68±0.35	V	58.16±4.41

3.2 Elastic modulus

The elastic modulus of CMBs and its classification are displayed in Fig. 4. As shown in Fig. 4, the elastic modulus of CMBs decreases with an increase in coir fiber proportion at the same density. Conversely, at the same coir fiber proportion, increasing the density of CMBs results in a higher elastic modulus. Additionally, the influence of coir fiber proportion on the elastic modulus becomes more pronounced as the density increases. The elastic modulus of CMBs was determined by the constituent materials and their adhesion condition (Jang et al. 2020). And the ethylene-propylene fibers in the CMB primarily served as a binding agent. At the same density level, a lower proportion of ethylene-propylene fibers led to weaker adhesion between coir fibers, resulting in lower strength and stiffness, and consequently, a lower elastic modulus. At the same coir fiber proportion, a lower density meant larger gaps between fibers. Thus, when compressed, fibers required a greater compression distance under the same applied stress, thereby reducing the elastic modulus (Chicos et al. 2022). Furthermore, as density increased, both fiber contents increased, indicating that melted ethylene-propylene fibers would create more bonding points in the gaps between coir fibers, leading to better adhesion and a greater impact on the elastic modulus. Based on the measured elastic modulus, the CMBs were divided into 12 strength levels for further testing.

The matching results between acupoint stimulation level and elastic modulus level of CMBs are displayed in Table 2. In this test, if over 70% of participants selected the same elastic modulus level of CMB at the same position when feeling stimulation sensation, it was determined that the CMB of that elastic modulus level was suitable for the acupoint stimulation level at this CMB position. From Table 2, it is evident that at the same CMB position, as the acupoint stimulation level increases, the corresponding elastic modulus level of CMB also increases. Furthermore, at the same acupoint stimulation level, different CMB positions match different elastic modulus levels of CMBs. Specifically, the average elastic modulus level matched by the CMB positions on the right side of the lumbar area (R1–R6) is one level higher than those on the left side (L1–L6). Along the spine midline, the average elastic modulus level matched by the CMB positions on the lower lumbar area (M3 and M4) is three levels higher than those on the upper (M1 and M2). This variation aligned with the changes in stimulation pressure when feeling stimulation sensation at different CMB

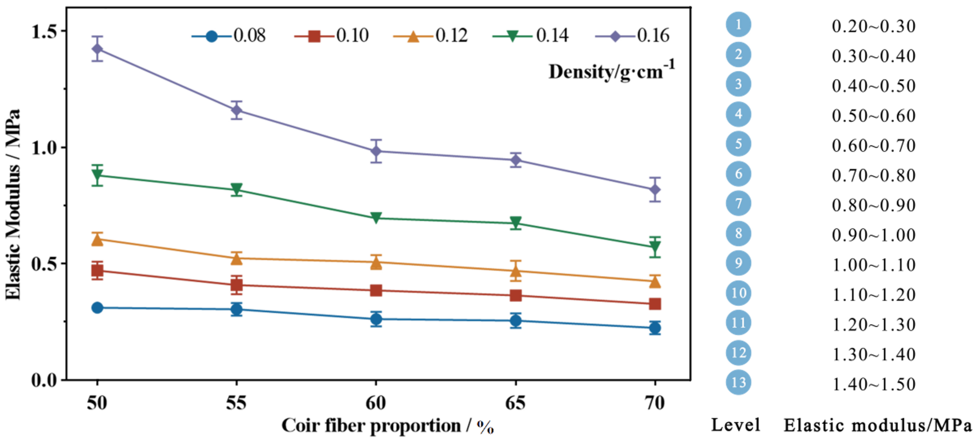

Figure 4. Elastic modulus of CMBs and its classifications

positions. Additionally, CMBs with elastic modulus levels of 1, 12, and 13 were not selected. This indicated that too low or too high elastic modulus levels of CMBs could not provide suitable stimulation sensation.

Table 2. Matching results between stimulate levels and elastic modulus levels of CMBs

CMB Position	Stimulation Level	Stimulate Pressure (N)	Elastic Modulus Level	CMB Position	Stimulation Level	Stimulate Pressure (N)	Elastic Modulus Level
L1	III	44.32±7.21	5	R1	III	49.83±6.38	6
	IV	50.59±6.97	6		IV	53.78±6.69	6
	V	57.17±6.63	7		V	58.66±6.24	7
L2	III	43.52±3.73	5	R2	III	47.74±6.09	5
	IV	47.19±4.16	5		IV	52.82±6.14	6
	V	52.33±4.44	6		V	57.64±5.78	7
L3	III	46.77±4.38	5	R3	III	51.36±6.73	6
	IV	52.24±3.96	6		IV	57.53±7.16	7
	V	57.91±4.22	7		V	62.28±6.83	8
L4	III	45.72±5.29	5	R4	III	48.52±3.94	6
	IV	51.48±5.02	6		IV	54.39±4.26	6
	V	55.37±5.76	7		V	58.16±4.41	7
L5	III	68.29±7.39	8	R5	III	74.87±7.18	9
	IV	74.60±8.01	9		IV	79.22±7.39	10
	V	81.35±7.68	10		V	87.33±8.04	11
L6	III	59.14±6.64	7	R6	III	61.31±5.77	7
	IV	64.72±6.93	8		IV	66.62±5.94	8
	V	71.18±6.04	9		V	73.34±6.17	9
M1	III	23.35±4.86	2	M3	III	52.87±6.07	6
	IV	30.67±4.31	3		IV	58.44±6.69	7
	V	35.93±5.09	4		V	65.59±6.55	8
M2	III	34.51±4.78	4	M4	III	53.79±4.08	6
	IV	40.79±5.74	4		IV	58.81±5.07	7
	V	45.82±5.11	5		V	63.98±5.45	8

3.3 Physiotherapy effects

To further investigate the effect of acupoint stimulation on low back pain, CMBs corresponding to each acupoint stimulation level were placed at the 16 CMB installation holes based on the matching results between the acupoint stimulation and the elastic modulus. The CLPs with CMBs corresponding to acupoint stimulation levels of III, IV, and V were named CLP1, CLP2, and CLP3, respectively.

The physiotherapy effects of CLPs with different acupoint stimulation levels are presented in Fig. 5. Compared to the control group (CLP0), the changes in SBP, DBP, HR, and SpO_2 for the experimental groups (CLP1, CLP2, CLP3) are more obvious. Specifically, the average increments in SBP, DBP, and HR for the CLPs are 9.8%, 7.2%, and 37.4% higher than those of CLP0, while the average decrement in SpO_2 is 18.4% lower than that of CLP0. Furthermore, the fatigue (VAS) and anxiety (STAI) levels increase after using CLP0 but decrease after using the CLPs. These results indicated that the CLPs could provide better physiotherapy effects compared to CLP0.

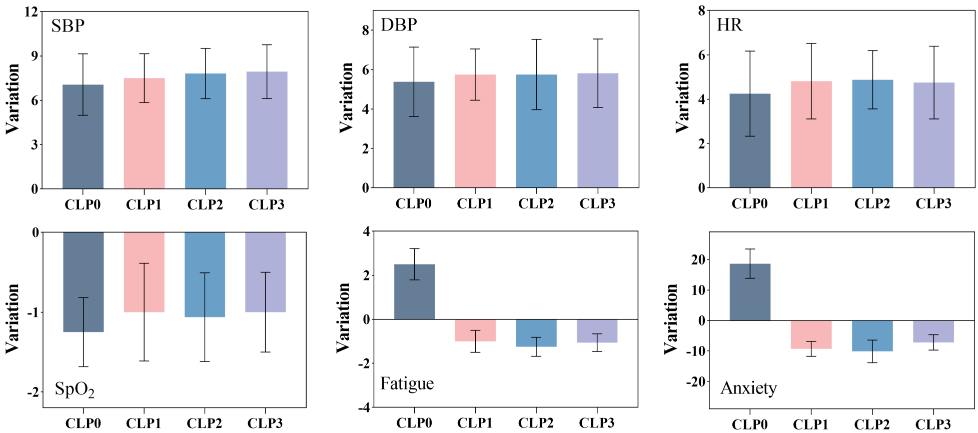

Figure 5. Physiotherapy effects of CLPs with different acupoint stimulation levels

When comparing among the CLPs, the changes in SBP, DBP, HR, SpO_2, VAS, and STAI are less pronounced, indicating that CLPs with acupoint stimulation levels of III, IV, and V all had notable physiotherapy effects. With increasing acupoint stimulation level, the VAS and STAI scores initially increase and then decrease. Notably, CLP2, corresponding to acupoint stimulation level IV, achieves the greatest reduction in fatigue (1.25 points) and anxiety scores (10.13 points), indicating that acupoint stimulation level IV had a more significant advantage in physiotherapy effects.

4. Conclusion

This study utilized coir fiber as the base material to develop a lumbar support pillow that integrates traditional Chinese medicine acupoint massage principles. By strategically positioning CMBs at key acupoints, the CLP effectively provided targeted stimulation, thereby reducing lumbar discomfort among sedentary individuals.

Experimental results confirmed that the physiotherapy effects of CLPs were influenced by both the acupoint stimulation levels and the elastic modulus of CMBs, which could be regulated through process parameters such as density and coir fiber proportion. As density increased or coir fiber proportion decreased, the elastic modulus of CMBs increased, resulting in greater stimulation pressure and higher acupoint stimulation levels. The optimal preparation technology for CMBs involved heating at 150 °C for 50 minutes with a coir fiber proportion of 50-70 wt.%.

Physiotherapy tests revealed that using the CLP for one hour led to significant improvements in lumbar fatigue and anxiety. Participants experienced reductions in SBP and DBP by 5.2% and 4.8%, respectively, while lumbar fatigue and anxiety scores decreased by an average of 38.5% and 31.7%. CLPs with an acupoint stimulation level of IV exhibited superior physiotherapy effects compared to those with acupoint stimulation levels of III and V.

Additionally, the use of coir fiber as a bio-based, renewable material enhances sustainability in ergonomic product design. These findings highlight the potential of combining biomechanical design with traditional Chinese medicine physiotherapy for innovative lumbar support solutions, providing new insights into sustainable and therapeutic seating accessories.

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Competing Interests

None

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