



Original Article

Effects of mechanical-bed massage on exercise-induced back fatigue in athletes

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Abstract. [Purpose] The study aimed to preliminarily investigate the effects of mechanical-bed massage on exercise-induced back fatigue in athletes. [Subjects and Methods] Twelve male college athletes, randomly allocated to experimental or control groups, were instructed to perform reverse sit-up for 8 sessions until they became fatigued. The experimental group received a 20-min mechanical-bed massage session, while the control group rested on a bed for the same period of time. Visual Analogue Scale (VAS) on perceived back muscle fatigue, back muscle endurance, and Heart Rate Variability (HRV) parameters including stress index (SI), HRV index, SDNN, RMSSD, pNN50, LF, HF, and LF/HF were analyzed. [Results] Immediately and 24 hours after the intervention, the VAS significantly differed between the groups. Experimental group's HF was significantly higher immediately after the intervention than control group. Experimental group's LF and LF/HF were significantly lower immediately after the intervention than the control group. [Conclusion] Mechanical bed massage may help athletes overcome the subjective feelings of exercise-induced fatigue, modulate the automatic nervous system activity, especially for balancing sympathetic and parasympathetic activities. Therefore, mechanical bed massage may facilitate recovery from muscle and central fatigue after athlete training or competition.

Key words: Mechanical-bed massage, Exercise-induced fatigue, Heart rate variability

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INTRODUCTION

Manual massage can be defined as the manipulation of the soft tissues of the body by a trained therapist as a component of a holistic therapeutic intervention¹⁾. Although the mechanism of massage on the body is still unclear, it has been used as one of the modalities for rehabilitation and promoting relaxation for thousands of years around the world. In the recent years, according to some observations, experiences, and evidence-based studies, sports medicine experts, coaches, and athletes believe that manual massage can have several benefits to the body; therefore, massage is widely used in sports. Recovery from fatigue and elimination of fatigue are the examples of these benefits. Manual massage has been found to affect both the body's overall fatigue²⁻⁴⁾ as well as local fatigue, such as thumb fatigue⁵⁾, quadriceps fatigue⁶⁾, and lumbar muscle fatigue⁷⁾.

Mechanical massage refers to the manipulation of soft tissues using machines, which include chair, bed, and other mechanical devices. Most of the mechanical massage techniques imitate manual massage. A comparison of manual massage with mechanical massage shows that the instruments have several advantages^{8, 9)}. With the increasing number of mechanical

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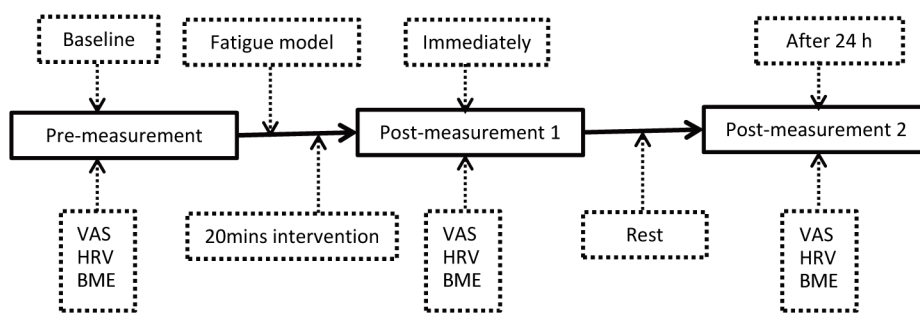


Fig. 1. Trial flow chart that displays the protocol of this study.

VAS: Visual analogue scale; HRV: Heart rate variability; BME: Back muscle endurance.

massage device users, massage devices are becoming more and more popular, especially the mechanical massage chair and bed. The total sales of mechanical massage instrument in the world keep increasing: 5.6 billion dollars in 2008, 8.1 billion dollars in 2012, and 10 billion dollars in 2015⁹). The Japanese are more likely than people from other countries to use mechanical massage chair and bed, accounting for 46% of the Japanese households. The market penetration of mechanical massage chair or bed is more than 40% in the developed countries of Europe and Americas, over 10% in South Korea, Singapore, and Taiwan¹⁰). Some benefits of mechanical massage have been described by researchers, such as improving circulation, reducing muscle tension, increasing lymphatic drainage, and increasing skin tone⁹). However, most of these benefits have been reported based on the experiences of people. More evidence-based studies are needed to be researched.

Back muscle is an important part of the human body, plays a key role in keeping the body upright and balanced and is needed to perform almost all physical activities. Sitting, standing, and walking for a long period of time can cause back muscle fatigue and disorders, such as lumbar muscle strain, increased intradiscal pressure, injury of the intervertebral disc, and strained facet joints. Back muscle problem is one of the most common musculoskeletal disorders and a burden for the patient and family¹¹). In the USA, about 80% of the adults have had an episode of back muscle problem at least once in their lives¹²), and more than 70% of the population in the western societies experience lower back pain in a given year. Back muscle problem is the most expensive ailment in the working age, with an estimated 10 billion euros spent annually on medical costs in Germany and more than 30 billion dollars spent in the USA¹³).

In sports, High-intensity and long-duration exercise can cause back muscle fatigue and back muscle injury of athletes. Improving the performance of athletes by dealing with the relationship of back strength training, fatigue recovery, and injury prevention has several benefits. Therefore, back muscles and their related problems are not only important for athletes but also for common people.

Up until now, there has been no sufficient evidence to support whether or not mechanical-bed massage has the same benefits as those of manual massage on muscle fatigue and recovery. The aim of this study was to investigate the effects of mechanical-bed massage on exercise-induced back fatigue and recovery in athletes. It may provide more evidence for the application of mechanical-bed massage to promote recovery from fatigue after strenuous back exercises.

SUBJECTS AND METHODS

To avoid the environmental impact on the results, which includes ambient temperature, humidity, noise, and lighting, all the experiments were conducted at Human Movement Science Laboratory, Faculty of Physical Education, Gannan Normal University, Ganzhou, China. The laboratory meets the following requirements: sufficient but not too much light, air conditioned and quiet room, about 50% humidity and room temperature at 22–25°C. Before the measurement, the athletes were instructed to rest for more than 15 minutes and keep a calm state of mind and relax.

All the volunteer athletes were students at the Faculty of Physical Education, Gannan Normal University, Ganzhou, China. They were recruited to participate in this study if they met the following criteria: (1) Inclusion: male, aged 17–22 years, college athletes and have participated in sports training for more than 3 years, Body Mass Index (BMI): 18.5–24, no back injury within the last 6 months, no smoking within the last 1 week, no alcohol consumption within the last 1 week, no current health problems. (2) Exclusion: having been on any form of medication or beverage, such as caffeine, amphetamine, and corticosteroid that might affect athletic performance. Twelve college student-athletes who met the criteria volunteered to participate. They were randomly allocated into two groups, control group and experimental group using block randomized allocation with block sizes of 2 and 4. Groups were assigned using a pre-generated random assignment scheme enclosed in envelopes, which resulted in a total of 6 participants per group. The research protocol got the approval of the Ethics Committee of Khon Kaen University (ID of EC: HE602260), and all participants of this study wrote informed consent at the beginning of the study.

Figure 1 displays the trial flowchart, which describes the complete process of the experiment and the parameters need to be measured. During the experiment, all the subjects were required to maintain the same living habits, eat in the same canteen, go to bed before 10:30 pm the day before the experiment, and wake up before 8:00 am on the day of experiment. The subjects were asked to rest for 15 minutes before the baseline parameters, such as VAS, HRV, and Back Muscle Endurance (BME) were measured; following that, the fatigue model was applied to induce back muscle fatigue of subjects. The intervention was performed for 20 minutes (the mechanical-bed massage was provided to the experimental group for 20 minutes, while the control group just rested during the same period of time), and the parameters were measured to obtain the data immediately after intervention. After 24 hours of rest, the indicators of post-measurement 2 were tested the same way as the baseline.

In order to induce back muscle fatigue, the subjects were instructed to perform prone reverse sit-up until they felt back muscle fatigue or could not do any further. The reverse sit-up was performed in the prone lying position, fixed ankles and hip, hands behind the back of the head. They were instructed to extend their back consecutively for 8 repetitions per session. The participants were insisted on completing several sections until they could not complete the entire section. The interval (rest) time between 1st to 3rd section was 3 minutes, between 3rd to 5th section was 4 minutes, and between 5th to 8th section was 5 minutes.

In the experimental group, the participants lay supine on a mechanical-massage bed (STRONG SC-9903, Shanghai, China) for a session of massage. The total session was for 20 minutes, where the massage types are similar to kneading of manual massage. There are 5 procedures that can be selected from, which are as follows. Procedure 1: entire body and can stay on some acupoints; Procedure 2: entire body and no pause; Procedure 3: upper back; Procedure 4: lower back; Procedure 5: neck. Procedure 4 was selected for this study. The outline of massage was set according to the Jingluo theory of traditional Chinese medicine, and the name of this Jingluo is *Pangguang Jing*. These lines are also similar to the meridian lines (Itha and Pingkala) according to the theory of traditional Thai massage: the back area of mechanical-bed massage covered the latissimus dorsi, trapezius and erector spinae, and the main acupoints, including Xinyu (BL 15), Ganyu (BL 18), Danyu (BL 19), Shenyu (BL 23), Sanjiaoyu (BL 22), etc.

In the control group (Rest group), the subjects lay supine on the same mechanical-massage bed as that of the experimental group for 20 minutes, where the mechanical-massage bed was switched off. After all data for this study were collected, the participants could request to get the mechanical-bed massage if they wished.

The HRV was measured in the sitting position. All the participants were asked to remain calm as much as possible while measuring HRV. The HRV recording was done using SCHUHFRIED GmbH Biofeedback instrument (Biofeedback 2000 x-pert software version 4.2, Austria) for 5 minutes from the chest wall, which is considered to be the safest recording method with the smallest artifacts and the largest signals. The red electrode cable was attached to the left chest in the area on the fifth rib and the blue one to the right chest. The reference was attached to the cervical vertebrae. Some technical and parametric details were set, which are as follows. Data transfer: raw data curve (mV) and RR interval (ms) via Bluetooth, input range: ± 3.2 mV and ± 1.6 mV adjustable; frequency range: 0.4 Hz–100 Hz; sample rate: 1,000 Hz; data transfer rate: 100–200 readings/second and transfer at every heartbeat (fast Fourier transformation “FFT” data points 40 readings/second); common mode rejection: >100 dB. Various indices of the HRV were calculated in this study, which included stress index (SI), total number of all N-N intervals divided by the height of the histogram of all N-N intervals measured on a discrete scale with bins of 7.8125 ms (HRV index), standard deviation of all N-N intervals (SDNN; ms), the square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD; ms), the proportion derived by dividing the number of interval differences of successive N-N intervals greater than 50 ms (pNN50), low frequency power in normalized units (LF; n.u.), high frequency power in normalized units (HF; n.u.), and the ratio of LF and HF (LF/HF).

The participants were asked to rate their perceived back fatigue induced by the exercise on the Visual Analogue Scale (VAS) with a 10-cm line ranging from 0 to 10, where 0 meant no fatigue at all and 10 indicated an extreme feeling of fatigue¹⁴.

The Isometric Back Extension Endurance Test was used to measure the back muscle endurance of the participants. Endurance was evaluated by the duration of (holding time measured in seconds) the participants being able to hold the upper part of the body horizontal while lying prone, with no support on the body part above the iliac crests. The hands were kept behind the neck while the thighs and ankles were fixed to the table by 2 wide straps. The participants were instructed to hold the upper body parts in horizontal level as long as they could. During testing, the participants received encouragement once if their position fell under the horizontal level. The position was indicated by a plumb bob hanging from the ceiling that was adjusted to contact the back when the horizontal position was maintained. If the position was not immediately corrected or if the participant claimed that the position could no longer be held due to fatigue or discomfort, the test was ended and the holding time was recorded¹⁵.

All of the outcomes were presented as mean \pm standard deviation (SD). SPSS 19.0 software was used to analyze the data. This study aimed to explore the different effects of mechanical bed massage and resting on back muscle fatigue. Various parameters of different time points (immediately after the intervention and after 24 hours) between the two groups were analyzed. Since the type of data was continuous and normally distributed, independent samples t-test was used to compare independent data of different groups, and paired samples t-test was used to compare dependent data of the same group. To achieve statistical significance, 80% power (beta=0.2) and alpha level of 0.05 were used.

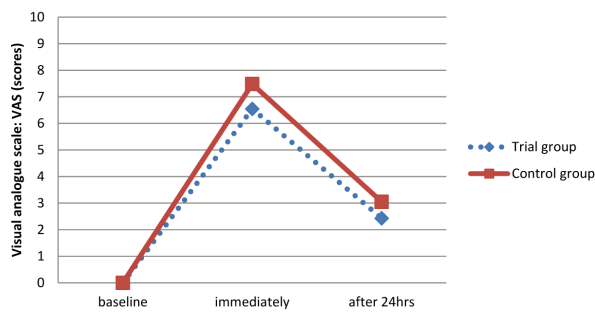


Fig. 2. Visual analogue scale (VAS) scores at baseline, immediately after the intervention and 24 hours after the intervention for experimental group (Mechanical-Bed Massage group) and control group (rest group). Values are presented by means \pm standard deviation (SD).

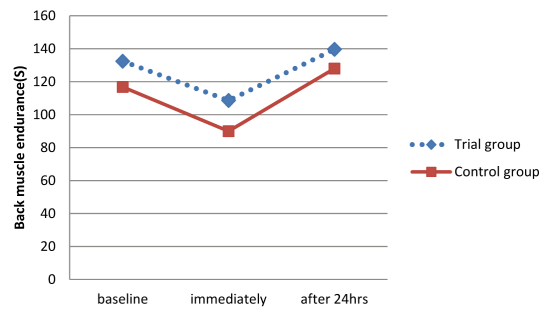


Fig. 3. Back muscle endurance by Isometric Back Extension Endurance Test at baseline, immediately after the intervention, and 24 hours after the intervention for the experimental group (Mechanical-Bed Massage group) and control group (rest group). Values are presented by means \pm standard deviation (SD).

RESULTS

The baseline characteristics of the participants were as follows: for the control group, the average height was 173 ± 5.2 cm, the average weight was 65.4 ± 5.1 kg, the average BMI was 21.9 ± 1.7 , the average age was 18.6 ± 1.1 years, the back muscle force was 119.7 ± 15.6 kg, and the back muscle endurance was 116.8 ± 24.4 s; for the experimental group, the average height was 172.7 ± 6.0 cm, the average weight was 65.8 ± 5.7 kg, the average BMI was 22.1 ± 1.9 , the average age was 20.2 ± 0.6 years, the back muscle force was 116.7 ± 16.9 kg, and the back muscle endurance was 132.5 ± 20.7 s.

The changes of perceived VAS at different points of time are presented in Fig. 2, which includes the VAS scores at baseline, immediately after the intervention, and 24 hours after the intervention. These values were 0, 7.48 ± 0.373 , and 3.05 ± 0.27 , respectively, in the control group and 0, 6.55 ± 0.62 , 2.43 ± 0.32 in the experimental group. Significant differences were found between the mechanical bed massage group and the resting group, both immediately after the intervention and 24 hours after the intervention, p values were 0.01, and 0.005, respectively. Both the groups experienced no back muscle fatigue at the beginning of this experiment and showed a similar trend immediately after the intervention and 24 hours after the intervention. It was noted that the VAS scores of the massage group were slightly lower than those of the control group.

Figure 3 shows back muscle endurance at baseline, immediately after the intervention and 24 hours after the intervention. These values were 132.50 ± 20.73 s, 108.67 ± 14.09 s, and 139.67 ± 17.19 s, respectively, in the experimental group, and 116.83 ± 24.35 s, 90.00 ± 18.17 s, and 128.00 ± 20.29 s in the control group. There was no statistically significant difference between the two groups at both immediately after the intervention and 24 hours after the intervention. The data shows that back muscle endurance decreased due to exercise-induced back muscle fatigue, after 20 minutes of rest or mechanical bed massage intervention is still lower than the baseline. However, no significant difference existed between baseline and 24 hours after the intervention in both group ($p > 0.05$, paired samples t-test). The duration of time for back muscle endurance exceeded the baseline in the experimental group at 24 hours after the intervention may be due to the phenomenon of overcompensation or recovery. Furthermore, the fall time of the participants' back muscle endurance can be calculated through the value of baseline and immediately after the intervention, and then calculate the rate of decline. The fall time of the experimental and control groups were 23.83 ± 28.34 s and 26.83 ± 27.30 s, respectively; no significant difference existed in both groups. The rate of decline in experimental group and control group were 18.0% and 23.0% respectively, the rate of decline in the experimental group was lower than that in the control group.

The HRV indices of this study include time domain (SI, HRV index, SDNN, RMSSM, and pNN50) and frequency domain (LF, HF, and LF/HF). Table 1 shows the values of both experimental and control groups at baseline, immediately after the intervention, and 24 hours after the intervention. There were no statistically significant differences among the HRV indices between the experiment and control groups at baseline and 24 hours after the intervention. The same statistical results were observed in the time domain indices of HRV immediately after the intervention, whereas, all of the frequency domain indices significantly improved in the experimental group. The HF tested immediately after the intervention was significantly higher in the experimental group than that in the control group ($p < 0.05$); however, the LF and LF/HF immediately after the intervention were significantly lower in the experimental group than that in the control group.

Table 1. HRV indices of different measurement points for both experimental and control groups

| Outcome | Baseline | | | Immediately | | | After 24hrs | | | | | |
|------------|--------------------------|---------------------|-----------------------------|-------------|--------------------------|---------------------|------------------------------|--------------------|--------------------------|---------------------|------------------------------|---------|
| | Experimental group (n=6) | Control group (n=6) | Difference (95% CI) | p-value | Experimental group (n=6) | Control group (n=6) | Difference (95% CI) | p-value | Experimental group (n=6) | Control group (n=6) | Difference (95% CI) | p-value |
| SI | 29.36 ± 17.41 | 20.10 ± 12.42 | -9.27 (-28.72 to 10.19) | 0.314 | 47.21 ± 23.11 | 73.66 ± 32.92 | 26.46 (-10.13 to 63.04) | 0.138 | 18.74 ± 14.25 | 45.43 ± 26.49 | 26.69 (-0.67 to 54.05) | 0.055 |
| HRV index | 3.56 ± 0.578 | 4.23 ± 1.13 | 0.67 (-0.49 to 1.82) | 0.226 | 3.50 ± 1.47 | 2.80 ± 1.18 | -0.70 (-2.42 to 1.01) | 0.383 | 4.30 ± 1.17 | 4.11 ± 1.80 | -0.20 (-2.15 to 1.75) | 0.828 |
| SDNN (ms) | 91.87 ± 24.20 | 133.94 ± 41.30 | 42.07 (-1.48 to 85.61) | 0.057 | 118.57 ± 80.46 | 72.01 ± 61.49 | -46.56 (-138.68 to 45.56) | 0.286 | 130.84 ± 43.63 | 115.34 ± 63.97 | -15.50 (85.94 to 54.94) | 0.635 |
| RMSSD (ms) | 73.59 ± 29.16 | 127.13 ± 80.48 | 53.54 (-24.32 to 131.41) | 0.156 | 118.90 ± 103.34 | 60.48 ± 82.15 | -58.42 (-178.50 to 61.67) | 0.304 | 123.94 ± 68.53 | 97.00 ± 97.34 | -26.94 (-135.22 to 81.35) | 0.592 |
| pNN50 (%) | 27.81 ± 12.87 | 44.58 ± 5.82 | 16.76 (3.91 to 29.62) | 0.016 | 35.50 ± 27.73 | 11.90 ± 18.68 | -23.59 (-54.01 to 6.82) | 0.115 | 34.75 ± 20.88 | 28.28 ± 18.05 | -6.47 (-31.58 to 18.63) | 0.578 |
| LF (n.u.) | 46.33 ± 8.21 | 41.71 ± 6.67 | -4.61 (-14.23 to 5.01) | 0.311 | 42.28 ± 12.37 | 58.15 ± 10.79 | 15.87 (0.94 to 30.79) | 0.039 ^a | 43.38 ± 7.61 | 51.51 ± 8.64 | 8.13 (-2.34 to 18.60) | 0.114 |
| HF (n.u.) | 53.67 ± 8.21 | 58.291 ± 6.67 | 4.61 (-5.01 to 14.23) | 0.311 | 57.72 ± 12.37 | 41.85 ± 10.79 | -15.87 (-30.79 to -0.94) | 0.039 ^a | 56.62 ± 7.60 | 48.49 ± 8.64 | -8.13 (-18.60 to 2.34) | 0.114 |
| LF/HF | 0.91 ± 0.37 | 0.73 ± 0.19 | -0.18 (-0.55 to 0.20) | 0.321 | 0.80 ± 0.37 | 1.52 ± 0.63 | 0.72 (0.06 to 1.39) | 0.035 ^a | 0.79 ± 0.25 | 1.12 ± 0.41 | 0.33 (-0.11 to 0.77) | 0.126 |

^aStatistically significant difference between experimental group and control group (defined as p<0.05).

SI: stress index; SDNN: standard deviation of all N-N intervals; RMSSD: the square root of the mean of the squares of differences between adjacent NN intervals; pNN50: the proportion derived by dividing the number of interval differences of successive N-N intervals greater than 50 ms; LF: low frequency power in normalized units; HF: high frequency power in normalized units; LF/HF: the ratio of LF and HF.

DISCUSSION

Massage has been widely used in sports to deal with muscle fatigue and in the recovery of athletes. In the previous studies, closer attention has been paid to prevent fatigue accumulation and accelerate fatigue recovery^{3, 5, 7}. It is undeniable that massage has a positive influence on rehabilitation care. However, the mechanism of massage is still unclear. Some studies have shown that massage is probably associated with the physiological^{1, 16}, psychological^{17, 18}, biomechanical¹⁹, and neurological mechanisms²⁰. Based on the massage theory, the mechanical bed massage was invented and used to imitate the manual massage. To our knowledge, there are very few studies on the practical use of mechanical massage devices²¹, and experimental research on the effects of mechanical massage bed on fatigue has not been done. This study was carried out to explore the possible effects of mechanical bed massage on exercise-induced back fatigue using subjective fatigue evaluation, back muscle endurance, and HRV analysis.

Visual analogue scale is a subjective assessment tool to evaluate fatigue severity. According to a previous report, massage could significantly decrease the degree of VAS scores for participants with localized lumbar muscle fatigue⁷. This phenomenon was further confirmed in this study; the VAS scores of the participants decreased significantly not only immediately after the mechanical bed massage, but also 24 hours after the mechanical bed massage. Our findings suggest that the application of mechanical bed massage can help the participants overcome subjective feeling of exercise-induced back fatigue resulting from 8 sections of prone reverse sit-up.

In many studies, fatigue was examined by assessing the endurance time. This approach was based on a presumption that there is an association between the decline in maximal force generating capacity and the time to exhaustion²². A.N. Rinder and C.J. Sutherland used the number of leg extensions as the assessment tool to evaluate quadriceps endurance to investigate the effects of massage on quadriceps performance after exercise fatigue. The results showed that the number of leg extensions of the massage group was significantly higher than that of rest group, which means that massage was shown to be significantly better than rest of the treatments in aiding recovery from fatigue⁶. There were no statistically significant differences in the recovery from fatigue between experimental group and control group immediately after the intervention. The reason might be that the characteristics of participants at baseline had a certain degree of difference. Therefore, another value was used to assess the recovery of back muscle fatigue, which is the fall time of back muscle endurance. Although no significant difference existed between two groups, the lower rate of decline for back muscle endurance in experimental group means that mechanical bed massage can speed up the recovery of the exercise-induced back muscle fatigue. The mechanism may be that mechanical bed massage can improve the velocity of blood flow and accelerate the elimination of metabolites.

The HRV is the beat-to-beat variation in time of consecutive heart beats expressed in normal sinus rhythm on electrocardiogram recordings; it is a noninvasive, practical, and reproducible measure of the autonomic nervous system function²³. In sports, the HRV has been used as a tool for diagnostic performance and monitoring training²⁴, which also has been recognized as a useful method for the measurement of fatigue²⁵⁻²⁸. Previous studies have shown that manual massage or a combination of other methods can enhance the HRV, such as, myofascial trigger-point massage therapy can significantly increase the parasympathetic activity¹⁸, facial massage can enhance the LF/HF²⁹, self-massage combined with home exercise can increase the rate of LF and HF³⁰, head-neck massage showed a significant interaction for HRV index³¹, massage therapy with a range of motions had a positive effect on HRV development³², traditional Thai massage increased HF and total power frequency³³. In our study, only frequency domain indices had significant differences, and no significant differences existed in any of the time domain indices. The reason for this result may be interpreted as many frequency domain indices being strongly correlated with time domain indices, but this situation is only suitable for long-term recording of HRV, and the recording must take more than 18 hours. When considering the stationary of HRV recording, time domain indices are better than frequency domain indices for analyzing the long-term recording of HRV. On the contrary, frequency domain indices are more suitable to analyze short-term recording of HRV than time domain indices³⁴. The HF of experimental group was significantly higher than that of the control group, and the LF, LF/HF of the experimental group was significantly lower than that of the control group, which indicates that mechanical bed massage can enhance HRV, increase parasympathetic activities, and maintain the balance of sympathetic and parasympathetic activities because HF in normalized units is considered a marker of vagal modulation, LF in normalized units is considered as a marker of sympathetic modulation, and LF/HF mirrors sympathovagal balance or reflects sympathetic modulation³⁵. The mechanisms by which massage affects HRV may be as follows. Massage has been found to increase the level of dopamine and serotonin (5HIAA)³⁶ and decrease the level of cortisol³⁷⁻³⁹ and catecholamines⁸, which further indicate that massage can decrease stress and anxiety and promote relaxation^{40, 41}, all of which could be expressed in the form of increased HF and decreased LF and LF/HF.

There are some limitations to this study. Back muscle endurance was different at the baseline of both the groups, which may have affected the results of this experiment because fatigue recovery depends on the physiological ability of the athlete, such as highly trained athletes can recover from exercise-induced fatigue more quickly than less trained athletes⁴². In addition, only one session of mechanical bed massage was used in this study, which may not be sufficient to attain the maximum effects for exercise-induced back fatigue. Therefore, longer duration of the experiment with randomized controlled trials should be considered in the future studies.

According to the results of this study, mechanical bed massage may decrease muscle fatigue and facilitate recovery as

indicated in the improvement of subjective feeling of exercise-induced fatigue, modulate the activity of automatic nervous system, especially to maintain the balance of the sympathetic and parasympathetic activities. Therefore, we suggest that mechanical bed massage could be seen as an effective means of recovery for exercise-induced back fatigue after athlete training or competition.

Conflict of interest

The authors declare no conflict of interest.

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