12週的全身垂直律動訓練對於青年族群骨盆本體感覺以及非特異性下背痛的影響

Effect of 12-Week Whole-Body Vibration Exercise on Lumbopelvic Proprioception and Pain Control in Young Adults with Nonspecific Low Back Pain

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簡述內容：

一般人應該都曾有過腰痛背痛的經驗，而「非特異性下背痛」又占大多數，指的是無法明確定義疼痛的真正原因。而會影響到下背痛的原因可能有：肌肉拉傷、椎間盤突出與退化、關節疾病、脊椎骨折、脊神經壓迫、姿勢不正、器官發炎、感染、勞動、肥胖等多種因素所引起，而疼痛時間的長短或週期不定，卻也為生活上帶來相對的困擾。

由研究發現採用全身垂直律動進行12週的律動運動訓練，能夠加強肌肉的收縮與伸張，有效改善並緩解下背痛帶來不適的症狀，並對日常生活帶來顯著的助益。

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Background: Nonspecific low back pain (NSLBP) accounts for a large proportion of low back pain cases. The present study aimed to investigate the effect of the whole-body vibration (WBV) exercise on lumbar proprioception in NSLBP patients. It was hypothesized that WBV exercise enhances lumbar proprioception.

Material/Methods: Forty-two patients with NSLBP performed an exercise program 3 times a week for a total of 12 weeks of WBV. The lumbar proprioception was measured by joint position sense. Outcomes were lumbar angle deviation and visual analogue scale (VAS) score.

Results: After the 12-week WBV exercise, lumbar flexion angle deviation was reduced from 3.65±2.26° to 1.90±1.07° (P=0.0001), and extension angle deviation was reduced from 3.06±1.85° to 1.61±0.75° (P=0.0001), significantly lower than baseline. After participating in the 12-week WBV exercise, a significant pain reduction was observed (P=0.0001). Men in the whole group (n=32) indicated significantly lower angle deviations in flexion and extension, whereas women (n=10) indicated significantly lower flexion angle deviation (P=0.037), and no significant difference was found in extension angle deviation (P=0.052). However, by subdividing the entire group (n=42) into poor and good proprioceptive groups, WBV exercise presented significant enhancement of lumbar proprioceptive ability in the poor flexion proprioception subgroup, poor extension proprioception subgroup, and good extension proprioception subgroup (each P=0.0001), but not in the subgroup with good flexion proprioceptive ability (P=0.165).

Conclusions: Lumbar flexion and extension proprioception as measured by joint position sense was significantly enhanced and pain was significantly reduced after 12-week WBV exercise in NSLBP patients. However, the patients with good flexion proprioceptive ability had limited proprioceptive enhancement.

MeSH Keywords: Chronic Pain • Low Back Pain • Proprioception • Exercise • Vibration

Abbreviations: **NSLBP** – nonspecific low back pain; **WBV** – whole-body vibration; **VAS** – visual analogue scale; **LBP** – low back pain; **JPS** – joint position sense; **ChiCTR** – Chinese Clinical Trial Registry; **ICC** – intraclass correlation coefficient; **MCID** – the minimal clinically important difference; **SD** – standard deviation; **CLBP** – chronic low back pain; **MCE** – motor control exercise

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Background

Low back pain (LBP), as a symptom rather than a disease, like headache and dizziness [1], is one of the most prevalent and expensive musculoskeletal conditions [2]. LBP is a leading cause of years lived with disability, which increased by 54% between 1990 and 2015, with the biggest increase seen in low-income and middle-income countries [3]. The prevalence increased by 18% from 2006 to 2016 [4], and its lifetime prevalence was reported to be 84% [5]. Nonspecific low back pain (NSLBP) accounts for a large proportion of LBP cases (commonly cited as 90%) [6], which is LBP with an unrecognizable, unknown specific pathology (e.g., radicular syndrome, cauda equina syndrome, fracture, infection, osteoporosis, structural deformity, inflammatory disorder, or tumor) [1]. The pathogenesis of NSLBP is not fully understood [5]. Clinicians and patients were recommended by the American College of Physicians to select nonpharmacologic treatment [7] with exercise [8], multidisciplinary rehabilitation [9], electrical therapies [10], and magnetic therapy [11] to reduce pain and its consequences.

NSLBP patients showed an impaired proprioception compared with healthy controls [12–14]. Proprioceptive sense, by definition, is a result of the central processing by the central nervous system of afferent information about joint position, joint force, and joint movement from various mechanoreceptors in muscle spindles, Golgi tendon organ, and the fibrous membrane in joint capsules [15]. Proprioception has been shown to be a key component of motor control and joint stability during daily activities [16], and also coordinates movement and affects injury risk during sports [17]. Lumbar instability also restricts muscle strength, endurance, and flexibility [18] and makes recurrence of LBP more likely [19]. Hence, impaired proprioception affects normal coordinated movement. Decreased lumbar proprioception may lead to higher sports injury risk, an increase in pain intensity, and lumbar disability. A negative correlation between lumbar proprioception and pain was described in our previous study [20].

In recent years, whole-body vibration (WBV) exercise has increased in popularity in pain relief and physical performance in various clinical populations [21–24]. Conditions that have been studied include anterior cruciate ligament reconstruction [25], osteoporosis [26], fibromyalgia syndrome [27], overweight/obesity [28], cerebral palsy [29], post-stroke [30], and chronic NSLBP [31]. WBV requires the individual to perform static or steadily controlled exercises on an oscillating platform [32,33]. WBV improves muscle function through increased reflexive activity from the stimulation of the muscle spindle system [25] and also from increased corticomotor excitability [34]. This mechanism has also been suggested to reduce LBP, which has been previously shown to be associated with reduced lumbar segmental stabilization muscle activity. WBV increases reflexive activity and subsequently strengthens lumbar segmental muscles to alleviate LBP [35,36]. WBV with high vibration levels increase the risk of LBP [37], but frequencies below 20 Hz induces muscle relaxation and alleviates LBP caused by paravertebral muscle spasm [38]. Some additional benefits of WBV exercise are decreased heart rate and blood pressure [28,39], as well as improved cardiac autonomic function [40] and anti-inflammatory status [41]. These benefits assist overall health to mitigate the risk of LBP. Another appealing characteristic of WBV exercise is its suitability for someone unable to perform strenuous exercise modalities.

Proprioception is one of several objective measures used to determine the effectiveness of WBV exercise on NSLBP. Although proprioceptive sense plays an essential part in joint stability and injury prevention [42], few studies have investigated the effect of WBV exercise on lumbar proprioception among NSLBP patients, and the effect of WBV exercise on other segment proprioception is also unclear. Several studies demonstrated that a single session of WBV does not influence knee joint proprioception [43] and lumbar repositioning ability [44] in normal individuals. However, Myung-Sook et al. found that 3 weeks of WBV training was effective in improving ankle joint position sense (JPS) in children with cerebral palsy [29]. Hence, WBV exercise may have positive effects on proprioception after several weeks of training. Regarding the effect of WBV exercise in NSLBP patients, WBV training was reported to have significant positive effects on functional capacity (evaluating by the Roland and Morris disability questionnaire score, the Oswestry Disability Index, and the quality of life questionnaire SF-36) [45], balance ability, and pain of NSLBP patients [46]. However, research on the effect of WBV exercise on lumbar proprioception is lacking. The positive influence of WBV exercise on lumbar proprioception and alleviation of pain would be beneficial for NSLBP patients. NSLBP patients with poor proprioception might also benefit from the WBV training program.

The purpose of the present study was to determine the effect of WBV exercise on lumbar proprioception and pain control in NSLBP patients. We hypothesized that WBV exercise would enhance lumbar proprioception and reduce pain, and that patients with poor proprioceptive sense would get more clinical benefit from WBV exercise.

Material and Methods

The study had a one-group pretest-posttest design and was approved by the Ethics Committee of the Shanghai University of Sports, China, and by the Chinese Clinical Trial Registry (registry number ChiCTR-TRC-13003708). All participants signed written informed consent.

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Sample size

GPower 3.1.9.2 was used for power calculation. Previous studies reported effect sizes (Cohen's d) of −0.85 by investigating WBV effects on VAS in elderly individuals [47]. Therefore, to conduct a paired-samples *t* test, with an alpha of 0.05 (2-tailed), power of 0.9, and an effect size of 0.85, the estimated sample size was 17 participants. With an attrition rate of 20%, the sample size required for the study was 21 participants.

Participants

A total of 42 individuals participated in this study. All subjects underwent x-ray and MRI to exclude specific low back pain, and the clinician performed lumbar function tests assessing lumbar flexion, extension, and rotation. Inclusion criteria were: 18–35 years of age, low back pain persisting for approximately 12 weeks or longer, and at least 3 episodes. Exclusion criteria were: taking analgesic and/or anti-inflammatory agent, previous major trauma and/or surgery of the spine, serious spinal pathology (vertebral fracture, inflammatory arthropathy, spondylolisthesis, rheumatic diseases, cauda equina syndrome, tumor or cancer), cardiovascular and/or neurological disorders, insufficiently treated hypertension, acute inflammation of the musculoskeletal system, and pregnancy. The doctor excluded specific low back pain patients by taking their history, performing a physical examination, and laboratory testing. Participants were asked not to change their daily lifestyle and or to perform additional physical therapy during the study period.

Procedure

This was a longitudinal study investigating the effect of WBV exercise in NSLBP patients (Figure 1). Each participant performed exercises 3 times a week for a total of 12 weeks, and the sessions could not be performed on consecutive days. Each training session consisted of 5 min of warm-up, 18 min of WBV, and 5 min of cool-down exercises. Lumbar joint position sense (an indirect measurement of proprioception) and the visual analogue scale (VAS) scores were recorded before and 12 weeks after WBV exercise.

Intervention

All exercises were performed on a vertical vibration instrument (AV001; BODYGREEN, Taiwan, China). Participants were asked to take off their shoes to avoid slowing vibrations on the human body. WBV exercise contains 6 exercise postures: squat, kneeling, bridge, bridge with leg lift, bridge and knee flex, and back release. Postures were maintained for 60 s, except for squat, which was maintained for 90 s, and repeated twice with 30 s of rest. In clinical practice, these postures are widely used and are safe for patients with LBP. The vibration frequency was 9 Hz, and the amplitude was 2 mm. Figure 2 and Table 1 display more detailed information about the WBV exercise protocol. WBV exercises were completed under the supervision of registered physical therapists.

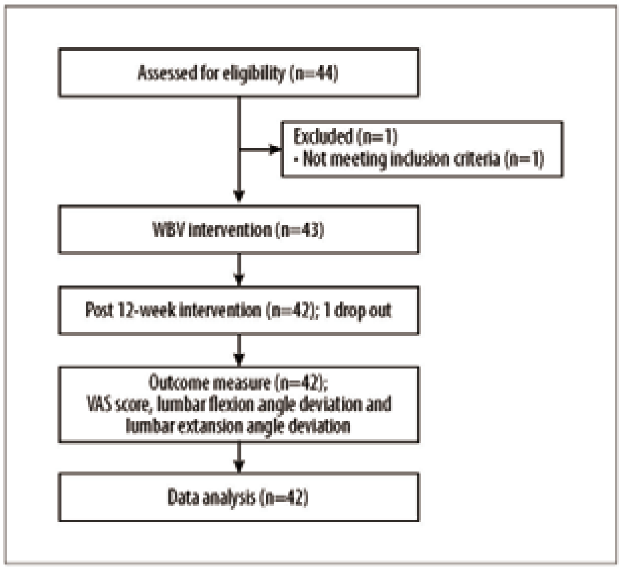

Figure 1. Flowchart of the study. WBV, whole-body vibration; VAS, visual analogue scale, was used to assess pain intensity.

Measurement

Lumbar joint position sense

Lumbar joint position sense (JPS), an indirect measure of proprioceptive sense, was evaluated before the WBV exercise and after the 12-week WBV exercise by using Con-Trex Multi-Joint System (CMV AG, Dübendorf, Switzerland).

In the measurement setup, participants stood in neutral position, and were asked to wear a blinder and earplugs to remove visual and auditory disturbance. From the starting neutral standing position, the trunk of the participant was passively flexed to a random predetermined target angle in constant-velocity mode. Participants were instructed to relax their bodies and avoid any active muscle contraction when bending the trunk to the target angle. Participants maintained the target angle for 3 s to memorize the position. Then, the participants returned passively to the starting position. Subsequently, a hand-held trigger was given to participants and were instructed to return to the target position from the neutral position. Upon pressing the pause button on the trigger, the investigator recorded the actual angle. The process was repeated for total of 6 times in series (3 times for lumbar flexion and 3 times for lumbar extension). The absolute error angles, which deviated from the actual angle to the target angle, were calculated and taken as

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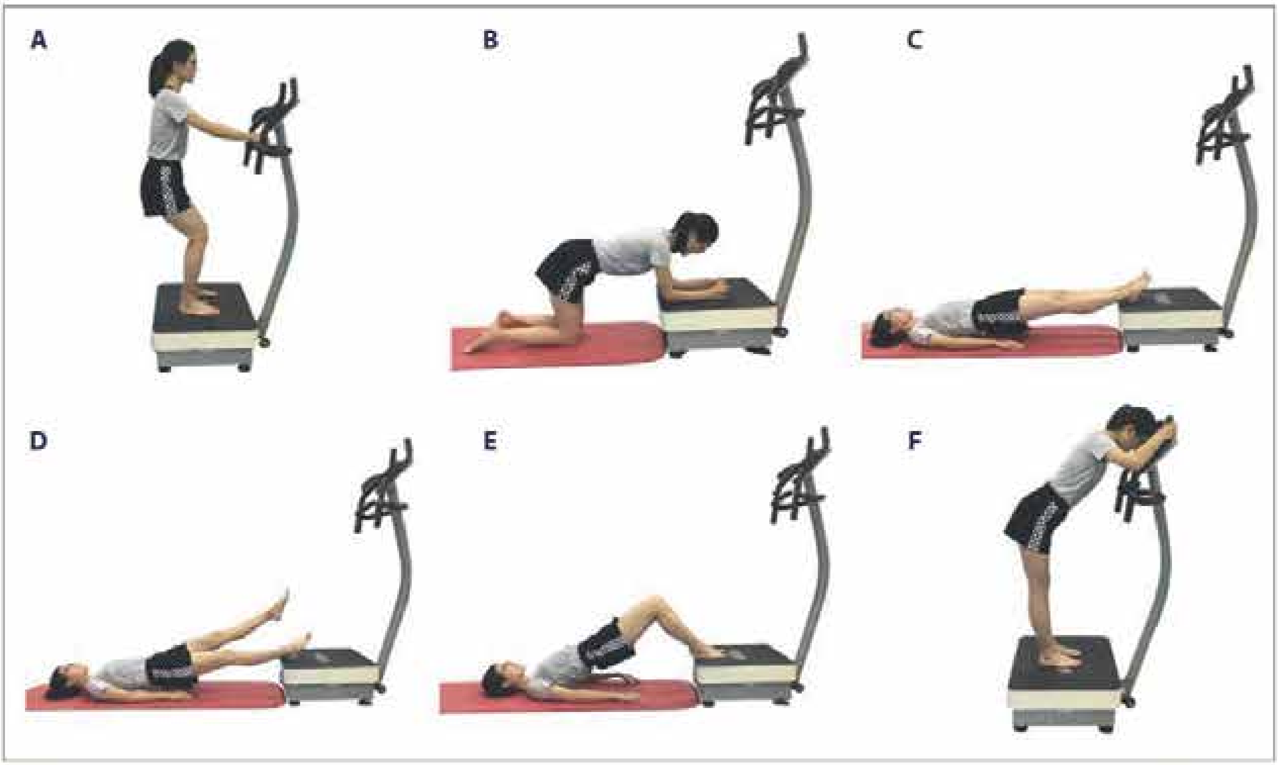

Figure 2. Training program for whole-body vibration exercise. Training program included: (A) squat, (B) kneeling, (C) bridge, (D) bridge with leg lift, (E) bridge and knee flex, and (F) back release.

Table 1. Parameters and intensity of whole-body vibration exercise.

Exercise program	Each time (s)	Repetitions (n)	Frequency (Hz)	Rest interval (s)	WBV total time (s)
Squat	90	2	9	30	180
Kneeling	60	2	9	30	120
Bridge	60	2	9	30	180
Bridge with leg lift	60	2	9	30	120
Bridge and knee flex	60	2	9	30	120
Back release	60	2	9	30	180

an average for lumbar flexion and extension, which is also the angle deviation. The larger value of absolute error value angle indicated inferiority in lumbar joint position sense, thereby indicating worse proprioceptive acuity.

Before this study, we did a pilot study to determine the reliability of the Con-Trex Multi-Joint lumbar testing system. Twenty-five NSLBP patients participated in the pilot study. All subjects' lumbar proprioception was tested by the above procedures, and performed the same test after 2 days. The re-test reliability was calculated by intraclass correlation coefficient (ICC). ICC value ranges between 0 and 1 and can be interpreted as excellent: ≥0.75, good: 0.60–0.74, fair: 0.40–0.59, or poor: <0.4 [48]. We found the above procedures had good reliability (flexion angle deviation: 3.33±1.82° for first test, 3.22±1.22° for re-test, ICC=0.766; extension angle deviation: 2.78±1.47° for first test, 3.08±0.78° for re-test, ICC=0.719) [49].

Pain intensity

The visual analogue scale (VAS) was used to assess pain intensity, which used a 100-mm horizontal line marked from 0 to 10 from left to right, in which "0" meant no pain and "10" meant the worst pain imaginable. Participants specify their pain intensity by indicating a position between 2 end-points along a continuous line. The minimal clinically important difference

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Table 2. Demographic and clinical characteristics of participants (n=42).

	Men (n=32)	Women (n=10)	Total (n=42)
Age (y)	21.9±3.2	20.5±2.0	21.6±3.0
Height (cm)	171.50±6.53	173.90±6.57	172.07±6.54
Weight (kg)	67.75±10.66	67.20±12.50	67.62±10.96
BMI (kg/m²)	22.91±2.41	22.14±3.33	22.73±2.64
Time since first experience with NSLBP (mo)	9.2±3.6	6.8±1.87	8.6±3.4
VAS-baseline	4.47±1.27	5.10±0.99	4.62±1.23
Flexion angle deviation-baseline	3.79±2.37	3.18±1.90	3.65±2.26
Extension angle deviation- baseline	3.21±1.94	2.57±1.52	3.06±1.85

BMI – body mass index (calculated as weight in kilograms divided by height in meters squared); NSLBP – nonspecific low back pain; VAS – visual analogue scale. Values are expressed as mean ±SD.

(MCID), identified as a change of 2 or more points [50], was also used to evaluate the therapeutic effect after 12-week WBV training.

Statistical analysis

Microsoft Excel 2016 and SPSS 20.0 were used for data logging and statistical analysis. Demographic data were collected for descriptive statistics, which are described as mean ± standard deviation (SD).

The paired-samples *t* test was used to compare lumbar angle deviations and VAS scores before and after WBV exercise. The changes in lumbar angle deviations and VAS score were also calculated, and a negative difference meant that the participant had improvement in proprioception and pain intensity after WBV intervention. Then, using the baseline lumbar angle deviation value as the reference value, the group of 42 participants were divided into 2 proprioceptive subgroups (good and poor). In the good proprioceptive subgroup, participant whose lumbar angle deviations were below the group mean before WBV exercise were included. Participants whose lumbar angle deviation above the group mean were included in the poor proprioceptive subgroup. The same analysis via paired-samples *t* test was utilized for the 2 subgroups. The same approach was used for VAS subgroups. The good VAS subgroup included participants with VAS scores lower than the group mean before WBV exercise, and the poor VAS subgroup contained participants with higher VAS score. The level of significance was set at 0.05. Treatment effect was calculated by comparing the differences in outcome measured over the 12-week training program.

Lastly, odds ratio and the corresponding 95% confidence intervals were estimated to assess the differences between subgroups for perceived benefit of WBV exercise (gender, pain intensity, and lumbar proprioception above the MCID). In addition, chi-square tests were also used to determine whether there was a difference between the subgroups in the proportion of participants reporting perceived benefits.

Results

Forty-two NSLBP patients aged 18–34 years old (average age 21.6±3.0 years old; 32 males and 10 females) voluntary participated in this study. Other baseline demographic and clinical characteristics of participants are shown in Table 2.

Proprioception

After the 12-week WBV exercise program, lumbar flexion angle deviation was reduced from 3.65±2.26° to 1.90±1.07° ($P=0.0001$) and extension angle deviation was reduced from 3.06±1.85° to 1.61±0.75° ($P=0.0001$), which were significantly lower than baseline (Table 3).

The whole group was subdivided into good or poor flexion proprioceptive groups according to baseline values. A total of 19 participants showing flexion angle deviations above 3.65° (group mean value) were included in the poor flexion proprioceptive group, and 23 participants showing lumbar flexion angle deviations below 3.65° were included in the good flexion proprioceptive group. For the subgroup with poor flexion proprioception, the difference in lumbar flexion angle deviation significantly decreased after WBV intervention ($P=0.0001$). No significant difference was found in the good flexion proprioceptive group ($P=0.165$). For extension proprioception, 16 participants were included in the poor extension proprioceptive group (extension angle deviations above the group mean

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Table 3. Comparison of lumbar angle deviation and VAS score between baseline and after 12-week WBV exercise.

	Baseline	12 weeks	Mean change from baseline to 12 weeks (95% CI)	% change	P value[#]	Effect size
Whole group (n=42)						
Flexion angle deviation (°)	**3.65±2.26**	**1.90±1.07**	**−1.75 (−2.48 to −1.01)**	**−26.4±57.5**	**0.0001***	**0.75**
Subgroup <3.65° (good flexion proprioception; n=23) (°)	2.10±0.88	1.76±0.89	−0.34 (−0.82 to 0.15)	0.6±61.3	0.165	0.30
Subgroup >3.65° (poor flexion proprioception; n=19) (°)	5.52±1.98	2.06±1.26	−3.45 (−4.57 to −2.34)	−59.1±29.5	0.0001*	1.49
Men (flexion proprioception; n=32) (°)	3.79±2.37	1.98±1.11	−1.81 (−2.70 to −0.92)	−30.0±48.4	0.0001*	0.73
Women (flexion proprioception; n=10) (°)	3.18±1.90	1.63±0.92	−1.54 (−2.97 to −0.12)	−14.9±82.4	0.037*	1.77
Extension angle deviation (°)	**3.06±1.85**	**1.61±0.75**	**−1.44 (−1.98 to −0.90)**	**−35.9±27.9**	**0.0001***	**0.83**
Subgroup <3.06° (good extension proprioception; n=26) (°)	1.90±0.74	1.46±0.67	−0.43 (−0.62 to −0.25)	−21.7±20.2	0.0001*	0.93
Subgroup >3.06° (poor extension proprioception; n=16) (°)	4.94±1.52	1.86±0.84	−3.08 (−4.05 to −2.12)	−58.9±23.1	0.0001*	1.70
Men (extension proprioception; n=32) (°)	3.21±1.94	1.64±0.73	−1.56 (−2.22 to −0.91)	−37.4±27.5	0.0001*	0.86
Women (extension proprioception; n=10) (°)	2.57±1.52	1.52±0.87	−1.05 (−2.12 to 0.01)	−31.1±30.1	0.052	0.71
VAS	**4.62±1.23**	**3.00±1.38**	**−1.62 (−2.14 to −1.10)**	**−28.3±47.9**	**0.0001***	**0.96**
Subgroup <4.62 (good VAS; n=21)	3.67±0.73	2.86±1.11	−0.81 (−1.43 to −0.188)	−13.1±57.8	0.013*	0.59
Subgroup >4.62 (poor VAS; n=21)	5.57±0.81	3.14±1.62	−2.43 (−3.16 to −1.70)	−43.6±29.8	0.0001*	1.52
Men (VAS; n=32)	4.47±1.27	3.03±1.12	−1.44 (−2.02 to −0.85)	−23.3±50.6	0.0001*	0.88
Women (VAS; n=10)	5.10±0.99	2.90±2.08	−2.20 (−3.50 to −0.90)	−44.5±35.5	0.004*	1.21

VAS – visual analogue scale; Values are expressed as mean ±SD; [#] analyzed by the paired-sample *t* test; * significant at $P<0.05$.

value of 3.06°), and 26 participants were included in the good extension proprioceptive group. Both subgroups showed significant improvement in extension proprioception after WBV exercise (poor extension proprioceptive group: P=0.0001, good extension proprioceptive group: P=0.0001).

After WBV exercise, men in the whole group (n=32) had significantly lower flexion and extension angle deviations (flexion angle deviation: P=0.0001, extension angle deviation: P=0.0001) after intervention. However, women (n=10) had significant lower flexion angle deviation (P=0.037), but showed no significant difference in extension angle deviation (P=0.052).

VAS

At baseline, the mean VAS value was 4.62±1.23, and participants had significant pain reduction after the 12-week WBV exercise program (VAS value: 3.00±1.38, P=0.0001). The poor VAS subgroup, containing 21 participants, had VAS values that were higher than the group mean value of 4.62. Correspondingly, 21 participants were in the good VAS group. For both subgroups, WBV exercise significantly reduced VAS scores (poor VAS: P=0.0001, good VAS: P=0.013). At baseline, the mean VAS value was 4.47±1.27 for males in the whole group (n=32) and 5.10±0.99 for women (n=10). After the 12-week WBV exercise program, the mean VAS value was significantly reduced

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Table 4. Number and proportion of participants having a minimal clinically important change in gender, proprioception, and pain intensity after 12-week intervention.

Subgroups	MCID		Odds ratio (CI 95%)	P value#
	Benefit; n (%)	No benefit; n (%)		
Gender			**0.221 (0.040 to 1.205)**	**0.066**
Men	15 (46.9%)	17 (53.1%)		
Women	8 (80.0%)	2 (20.0%)		
Flexion proprioception			**0.793 (0.233 to 2.699)**	**0.711**
Good flexion proprioception	12 (52.2%)	11 (47.8%)		
Poor flexion proprioception	11 (57.9%)	8 (42.1%)		
Extension proprioception			**0.907 (0.259 to 3.177)**	**0.879**
Good extension proprioception	14 (53.8%)	12 (46.2%)		
Poor extension proprioception	9 (56.2%)	7 (43.8%)		
Pain intensity			**0.094 (0.022 to 0.398)**	**0.001***
Good VAS	6 (28.6%)	15 (71.4%)		
Poor VAS	17 (81.0%)	4 (19.0%)		

MCID – minimal clinically importance difference, identified as a change of 2 or more VAS points to evaluate the therapeutic effect after 12-week whole-body vibration training; VAS – visual analogue scale; CI – confidence interval; * significant at $P<0.05$; # analyzed by chi-squared test.

to 3.03±1.12 for men (P=0.0001) and 2.90±2.08 for women (P=0.004) (Table 3).

MCID in gender, proprioception, and pain intensity

Participants with poor VAS reported significantly greater benefits from WBV exercise compared to participants with good VAS (P=0.001). No significant differences between subgroups were found for gender, flexion proprioception, or extension proprioception, in relation to the proportion of participants who attained MCID (Table 4).

Discussion

WBV, which is a noninvasive intervention, has become an increasingly popular treatment for LBP. To investigate whether the proprioceptive performance of NSLBP patients can be improved by WBV exercise, the effect of WBV exercise on lumbar proprioception and pain control in NSLBP patients was examined. The present findings showed a significant difference in lumbar angle deviation change and VAS change after WBV exercise (flexion proprioception: P=0.0001, extension proprioception: P=0.0001, VAS: P=0.001). These results provide a possible explanation as to why a 12-week WBV program relieved pain and improved function for patients with chronic nonspecific low back pain in previous studies [47,51,52]. These positive effects might be an increase in proprioception of the lumbopelvic area, which improved the outcome of muscle co-ordination.

Categorizing the data at baseline into good and poor flexion proprioception revealed that WBV exercise significantly decreased the lumbar flexion angle deviation of NSLBP participants whose lumbar flexion angle deviation value was more than 3.65° (P=0.0001). WBV improved the flexion performance of those NSLBP patients classified into the poor flexion proprioception group (n=19). Conversely, WBV had no noticeable effect on flexion proprioception of participants with good flexion proprioception (n=23, lumbar flexion angle deviation was less than 3.65°). The findings of Hosp et al. [53] and Callaghan et al. [54] indirectly support these observations, as they demonstrated that healthy participants whose knee proprioception was graded as good did not benefit from the intervention.

In our previous cross-sectional study, we found that decreased lumbar muscle strength, endurance, and lumbar proprioception of the lumbar vertebra lead to an increase in pain intensity and lumbar disability [20]. Therefore, we hypothesized that patients with poor proprioceptive sense might have more clinical benefit from performing WBV exercises. Clinical benefit was measured by minimal clinically important difference (MCID), defined as a change of 2 or more VAS points [50] after the intervention. However, results of the present study do not confirm this hypothesis. No significant differences between

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subgroups were found in flexion proprioception or extension proprioception in relation to the proportion of participants who attained MCID. However, an increased proportion of participants with poor VAS perceived a benefit in their clinical symptoms after the 12-week WBV intervention. Combined with the above results showing that WBV exercise decreased lumbar angle deviation significantly for NSLBP patients with poor proprioception, this finding indicated that NSLBP patients with severe pain and poor proprioception might be more suitable for WBV intervention.

Considering the gender factor, WBV showed a demonstrable effect on flexion proprioception but not extension proprioception for women in the whole group. Correspondingly, WBV showed a demonstrable effect on proprioception for men in both flexion and extension in the whole group (both P=0.0001). Few studies have reported on gender differences for NSLBP patients in lumbar proprioception based on WBV intervention. Ye et al. found that women were less sensitive than men in lumbar extensor endurance for WBV exposure [55]. Lumbar muscles in women have a higher proportion of cross-sectional area of type I fibers than men (73% and 56%, respectively) [56]. Type Iα afferent activities increased after vibration training, and type II afferents were also sensitive to vibration, especially when muscle contraction occurs. Because recruitment of type Iα afferents would precede that of type II afferents with somatosensory and perceptual stimulations, type II afferent fibers were used as elements to activate proprioception [57]. Women had a higher proportion of type Iα afferents fibers. Consequently, WBV training for women with NSLBP induced lower activations of type II afferent fibers, thereby resulting in relatively less improvement in proprioception. This is in line with the current findings.

Recently, a number of studies have reported that the LBP incidence in children and young adults is similar to that in adults [58–61], and even the lifetime prevalence rates increase with the age of the subjects [62]. Physically heavy work at a young age [63], psychological distress during childhood [64], and abdominal obesity [65] have been found to be the main risk factor for low back pain, not only during childhood, but also in early adulthood. Lifestyle-factors such as smoking, alcohol consumption, and overweight are was positively associated with LBP [66].

A meta-analysis of surgical versus nonsurgical treatment of chronic low back pain (CLBP) suggested that nonsurgical treatment was slightly more effective, feasible, and safe [67]. Nonsurgical physical therapies like low-level laser therapy [68], magnetic therapy [11], electrical therapies [10], extracorporeal shockwave therapy [69], and high-intensity laser therapy [70] have a favorable effect on self-reported pain and functional limitations on NSLBP. These results are in line with our study, but no previous study has reported on the effect of proprioception on the lumbopelvic area.

The present study contains certain limitations. First of all, our age range was narrow and the sample was small. All participants were young individuals, and the average age was 21.6 years old (range: 18–34 years old). Thus, these results did not represent the condition of the entire population. Furthermore, proprioceptive senses included position sense, motion perception, and vibration sensation; however, this study only tested position reproduction, particularly position sense. Given that the sense of joint movement and vibration was difficult to quantify under the conditions in the present study, the effort to improve accuracy and comprehensiveness of proprioceptive sensation testing is another important research field. Our findings are based on a single-group pre-post test design without a control group, which increases the risk of bias, and the lack of follow-up observations is another limitation. Future studies involving a control group and long-term follow-up observation are needed to ensure that the improvements we demonstrated are due to the whole-body vibration exercise, thereby strengthening the validity and credibility our study findings. Furthermore, it would be useful to evaluate the effect on lumbopelvic proprioception and pain control of different training approaches.

Conclusions

Lumbar flexion and extension proprioception, as measured by joint position sense, were enhanced significantly, and pain was also significantly reduced in NSLBP patients after completing the 12-week WBV exercise program. However, patients with good flexion proprioceptive ability had limited proprioceptive enhancement.

Conflicts of interest

None.

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以小鼠模式探討全身振動訓練對於生理生化表現以及運動疲勞之影響

Investigation of Whole-body Vibration Training on Physiological and Biochemical Characteristics in Mice

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簡述內容：

對於一般的運動來說，肌肉必須要承受該運動項目的生理適應性與疲勞度，因此處於過量或不當運動時身體可能會產生不適應與疲勞現象，本實驗證實經由被動式的全身垂直律動訓練刺激神經肌肉的敏感性，能促使肌力與爆發力的運動表現，並可促進運動後乳酸的排除，而研究也顯示在運動安全性上更是無庸置疑，因此運用全身律動的方式來訓練或作為平時規律的運動計畫，對於後續健康促進有顯著之效益，另外一般人運動後建議可以補充優質蛋白質，例如無糖溫豆漿或溫牛奶來協助肌肉的修補與生長，維持運動後的體力。

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以小鼠模式探討全身振動訓練對於生理生化表現以及運動疲勞之影響

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摘　要

緒論：近年來振動訓練是一種新穎訓練方式，相關研究提出振動訓練是可以提升肌力、爆發力與運動表現並適合應用於不同年齡族群中。本研究探討不同強度全身振動訓練介入對於生物體運動表現、運動疲勞以及生理生化反應之影響。**方法：**使用四週大雄性 C57BL/6J 品系小鼠爲模式，隨機分作三組，每組 8 隻動物：(1) 無振動訓練對照組 (sedentary control, SC)；(2) 相對較低強度振動訓練組 (5.6 Hz/0.13 g; relative low-intensity vibration, LV)；(3) 相對較高強度振動訓練組 (13 Hz/0.68 g; relative high-intensity vibration, HV)。振動訓練以每日振動 15 分鐘，每週 5 次，爲期 4 週，隨後進行各項測試包括：前肢抓力、衰竭性耐力運動測驗、疲勞生化指標分析、臨床血液生化檢測以及病理組織切片觀察。數據以單因子變異數進行分析 (SAS 統計軟體)，並以 Duncan's test 考驗不同組之間是否存在顯著差異，當 $p < .05$ 時達統計上之顯著水準。**結果：**兩組接受振動訓練 (LV 與 HV) 介入的小鼠比對照組，具有顯著提升肌力和衰竭性耐力運動的時間。在疲勞與肌肉損傷相關生化指標部分，振動訓練具有明顯降低單次運動測試後血氨與血乳酸濃度以及肌酸激酶活性上升的作用。在臨床血液生化方面，四週振動訓練顯著降低草醋酸轉胺酶、麩丙酮酸轉胺酶與肌酸激酶活性，以及尿素氮濃度。**結論：**本研究證實振動訓練四週的連續介入下，具有提升運動表現與抗疲勞之作用，而且不會造成健康小鼠在生理生化以及病理上之副作用。在提供一般健康成人的運動訓練指導上，全身振動訓練極具有健康促進的應用性。

關鍵詞：前肢抓力、有氧耐力、乳酸、血氨、肌酸激酶

壹、緒　論

振動訓練 (vibration training) 是近年來較新的運動訓練方式，許多研究提出振動訓練對於各年齡層或身體障礙者，皆可提升肌力、爆發力及體能表現 (林俊達、黎俊彥，2010；Tsuji et al., 2014)。另外，近年來也有學者提出振動訓練能夠提升肌肉的協調性、平衡能力與適應

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能力 (Pollock, Martin, & Newham, 2012; Wang et al., 2014)，故振動訓練對於運動表現上有正向的助益。以實施模式上，振動訓練可分成兩種分別爲直接法以及間接法，前者是將振動器固定於目標肌肉上，以局部振動方式進行刺激，例如：手握式或像皮帶固定住；後者則是利用振動式平臺置於身體遠端，振動力量經由身體傳遞到達目標肌群上，例如：全身振動訓練，目前振動式訓練多是此類 (Luo, McNamara, & Moran, 2005)，其訓練方式對身體負擔是相對較低、適用於無法從事傳統運動訓練者、於無負重狀態和無動態關節使用下皆可進行訓練 (Tsuji et al., 2014)。

全身振動訓練 (whole-body vibration training, WBV) 的理論，是以被動的方式將振動置於目標肌肉或肌腱上進行刺激而產生神經肌肉反射，當刺激後產生牽張反射 (stretch reflex) 之效果。而與振動訓練相似之處在於是藉由被動的振動刺激，以被動的方式促使肌肉產生牽張產生收縮進而促進肌肉活化，肌肉產生收縮力，而促進肌力的提升 (Mahieu et al., 2006)。振動訓練可使全身接受刺激並藉由身體的傳遞力量達到預定訓練的肌群，不論任何模式皆必須考量到身體的負荷程度，而其振動強度決定於頻率 (frequency)、振幅 (amplitude) 與加速度 (acceleration)。藉由三項參數調整與配合便可作爲不同類型的訓練強度 (Luo et al., 2005)。

過去的研究已經證實振動訓練對於多方面生理上的確具有功能的提升與改善之效果；在神經肌肉方面，在老人與停經婦女族群在 26-40 Hz 的振動頻率介入 8-24 週下可縮短 TUG (time up and go test) 時間及六公尺步行時間 (Pollock et al., 2012)，並增進伸膝肌群之動態肌力及靜態肌力 (Verschueren et al., 2004)；在骨骼系統方面，藉由長期振動訓練下，可增加近端幹骺端之海綿骨礦物表面及海綿骨體積 (Xie, Rubin, & Judex, 2008)，對停經後的婦女族群可增加腰椎之骨質密度與顯著降低跌倒之頻率 (von Stengel, Kemmler, Engelke, & Kalender, 2011)。在心血管系統方面，在振動訓練介入下可增加周邊血液循環、心跳速率增加與攝氧尖峰量 (Bogaerts et al., 2009)。在內分泌系統方面，振動訓練不僅是物理刺激外，經振動刺激後會改變體內賀爾蒙分泌，在年輕男性進行單回合 60 秒 10 次之劇烈振動刺激可提高睪固酮 (testosterone) 及生長激素 (growth hormone) 濃度同時降低皮質醇 (cortisol) 濃度 (Bosco et al., 1999)；在年輕女性進行 4 個月的振動訓練介入後，其發炎相關細胞激素 IL-1β、TNF-α 及骨調素 (osteopontin) 等含量顯著減少 (Humphries, Fenning, Dugan, Guinane, & MacRae, 2009)。

雖然多數的研究均探討振動訓練對於生理表現的促進效益，不過仍有部分學者討論振動訓練對於激烈運動後或訓練後，其疲勞改善的效果。其中改善肌肉疲勞與回復上，Aminian-Far, Hadian, Olyaei, Talebian, 與 Bakhtiary (2011) 研究結果發現，從事離心收縮運動前使用 35 赫茲的振動訓練 60 秒，能有助於減少運動後延遲性肌肉痠痛 (delayed-onset muscle soreness, DOMS) 的發生。另外，利用運動後立即 15 分鐘低頻率 (20 Hz) 之振動刺激，可有效改善自行車選手運動後乳酸清除的效率 (Carrasco, Sañudo, de Hoyo, Pradas, & Da Silva, 2011)。同時可使肌肉疲勞更快速地恢復與減緩的方法之一 (Kosar, Candow, & Putland, 2012)。部分學者提出振動訓練對於肌肉疲勞與回復之效果不佳之結果，以頻率 30 Hz 振幅爲 4 mm 進行 6 分鐘單次的振動介入後，使疲勞指標肌酸激酶 (creatine kinase, CK) 增加及出現輕微肌肉僵持現象 (de Hoyo, Carrasco, Da Silva-Grigoletto, & Sañudo, 2013)。由此可見，過去振動訓練相關研究中對於運動表現與相關疲勞的生理機轉結果不盡相同，仍須進一步研究釐清。

關於振動訓練的相關研究指出，因爲對象族群有所不同，且介入的頻率、振幅與時間亦不盡相同。因此，無法得到合理且最佳的振動頻率與振幅，同時，亦經常忽略振動此一物理介入的過

程，如條件不當的確會造成身體的傷害。如國際標準組織 (International Standard Organization, ISO) 訂定了「全身振動的暴露評估指引 ISO 2631」，對於人體曝露於振動的環境中的頻率、振幅與時間都有嚴格的限制，其主要目的就是要消除工作環境中所產生的振動，避免振動對人體的影響。然而，目前針對不同條件下的振動訓練介入是否對其造成生理生化上影響相關研究有限，但於過去學者研究指出使用低頻率的振動 (5-15 Hz)，具有機械性放鬆效果且助於加速恢復速度，以及刺激肌肉接受器以降低肌肉張力 (Cafarelli, Sim, Carolan, & Liebesman, 1990)。因此本研究選擇此頻率範圍，用以了解振動訓練下是否能夠提升運動表現與改善相關疲勞指標的生理活性外，更希望能從血液生化的角度來探討振動訓練所帶來的影響。

貳、方　法

一、實驗動物之飼養與分組

本次研究所使用之雄性四週齡大、24 隻 C57BL/6J 品系小鼠均採購於樂斯科生物科技股份有限公司 (宜蘭，臺灣)，該公司爲 AAALAC 認證知單位所提供的實驗動物均爲無特定病原菌之實驗動物，以確保研究實驗數據之品質。本次動物實驗之研究內容與實驗流程均受本校實驗動物照護及使用委員會所監督與審查，核准後執行，審查通過編號爲 IACUC-10205。實驗動物均在本校動物房內進行飼養與操作，房內溫度控制在 22 ± 2 °C、濕度 65 ± 5%，光照與黑暗各 12 小時並提供動物飼料 (Chow 5001, LabDiet, USA) 與水提供予小鼠自由攝食。在購入後，給予一週適應期後，將 24 隻 C57BL/6J 小鼠隨機分爲以下 3 組，每組 8 隻，分組如下：(1) 無振動訓練的對照組 0 Hz (sedentary control, SC)、(2) 相對低強度振動訓練組 5.6 Hz/0.13 g (low-intensity vibration, LV)、(3) 相對高強度振動訓練組 13 Hz/0.68 g (high-intensity vibration, HV)。振動訓練期間，均定時記錄不同處理組別個體的體重變化以及攝食量變化情形。

二、振動訓練流程與步驟

本實驗使用間接型式振動訓練法 (Huang, Tseng, Huang, Chung, Chuang, & Wu, 2014)，設備採用垂直律動儀 (Body Green®, Qigong Master, BW760, Taiwan)，此儀器之最低強度爲 (5.6 Hz, 0.13 g) 至最高強度 (13 Hz, 0.68 g)，屬於垂直式全身振動訓練。在此，研究設計以振動訓練介入，並設計出相對高及低之頻率 (Hz, g)，以相同振幅 2 mm，分成相對低強度 (5.6 Hz, 0.13 g) 及相對高強度 (13 Hz, 0.68 g) 進行本次的振動訓練強度。其振動條件以及訓練內容，如表 1 所示。

表 1

實驗分組以及振動訓練內容

分組	幅度 (mm)	頻率 (Hz)	強度 (g)	訓練頻率	訓練時間	訓練長度
SC 組	---	---	---	---	---	---
LV 組	2	5.6	0.13	每週 5 次	每次 15 分鐘	4 週
HV 組	2	13.7	0.68	每週 5 次	每次 15 分鐘	4 週

三、前肢抓力測試

爲了瞭解振動訓練介入四週後是否對於肌力是否具有提升之效果，本實驗使用動物前肢抓力測量裝置，分析各組動物間前肢抓力之變化，並測量其最大抓力數值 (grams)，藉以瞭解肌力提升情形。詳細的步驟如過去文獻所述 (Wu et al., 2013)。

四、衰竭性耐力運動測驗

爲了瞭解振動訓練介入四週後是否對於耐力表現是否具有提升之效果，本實驗以等同 5% 身體重量的鉛片固定於個體小鼠之尾根處，並將水溫固定於 28 ± 1 °C 之條件下；將小鼠放入水中進行衰竭性耐力測試，同時開始計時直至衰竭爲止，此段持續游泳之時間並記錄爲衰竭性耐力之時間。衰竭之判定定義爲小鼠口鼻末入水平面下持續 7 秒鐘而無法浮出水面進行呼

吸，則判定為衰竭，詳細步驟如先前文獻所述 (Wu et al., 2013)。

五、血液生化指標分析

過去文獻資料指出，運動後的乳酸 (lactate)、血氨 (ammonia, NH_3)、血糖(glucose, GLU) 濃度以及 CK 活性可以分別作為運動後疲勞以及肌肉損傷的重要生化指標 (Wang et al., 2012; Wu et al., 2013)，本研究也分析比較運動後各組 NH_3 與 GLU 濃度以及 CK 活性變化。在衰竭性耐力測試後第四天進行單次游泳測試，當日則是在餵食結束 30 分鐘之後，針對各組動物進行單次、無負重、固定 15 分鐘游泳運動測試，水溫控制在 28 ± 1 °C 每隻動物都在固定游泳 15 分鐘之後，立即利用顏面採血法 (不需麻醉) 收集約 0.3 mL 血液於微量離心管中，於 4 °C、1,500 ×g 條件下離心 15 分鐘。將血清分裝至微量離心管中，並立即進行疲勞相關血液生化分析，項目包括：乳酸、NH_3 與 GLU 濃度，以及 CK 活性。

在長期振動訓練下是否對於生理生化相關數值造成影響方面的評估，則是在上述樣本採樣完成，再給予一週的休息與持續的振動訓練介入後，經由二氧化碳犧牲後立即利用心臟採血法採集血液 (約 1 mL)、組織樣本進行後續的分析處理，經由上述離心處理後之血清經由血液生化自動分析儀 (Hitachi 7060, Hitachi, Tokyo, Japan) 進行分析。本階段的血液生化分析主要為天門冬胺酸轉胺酶 (asparate aminotransferase, AST)、丙胺酸轉胺酶 (alanine aminotransferase, ALT)、鹼性磷酸酶 (alkaline phosphatase, ALP)、乳酸脫氫酶 (lactate dehydrogenase, LDH)、白蛋白 (albumin)、總膽紅素 (total bilirubin, TBIL)、總蛋白 (total protein, TP)、尿素氮 (blood urea nitrogen, BUN)、肌酸酐 (creatinine, CREA)、尿酸 (uric acid, UA)、總膽固醇 (total cholesterol, TC)、三酸甘油脂 (triacylglycerol, TG)、GLU 以及 CK 等項目來評估長期振動訓練對於生理生化之影響 (Chen, Huang, Chiu, Chang, & Huang, 2014)。

六、組織器官秤重與病理切片評估

在犧牲後，不同組織器官樣本包含，心臟 (heart)、肺臟 (lung)、肝臟 (liver)、腎臟 (kidney)、肌肉 (muscle)、棕色脂肪 (brown adipocyte tissue, BAT)、副睪脂肪 (epididymal fat tissue, EPF) 等，分別取出並以生理食鹽水 (Saline) 清洗後，拭乾秤重秤；除了記錄相關重要臟器重量外，其肝臟、肌肉 (包含比目魚肌與腓腸肌總和)、心臟、腎臟和肺臟均放置於 10% 福馬林液中固定 24 小時，其後將組織器官修整 (trimming) 至欲觀察之切面後，進行石蠟包埋切片。所包埋組織之石蠟樣本經切片機，切出約 4μm 厚薄之切片樣本經由 H&E 染色 (蘇木紫-伊紅) 後進行後續型態與病理的進一步評估，並以 CCD 鏡頭之光學顯微鏡拍攝記錄 (BX-51, Olympus, Tokyo, Japan)。

七、統計分析

所有數值以 Mean±SEM 表示，每組小鼠數量皆為 8 隻。採用 SAS 電腦統計套裝軟體進行單因子變異數分析 (one way analysis of variance, ANOVA)，並以 Duncan's test 測試不同處理組別間是否具有差異，並以上標英文符號之異同來呈現，$p < .05$ 代表具有統計上之意義。另外，為了瞭解補充不同振動訓練強度下在各測試項目是否具有劑量效應 (dose effect)，同樣以 SAS 軟體進行趨勢分析 (trend analysis)，並以 Cochran-Armitage test 進行檢定。

參、結　果

一、振動訓練對於體重、飲水與攝食量之影響

在振動訓練介入前測得 SC、LV 以及 HV 三組小鼠間的基礎體重並無顯著差異。在經過 4 週振動訓練介入後，觀察到三組小鼠間的體重皆隨著飼養時間增加而顯著上升。在最後一週，三組體重分別為 24.1 ± 0.4 (SC 組)、24.0 ±

0.4 (VL 組) 和 24.1 ± 0.3 (VH 組) 克重，兩組振動訓練組與對照組間之體重並無顯著差異 (表 2)。在飲食狀況記錄上，SC 組、LV 組與 HV 組在飲水量分別為 5.1 ± 0.1、5.3 ± 0.5 和 5.1 ± 0.2 毫升/每隻/每天，且在攝食量分別為 4.1±0.1、4.1 ± 0.1 和 4.1 ± 0.1 克/每隻/每天，三組間的飲水與攝食量均無明顯差異 (表 2)。

二、振動訓練對於前肢抓力之表現

在振動訓練介入後，SC 組、LV 組、HV 組所顯示的前肢抓力分別為 95 ± 6、116 ± 3、126 ± 4 (g)。在 LV 組與 HV 組的前肢抓力表現分別比 SC 組顯著高 1.22 倍 (p = .0068) 與 1.33 倍 (p = .0002)。在趨勢分析中，前肢抓力的表現對於振動強度增加而有劑量效應之提升，在統計分析上具有顯著差異 ($p < .05$) (圖1A)。

三、振動訓練對於衰竭性耐力運動之表現

本研究中，在個體 5%負重的衰竭性游泳測試中，SC 組、LV 組與 HV 組的負重衰竭性游泳能力表現分別為：2.85 ± 0.25、5.12 ± 0.96、8.20 ± 1.04 分鐘。在游泳衰竭性時間部分，LV 組比 SC 組稍微增加 1.78 倍 (p = .0662)，而 HV 組則是明顯增加 2.88 倍 (p = .0002)。結果顯示，僅 HV 組相較於 SC 組達顯著增加水準，且在 HV 組也顯著高於 LV 組約 1.6 倍 (p = .0158)。在趨勢分析中，衰竭性耐力的表現對於振動強度增加而有劑量效應之提升，在統計分析上具有顯著差異 ($p < .05$) (圖 1B)。

四、振動訓練對於疲勞相關生化指標之影響

在運動訓練介入後，欲了解在固定運動強度 (15 分鐘無負重游泳) 介入後對於疲勞相關生化指標，如乳酸、NH_3、CK 和 GLU 是否具有影響。本研究結果中，運動後乳酸在 SC 組、LV 組和 HV 組分別為 7.4 ± 0.3、6.0 ± 0.2 與 6.2 ± 0.3 mmol/L (圖 2A)；LV 組與 HL 組相較於 SC 組乳酸濃度分別顯著減少了 19% (p = .0007) 及 16% (p = .0021)。運動後 NH_3 在 SC 組、LV 組和 HV 組分別為 146 ± 25.5、59 ± 4.1 與 57 ± 4.1 μmol/L (圖 2B)，LV 組與 HL 組相較於 SC 組 NH_3 濃度分別顯著減少了 59% (p = .0006) 及 61% (p = .0004)；運動後 GLU 濃度在 SC 組、LV 組和 HV 組分別為 201 ± 6.4、183 ± 5.3 與 173 ± 4.8 mg/dL (圖 2C)，LV 組與 HL 組相較於 SC 組 GLU 濃度分別顯著減少了 8.9% (p = .0343) 及 13.9% (p = .0019)；在運動後 CK 濃度在 SC 組、LV 組和 HV 組分別為 442 ± 112.7、287 ± 63.7 與 142 ± 61.9 (U/L) (圖 2D)，在平均值上 LV 組和 HV 組相較於 SC 組減少了 36% (p = .1982) 和 45% (p = .1019)，但在統計上卻無達顯著差異 ($p > .05$)。為了瞭解振動訓練強度不同對於運動後疲勞相關血液生化指標是否存在著劑量效應，由趨勢分析結果顯示，乳酸、NH_3 和 GLU 會隨著振動訓練強度增加而有顯著減少的作用 ($p < .05$)；但是，三組血清 CK 活性則是與振動訓練的強度無顯著影響 ($p > .05$)。

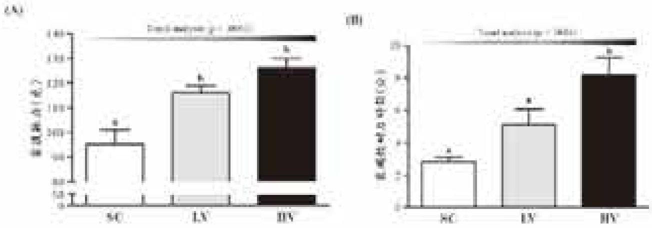

圖 1. 振動訓練對於運動表現之影響 (A) 前肢抓力 (B) 游泳衰竭性耐力。註：數據上方英文字母 (a, b) 相異者代表具有顯著差異 ($p < .05$)，若英文字母 (a, b) 相同者代表無顯著差異。

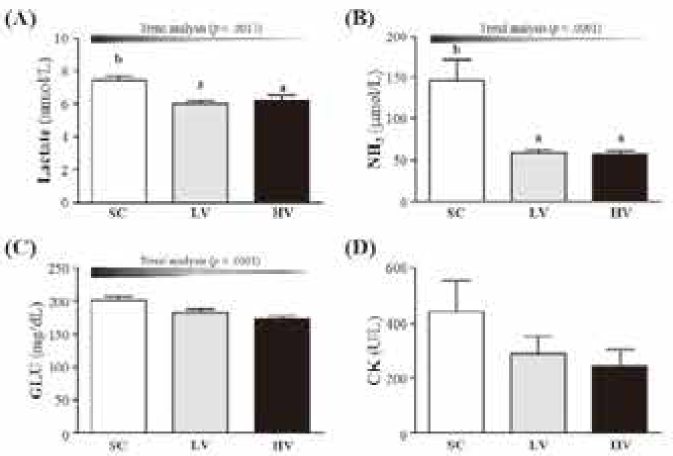

圖 2. 振動訓練對於固定運動強度介入後，對於運動疲勞相關血液生化指標之影響 (A) 乳酸 (lactate) (B) 血氨 (NH_3) (C) 血糖 (GLU) (D) 肌酸激酶 (CK)。註：數據上方英文字母 (a, b) 相異者代表具有顯著差異 ($p < .05$)，若英文字母 (a, b) 相同者代表無顯著差異。

五、振動訓練對於臟器重量與臨床生化數值之影響

無振動訓練的 SC 組、LV 組和 HV 組，三組實驗組別之小鼠每天分別以 0Hz、5.6 Hz 和 13 Hz，震動訓練爲期 28 天。犧牲後，採集血液與組織臟器樣本，包括心臟、肺臟、肝臟、腎臟、肌肉、棕色脂肪、副睪脂肪進行臟器重量檢測。如表 2 所示，在個體之肺臟、肝臟、腎臟、肌肉、棕色脂肪、副睪脂肪組織重量上在各組間並無顯著差異 ($p > .05$)。但在心臟上重量上，SC 組、LV 組和 HV 組三組分別爲 0.16 ± 0.01、0.13 ± 0.01 和 0.13 ± 0.004 克重，SC 組顯著高於振動訓練組約 1.23 倍 (分別爲 $p = .039$ 與 $p = .031$)；但各個臟器在與個體體重相除所得之相對重量百分比，更能觀察出振動訓練是否會對於臟器之重量有所影響。如表 2 所示，心臟在與個體之相對重量校正後發現 SC 組仍然顯著高於振動訓練組 ($p < .05$)；同樣在其他臟器之相對重量百分比的結果上，各組間亦無顯著之差異 ($p > .05$)。

表 2

振動訓練對於攝食量、體重與臟器重量之影響

項目	SC	LV	HV	Trend analysis (p value)
飲食量 (g/mouse/day)	4.1 ± 0.1	4.1 ± 0.1	4.1 ± 0.10	0.7874
飲水量 (mL/mouse/day)	5.1 ± 0.1	5.3 ± 0.5	5.1 ± 0.20	0.5241
初始體重 (g)	18.7 ± 0.4	18.4 ± 0.3	18.3 ± 0.30	0.4483
最終體重 (g)	24.1 ± 0.4	24.0 ± 0.4	24.1 ± 0.30	0.9021
心臟 (g)	0.16 ± 0.01^{b}	0.13 ± 0.01^{a}	0.13 ± 0.01^{a}	0.0769
肺臟 (g)	0.28 ± 0.01	0.29 ± 0.01	0.28 ± 0.01	0.9794
肝臟 (g)	1.29 ± 0.05	1.24 ± 0.04	1.20 ± 0.04	0.0806
腎臟 (g)	0.36 ± 0.01	0.35 ± 0.01	0.36 ± 0.01	0.8233
肌肉 (g)	0.30 ± 0.01	0.30 ± 0.01	0.31 ± 0.01	0.6137
棕色脂肪 (g)	0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.8633
副睪脂肪 (g)	0.27 ± 0.03	0.29 ± 0.03	0.28 ± 0.03	0.8675
心臟 (%)	0.65 ± 0.04^{b}	0.55 ± 0.02^{a}	0.55 ± 0.02^{a}	0.0471
肺臟 (%)	1.15 ± 0.06	1.19 ± 0.05	1.17 ± 0.04	0.9184
肝臟 (%)	5.37 ± 0.22	5.17 ± 0.09	5.00 ± 0.18	0.0130
腎臟 (%)	1.47 ± 0.05	1.47 ± 0.03	1.49 ± 0.03	0.9809
肌肉 (%)	1.26 ± 0.05	1.25 ± 0.02	1.28 ± 0.02	0.4890
棕色脂肪 (%)	0.31 ± 0.02	0.30 ± 0.02	0.31 ± 0.02	0.8194
副睪脂肪 (%)	1.11 ± 0.13	1.19 ± 0.12	1.16 ± 0.11	0.8327

註：數據上方英文字母 (a, b) 相異者代表具有顯著差異 ($p < .05$)，若英文字母 (a, b) 相同者代表無顯著差異。

在上述所採集之血液樣本經離心處理後，所得之血清進行相關生化分析了解振動訓練對於其影響性。如表 3 所示，在肝功能指數有密切相關性的 AST 與 ALT 部分，顯示前者 AST 在振動訓練介入之 LV 組與 HV 組相較於 SC 組均顯著下降了約 13% ($p < .05$)，在後者 ALT 在振動訓練介入下，僅 HV 組相較於 SC 組顯著下降了約 18% ($p = .0118$)；另一項與腎功能相關聯生化指標 BUN 方面，結果顯示 BUN 在振動訓練介入之 LV 組與 HV 組相較於 SC 組均顯著下降了約 8% (分別爲 $p = .0476$ 和 $p = .0413$)；另一項與肌肉損傷相關聯生化指標 CK 方面，結果顯示 CK 在振動訓練介入之 LV 組與 HV 組相較於 SC 組分別顯著下降了約 31 % ($p = .0250$) 與 33 % ($p = .0205$)。其他生化指標，如 ALP、LDH、albumin、TBIL、total protein、CREA、UA、TC、TG、GLU、ALB 濃度等項目的變化方面相較於 SC 組皆無統計差異 ($p > .05$)。

除了血液生化檢測外，本研究亦針對體內器官組織在本實驗條件下長時間振動訓練介入，是否會對相關臟器造成傷害而進行病理切片觀察，結果經由獸醫師觀察與報告後顯示振動訓練組別 (LV 組和 HV 組) 與 SC 組並無顯著差異 (結果未放入本文中)。

表 3

振動訓練對於臨床血液生化指標之影響

生化指標	SC	LV	HV	Trend analysis (p value)	
AST (U/L)	67 ± 3^{b}	58 ± 2^{a}	58 ± 2^{a}	0.0105	(↓)
ALT (U/L)	44 ± 3^{b}	41 ± 2^{ab}	36 ± 2^{a}	0.0017	(↓)
GLU (mg/dL)	185 ± 4	179 ± 3	185 ± 5	0.9201	
TP (g/dL)	5.4 ± 0.1	5.5 ± 0.1	5.6 ± 0.0	0.1614	
ALB (g/dL)	3.5 ± 0.0	3.6 ± 0.1	3.5 ± 0.0	0.5712	
TBIL (ug/dL)	24 ± 3	23 ± 2	22 ± 3	0.5370	
CREA (mg/dL)	0.30 ± 0.01	0.32 ± 0.01	0.31 ± 0.01	0.3303	
BUN (mg/dL)	28.0 ± 0.7^{b}	25.8 ± 0.7^{a}	25.7 ± 0.8^{a}	0.0165	(↓)
ALP (U/L)	401 ± 14^{b}	368 ± 8^{a}	423 ± 6^{b}	0.2134	
TC (mg/dL)	86 ± 2	83 ± 2	86 ± 3	0.9212	
LDH (U/L)	368 ± 30	339 ± 28	322 ± 19	0.1808	
TG (mg/dL)	73 ± 7	60 ± 4	68 ± 6	0.6364	
UA (mg/dL)	1.0 ± 0.1	1.0 ± 0.0	0.9 ± 0.1	0.3463	
CK (U /L)	172 ± 18^{b}	118 ± 15^{a}	116 ± 14^{a}	0.0302	(↓)

註：數據上方英文字母 (a, b) 相異者代表具有顯著差異 ($p < .05$)，若英文字母 (a, b) 相同者代表無顯著差異。

肆、討　論

在振動訓練對於身體組成與飲食的影響上，Maddalozzo, Iwaniec, Turner, Rosen, 與 Widrick (2008) 指出在過去雌性大鼠之動物研究指出在 12 週振動訓練介入下發現在體重上顯著下降，進一步分析相關身體組成發現其去脂身體質量 (lean body mass) 並無顯著影響，在脂肪量與脂肪率上振動訓練組明顯低於對照組，但在飲食攝取上與對照組相較並無顯著差異；與本次實驗相較，在體重改變上，振動訓練介入下並無顯著差異 (表2) 且脂肪量與脂肪率上亦無顯著之改變 (表2)，其主要的原因可能是在於振動訓練的時間不同所導致 (本實驗僅介入 4 週)，因而無法有效觀察到體重、脂肪量與脂肪率差異，推測振動訓練對於體脂肪上的影響需較長的介入時間。但飲食攝取上與前人研究結果相似，振動訓練並不會影響其攝食量。

振動訓練的生理機轉主要來自神經肌肉的適應，能促發張力性振動反射，引起快速反覆的刺激，增強肌梭反射敏感性，達到增加神經衝動的頻率及數量，同時徵招更多的運動單位，使肌力及爆發力等運動表現的提升 (Mahieu et al., 2006)，而前人的研究也指出在負重振動訓練下可提升田徑選手之力量和速度 (Wang et al., 2014)。因此，在本次實驗利用前肢抓力來評估其肌力表現影響，結果顯示在振動訓練的介入下，振動訓練組均顯著高於對照組 (圖 1A)，且隨著振動強度的劑量增加而提升抓力並具有顯著之劑量效應 ($p < .05$)，在有氧耐力相關的表現上，前人研究指出，針對振動訓練介入於老年與年輕族群上，顯示在心血管系統上可提升最大攝氧量與增加周邊血液循環 (Bogaerts et al., 2009)；從另外一個觀點討論，Rittweger, Mutschelknauss, 與 Felsenberg (2003) 利用振動訓練介入對於肌肉力竭後的影響，研究顯示搭配振動訓練組其肌肉力竭時間較控制組持久。同樣的肌腱反射幅度顯著高於控制組，表示振動訓練可增強神經肌肉興奮而提升肌力表現。而在本次結果中顯示較高強度振動訓練 (HV) 對於有氧耐力表現上，顯著高於對照組與 LV 組 (圖 1B) 且呈現顯著之劑量效應關係，推測本研究之相對高強度振動訓練可能藉由最大攝氧量提升與循環系統的改善進而提升有氧耐力運動表現。

本實驗針對振動訓練介入下，除了上述抓力與有氧耐力運動表現外，同時評估疲勞相關的血液生化指標，以了解振動訓練對生化活性之影響。過去的研究顯示，疲勞相關的常用生化指標，包含 乳酸、NH_3、CK 及 GLU (Wang et al., 2012; Wu et al., 2013)，作爲評估運動訓練生理生化上疲勞程度。過去研究指出，在力竭運動後針對不同回復方式來探討乳酸排除的程度與效率，其結果顯示振動結合動態休息方式可有效達到乳酸下降之效果 (黃彥霖等，2013)，以及運動訓練後利用肌肉振動方式可有效達到降低血乳酸含量。本研究主要探討振動訓練對於運動後乳酸含量之高低進行評估，結果顯示 (圖 2A) 在運動訓練介入下對於運動後乳酸含量相較於對照組顯著下降，因此可知振動效果介入除了前述研究可促進運動後乳酸排除效果外，更在運動前的訓練上具有減緩運動過程中所產生的乳酸含量。在 NH_3 方面，探討振動訓練影響的先前研究並不多，在本次實驗結果可知在振動訓練後，可減少單次運動後 NH_3 的濃度上升 (圖 2B)，推測振動訓練對於代謝率有提升之影響 (Friesenbichler, Nigg, & Dunn, 2013) 而使得 NH_3 能有效率的被代謝和排除。

在振動訓練與運動後的 GLU 與 CK 血液生化指標之關聯性進一步討論；葡萄糖爲運動過程中主要能量來源，隨著運動過程中的耗竭，可能導致運動疲勞發生進而影響運動表現，因此 GLU 的有效轉化與利用成爲關鍵性的因子，Manabe 等 (2012) 指出肌肉的收縮具有提升組織表現GLUT4的葡萄糖轉運分子之表現以協助葡萄糖之攝入作用。此外，短期或長期振動訓練具有改善胰島素敏感性、糖化血色素 (hemoglobin A1c, HbA1C) 與禁食 GLU 濃度的

效果 (Lee, Lee, & Song, 2013; del Pozo-Cruz, Alfonso-Rosa, del Pozo-Cruz, Sanudo, & Rogers, 2014)，在本研究結果指出在振動訓練後之組別，其運動後 GLU 顯著低於對照組別，可能是由於振動訓練造成肌肉高頻率的收縮促使 GLUT4 葡萄糖運送蛋白表現提高，或者可能是改善胰島素敏感性，而讓血液中葡萄糖分子有效率的進入組織提供能量使用，使得振動訓練組之 GLU 顯著低於對照組 (圖 2C)。在後者肌肉損傷的指標 CK 上，學者指出在無運動習慣的個體 (sedentary subjects) 與籃球選手在接受高強度的單次振動訓練下，其 CK 數值會顯著的提高，但在數小時之後即會回復到基礎值，且未呈現額外傷害 (Fachina et al., 2013)；在另一研究報告指出，在下坡跑步運動前給予振動訓練，對於運動後的 CK 數值具有顯著下降的效果 (Bakhtiary, Safavi-Farokhi, & Aminian-Far, 2007)。結合以上研究，推測在 4 週的振動訓練下可能造成肌肉的適應性進而在運動後其數值具有下降的效果，在本次實驗雖有下降但無達到顯著差異，推測如延長訓練時間應可更具有顯著保護成效。

振動訓練在代表生理狀態的相關生化指標上的影響並無太多相關文獻的報導，de Hoyo 等 (2013) 探討單次急性 WBV 訓練對於肌肉的生理反應並探討造成相關的肌肉傷害的指標 (CK 和 LDH)，結果顯示振動進入後一小時 CK 指標顯著提升並於 48 小時候回復至正常值；因此，本研究首次藉由代表不同生理功能性的生化指標角度切入探討振動訓練對其產生的影響，在相關的指標上發現在 4 週的振動訓練介入下發現對於肝功能指標 (AST 和 ALT)、腎功能指標 (BUN) 和肌肉損傷的指標 (CK) 具有顯著的向下調節作用 (表 3)。根據先前學者的研究報告指出，劇烈運動會誘發過度的氧化壓力與發炎反應，而造成骨骼肌、肝臟以及腎臟急性損傷情形發生 (Huang et al., 2009)。此外，振動訓練可調節血管內皮功能、動脈血流速度以及周邊血液循環等循環功能 (Bogaerts et al., 2009)，因此推測振動訓練介入下應可對於運動所誘發之氧化壓力與發炎反應有程度上的保護效果，以及可能透過血液循環改善而加速代謝發炎反應，但仍須未來利用相關的實驗設計來加以驗證。本研究利用臨床生理生化數值來了解振動訓練的影響外，同時利用病理切片的方式了解振動對於身體不同器官臟器所產生的影響，進一步了解相關的振動頻率與振幅是否合適，在不同組織病理切片經由病理學家判讀後，結果顯示本實驗所使用之不同強度振動頻率並無造成臟器與組織傷害。然而在本篇的振動訓練研究中，因使用的振動訓練平臺儀器的限制無法調整其振幅，因此選擇本機型最高與最低的頻率 (強度) 來探討其對運動疲勞與生理生化數值之影響，未來如能在此範圍的頻率下針對振幅來做調整而達到不同強度的介入，可進一步探討與評估其效益。

由本動物實驗結果可知在四週的振動訓練介入後，可顯著的改善疲勞相關血液生化指標，包含乳酸、NH_3 和 GLU，並提高運動表現能力，如抓力與衰竭性耐力表現；並以臨床生化指標的觀點來評估四週的振動訓練所產的影響，結果顯示對於肝功能指標 (AST 和 ALT)、腎功能指標 (BUN) 和肌肉損傷的指標 (CK) 具有保護與改善的生理功能；結合組織病理切片的觀察了解振動訓練與該振動強度對於身體是屬無害的範圍。在未來人體實務應用上，需進一步驗證是否振動訓練結合於運動員的運動處方中，除了對運動或訓練所造成的氧化壓力、發炎反應能有抑制效果，更對於運動表現能有所助益。

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Investigation of whole-body vibration training on physiological and biochemical characteristics in mice

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Abstract

Introduction: Vibration is a novel exercise training methods in recent years and many studies showed it could enhance the strength, power and physical performance in for all age populations and physical disabilities. In current studies, we try to investigate the effects of whole-body vibration training (WBV) on physiological and biochemical characteristics and anti-fatigue physiological activities in a mouse model. **Methods:** Twenty-four male C57BL/6 mice age 4 wk with SPF (specific pathogen free) certification were divided randomly into three groups (n = 8 per group): (i) sedentary control (SC), (ii) WBV at relative low-intensity (5.6 Hz, 0.13 *g*) (VL), or (iii) relative high-intensity (13 Hz, 0.68 *g*) WBV (VH). Animals of two vibration groups were subjected to vibration stimulus 15min/day, 5 days/week for 4 weeks. The exercise performance and exercise-induced fatigue test were evaluated using forelimb grip strength, endurance swimming time, exercise-related biochemical variables and pathological evaluation. Statistical differences among groups were analyzed by a one-way analysis of variance (ANOVA) and the Cochran-Armitage test for dose-effect trend analysis with use of SAS v9.0 (SAS Inst., Cary, NC, USA). $p < .05$ was considered as statistical significance. **Results:** Two WBV groups (the LV and HV groups) showed increased grip strength and exhaustive endurance time as compared to the SC group. And, WBV also produced dose-dependent decreases in serum lactate, ammonia and glucose levels after a single bout exercise test. In serum marker assays, WBV also significantly decreases the fasting serum levels of aminotransferases (AST and ALT), CK (creatine kinase) and blood urea nitrogen. **Conclusion:** The results of the current study suggest that 4-week WBV can improve exercise performance, anti-fatigue capacity, and has no adverse side effects on clinical biochemical assessments in health mice. Therefore, we suggest that WBV may have important health outcome implications as we work to design better exercise programs for general health people.

Key words: forelimb grip strength, aerobic edurance, lactate, ammonia, creatine kinase

振動運動對高強度間歇握力運動後握力表現與生理恢復之急性影響

Acute Effect of Vibration Exercise on Grip Strength and Physiological Recovery from High-Intensity Intermittent Grip Exercise

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簡述內容：

大部分的人都有肌肉痠痛的經驗，當超出一般運動量或做平常不習慣的運動後可能會更容易發生，尤其為運動完的1~2天最為明顯，甚至有些人會出現手無法抬高或腳無法正常走動等等的嚴重狀態，最主要是因為運動過程中會因乳酸堆積、肌肉pH值下降，造成肌肉酵素活性降低，進而形成肌肉活動的疲勞現象(急性肌肉痠痛)，因此有些人會選擇按摩或利用冰、熱敷來緩解不舒服的情況，經由實驗結果證實，當恢復期採用全身性或局部性的垂直律動，可改善乳酸堆積及肌肉疲勞現象，並可將身體放鬆至最大化，加速運動後精神的恢復。

Acute effects of vibration exercise on the grip strength and physiological recovery from high-intensity intermittent grip exercise

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Abstract

Purpose: The purpose of this study was to investigate the physiological effects of the vibration exercise during the recovery phase after high-intensity intermittent grip exercise.

Methods: Twelve female colleges voluntarily participated in this repeated measured and randomly crossover experiment. After maximum voluntary intermittent grip test (5 × reps, 9 1-min rest interval), all subjects were asked to immediately place their forearms on the BodyGreen vibration platform to perform the non-vibration (5 min, 0 Hz, 0 mm) or low-frequency vibration (5 min, 12 Hz, ± 3 mm) treatments. Immediately after the treatments, each subject was requested to perform 1 set of maximum voluntary grip test (6th set) again to clarify the acute recovery effects of vibration. The blood lactate concentrations and ratings of perceived exertion (RPE) were measured throughout the experiment. The peak force, mean force and percent fatigue at each set of maximum voluntary grip test were also analyzed by grip dynamometer.

Results: There were no significant differences on the peak force, mean force and percent fatigue in the 6 sets of grip test between two treatments. However, the RPE (vibration vs. non-vibration, 13.6 ± 2.1 vs. 14.3 ± 2.1, $p < .05$) and lactate increase ratio (vibration vs. on-vibration, 125.8 ± 31.1 vs. 161.3 ± 46.0 %, $p < .05$) at the 6th set of grip test in the vibration treatment were significantly lower than those in the non-vibration treatment.

Conclusions: These results indicated that the direct, local and low frequency vibration exercise could not improve the grip performance immediately after the high-intensity intermittent grip exercise, however, could ameliorate the perception of fatigue and the metabolic stress.

Key words: direct vibration, lactate, low frequency vibration, mechanical massage

David Nadler博士的創新治療方法，可減輕不同年齡及生活方式的患者疼痛並提高其活動能力

Innovative treatment therapies from Dr. David Nadler reduce pain and improve mobility for patients of every age and lifestyle

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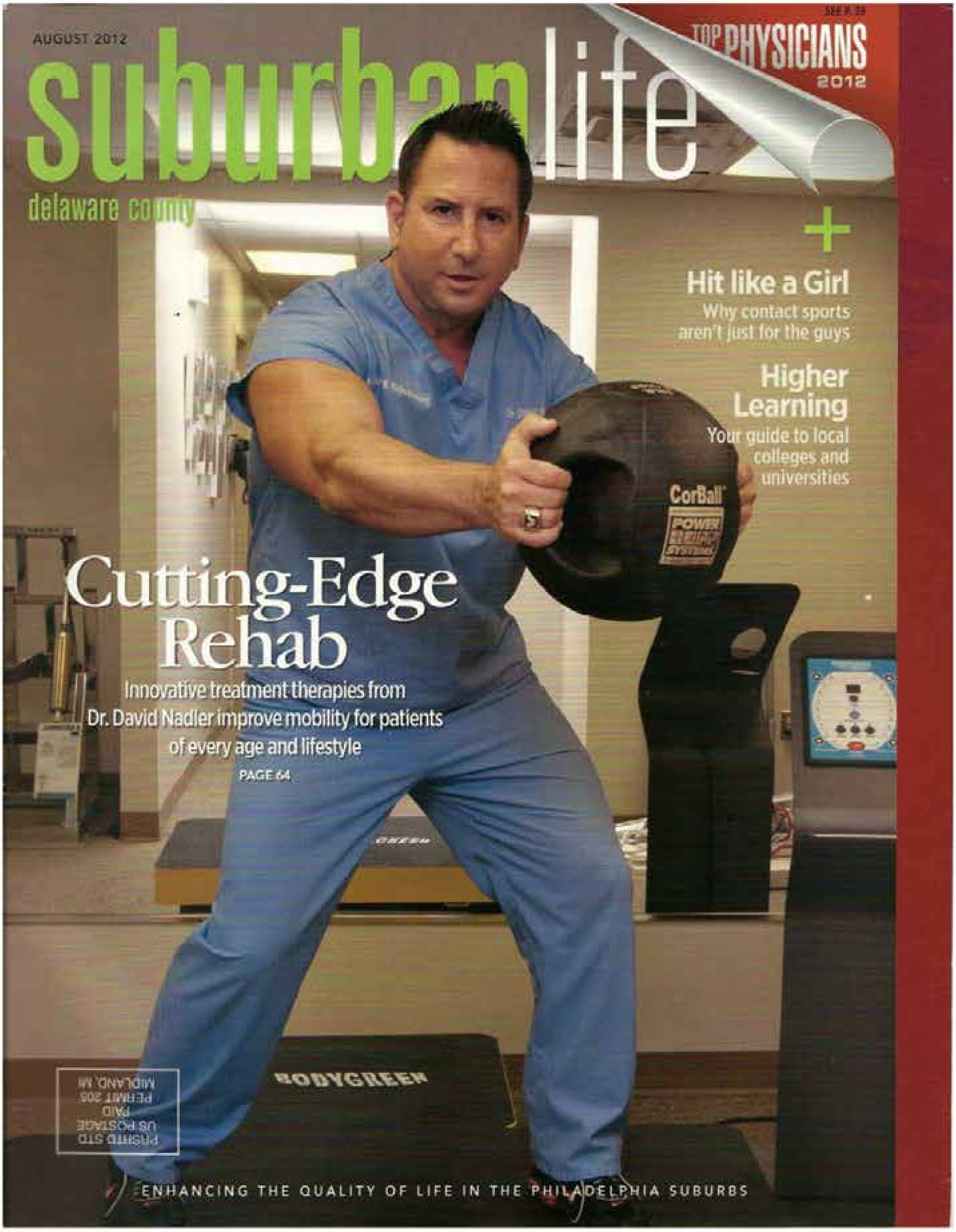
郊區生活雜誌–頂尖醫師篇，2012年8月

簡述內容：

一般人在日常生活當中可能多少會遇到一些拉傷、扭傷、撞傷等不同程度的運動傷害，而專業運動員受到運動傷害的機率更是大幅增加，但身為專業訓練運動員最害怕的正是運動所產生傷害與後遺症，有些嚴重者甚至終身無法再進行訓練與競技，而較輕微者也許能夠訓練，但可能會產生後續併發症效應。

本篇採用全身垂直律動的訓練，不僅可以為專業運動員帶來肌肉穩定度及運動表現，甚至可以在運動後採用全身垂直律動進行肌肉的釋壓與放鬆，可說是最佳的運動輔助工具，對運動前後的狀態帶來完整的平衡效果，而內容專訪醫師也提到，不僅可以運用在運動員，對於一般人也是很適合的治療模式。



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Cutting-Edge Rehab

Dr. David Nadler continues to seek new ways to help patients alleviate chronic pain and do the things they love at a high level. Here, he helps a patient using Linear Gravity Plate therapy.

Innovative treatment therapies from Dr. David Nadler reduce pain and improve mobility for patients of every age and lifestyle

BY BILL DONAHUE | PHOTOGRAPHY BY KAREN SHIMER

Dr. David W. Nadler has spent most of his 20-year career perfecting his talents in various areas of chiropractic care and sports medicine. Also, he has aggressively sought out new ways to help patients—from professional athletes in their prime to 90-year-old "weekend warriors"—with revolutionary treatments designed to not only alleviate chronic pain but also help patients continue to do the things they love at a high level.

"With any athlete, my goal is to get them back on the field as soon as possible—it's what any athlete wants," says Dr. Nadler, whose practice is based in Newtown Square. "I'm essentially creating a treatment plan and a treatment goal and helping them achieve that in the shortest period of time."

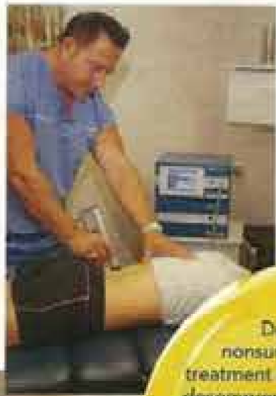
Dr. Nadler knows a thing or two about keeping athletes of all sorts at the top of their game. In his career he has treated professional athletes from many of the area's top sports teams, as well as competitors in national and international events, such as the X-Games, the FIFA Women's World Cup, and the Men's U.S. National Gold Cup soccer team. Locally his C.V. includes stints as chiropractic physician for National Lacrosse League's Philadelphia Wings; team chiropractic physician for the Philadelphia Barrage of Major League Lacrosse; team physician for the Major Indoor Soccer League's Philadelphia Kixx; and one of the team physicians for Arena Football's Philadelphia Soul.

Of course, his patients include people other than professional athletes. Even so, the goal is always the same: to get them back to an active, pain-free lifestyle.

"I have a 90-year-old patient who plays softball in an active softball league; he still hits and runs the bases," Dr. Nadler says. "Another patient is about the same age, and he is a competitive ballroom dancer who dances five days a week. When you're active, you keep the brain muscles intact as well as the muscles in the body, so there are multiple benefits of taking advantage of the therapies I offer here."

In addition to conventional chiropractic and sports-medicine treatments, new highly specialized treatments offered by Dr. Nadler—namely, Radial Shockwave Therapy, the Graston Technique, Game Ready, Spinal Decompression and Linear Gravity Plate Therapy—can alleviate pain and otherwise get patients back to feeling whole, if not even better than before.

Radial Shockwave Therapy: Known as extracorporeal radial shockwave therapy, this treatment uses a handheld device to transmit high-energy acoustic waves through the surface of the skin and into areas of the body that suffer from chronic pain. Each treatment, which can cause some slight but tolerable discomfort, increases the metabolic activity around the affected area to break up irritative scar tissue and calcific deposits. Afterward the surrounding area begins to heal with fresh tissue, thereby reducing the pain or even doing away with it entirely. Although most patients feel significant results after just a single treatment, Dr. Nadler recommends a five-treatment protocol to fully experience the therapy's benefits.



Dr. Nadler uses nonsurgical, noninvasive treatment such as vertebral axial decompression (right) to address herniated and degenerative disks, sciatica and other lower-back issues. With radial shockwave therapy (above), Dr. Nadler uses a handheld device to transmit high-energy acoustic waves into areas of the body that suffer from chronic pain.

"It's a much less invasive technique than surgery," says Dr. Nadler. "Essentially, the treatment is a controlled fashion of reinjuring the tissue, which then allows the body to regenerate newer, healthier tissue—and with a much faster outcome [than surgery]. The conditions that are most often treated vary, from lower-back syndromes, to frozen shoulders and tennis elbow and patellar tendinitis, to plantar fasciitis and other foot issues."

The Graston Technique: Through this unique soft-tissue mobilization, Dr. Nadler uses smooth stainless-steel instruments to effectively break down scar tissue and fascial restrictions. The instruments, which are shaped to treat different parts of the body, specifically detect and effectively treat soft-tissue areas exhibiting fibrosis or chronic inflammation that contribute to musculoskeletal pain—chronic tendonitis, strain/sprain complex, fasciitis issues, etc. He describes the treatment as "a little uncomfortable, but it's a nice way of breaking up the soft-tissue lesions and fibrotic tissue. I use it weekly in my practice, and I typically use it when other traditional therapies have failed."

Game Ready: Utilizing vasopneumatic compression therapy, Game Ready takes the RICE (rest, ice, compression, elevation) for edema management and turns it up a few notches. "For someone with a hot ankle that has really blown up, the Game Ready combines intermittent compression with circumferential cold therapy," he says. Described by some as "RICE meets NASA," Game Ready uses a flexible, form-fitting, spacesuit-technology wrap that can be applied to the ankle, shoulder, elbow, wrist or foot for a 20- to 25-minute session to significantly reduce swelling.

"Every pro sports team has one of these," Dr. Nadler says. "I call it an accelerated healing device because it's so effective in reducing swelling. With a patient who has a severe sprain of the ankle, I can get them back on the field within a week. The turnaround is a lot quicker as opposed to old-school thinking; with the RICE method, they could be out three weeks to a month, depending on the severity."

Vertebral Axial Decompression: Dr. Nadler uses a nonsurgical, noninvasive treatment known as vertebral axial decompression (VAX-D) to address patients' lower-back issues, such as herniated and degenerative disks, sciatica and failed-back syndrome. This device applies distractive force to the patient's back while harnessed to a table, and the lower half of table moves away from the midsection, creating pressure. Each treatment, which is "very gentle and not uncomfortable at all," says Dr. Nadler, generally lasts 30 minutes.

"It does a good job of opening up the intervertebral disk spaces, as there might be some herniation in there," he says. "It's an excellent tool to combat lower back pain, with a high success rate of about 80 percent. It can be utilized as a first line of defense or when other manual techniques have failed."

Linear Gravity Plate Therapy: This new-to-market treatment is so innovative that Dr. Nadler's is the only facility in the United States to offer it. Offering a form of linear whole-body vibration, the Linear Gravity Plate is a platform that creates mechanical repetitive movement through vibrations generated by a powerful motor. The device provides optimal stretch-reflex patterns, while working muscle fibers and stimulating mechanoreceptors. It can be used for sports rehabilitation and conditioning programs, though Dr. Nadler describes the applications as "near endless," to include osteoporosis management and resolving balance issues.

"You can take any athlete and have them mimic the activity they do—swinging a bat, taking a slapshot—and this recruits the exact muscles required to do that specific movement," he says. "The advantage is that, literally, there is so much stimulation and recruitment of muscle tissue that you can take an hour-long workout and cut it in half, because there are so many voluntary and involuntary muscles recruited to stabilize the body. ... With this machine, which is the only one like it in the U.S., I can adjust the increments of amplitude and frequency and tailor it toward a particular patient; there's nothing else like that on the market."

Dr. Nadler, who received his doctorate from Pennsylvania College of Chiropractic in Philadelphia, is a certified chiropractic sports physician from the American Board of Chiropractic Sports Physicians and is board certified from the National Board of Chiropractic Examiners. Also, he has been granted diplomate status through the American Academy of Pain Management.

"With a lot of these therapies," he adds, "I want to offer the best modalities I can to my patients, and a lot of these therapies you can't find in a traditional setting. I still have ultrasound, electrical stimulation and other physical-therapy modalities, but what's really unique about my practice, and what makes it stand apart from most others, is that I can offer treatment for everyone from a weekend warrior to a pro athlete. These therapies can help toward a pain-free lifestyle and, in some cases, and much more active, more fulfilling one." ▪

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