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Leg-Raise Exercise Is Effective for Maintaining Bone Mineral Content and Density in the Lumbar Spine of Young Women

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Abstract

Background: Exercises performed at home and not requiring a change of clothes or special equipment are easy to start and can be continued long-term. To prevent COVID-19 infection, people worldwide have refrained from leaving their homes unnecessarily since the beginning of 2020. Fewer opportunities for outdoor exercise and less time spent in the sunlight can have serious negative effects on the bones.
Objectives: The aim of this study was to clarify the effect of low-repetition leg-raise training on the dual-energy X-ray absorptiometry measured bone mineral content (BMC) and density (BMD) of the lumbar spine.
Methods: Eighteen healthy female university students performed leg-raise training at home, ten repetitions per day, three days per week, for six months. BMC and BMD (g/cm^2) of the right proximal femur and lumbar spine (L2–L4, anteroposterior view) were measured with dual-energy X-ray absorptiometry.
Results: This low-repetition, low-frequency leg-raise training significantly increased lumbar spine BMC and BMD in these young women. However, there was no significant effect of exercise on the BMC or BMD at any proximal femur site.
Conclusions: Home-based body weight leg-raise training may have effective mechanical stress to maintain or increase BMC and BMD of the lumbar spine.

Keywords: Resistance Training, Site-Specific Effects on Bone, Home-Based Exercise, Dual-Energy X-ray Absorptiometry (DXA)

1. Background

Several randomized experimental trials have reported that high-impact training with a relatively short duration of exercise per session and with relatively few repetitions locally increases bone mineral density (BMD) (1, 2). Resistance training significantly increases muscle hypertrophy and muscle strength, and the optimal resistance training intensity, number of repetitions, and frequency per week have been reviewed in detail (3). However, details about the intensity, number of repetitions, and frequency of resistance training necessary to maintain or enhance bone mineral content (BMC) and BMD have not been entirely clarified.

To prevent COVID-19 infection, people worldwide have refrained from leaving their homes unnecessarily since the beginning of 2020. Fewer opportunities for outdoor exercise and less time spent in the sunlight can have serious negative effects on the bones (4). Exercise that can be done quickly and easily in the comfort of home without the need to change clothes will last longer.

2. Objectives

The aim of this study was to investigate the possibility of maintaining and improving BMC and BMD in the lumbar spine, a frequent fracture site, with low-repetition, low-frequency leg-raise exercises performed at home and not requiring a change of clothes or special equipment.

3. Methods

3.1. Participants

The participants were women over 20 years of age (20.6 ± 0.6 years., the average height of 157.4 ± 3.7 cm) who were university students with experience in completing dietary surveys that required weighing food. The 18 participants in this study were non-smokers who had regular menstrual cycles, did not take medications, did not have regular exercise habits (including high-impact exercise), and did not have disorders involving the back and hip joints. All participants signed informed consent forms that described the study's objectives, all experimental protocols, and the management and security of personal information. This study was approved by the Suzuka University of Medical Science Ethics Committee (Approval No. 200501).

3.2. Bone Measurement

The BMC and aBMD (g/cm^2) of the right proximal femur and lumbar spine (L2–L4, anteroposterior view) were measured with dual-energy X-ray absorptiometry (DXA) (DCS-3000; ALOKA, Tokyo, Japan). The participants were in a supine position on the DXA machine. In accordance with the manual of the DXA measurement machine, the femoral neck, Ward's triangle, greater trochanter, total proximal femur, and lumbar spine were analyzed. The DXA measurements before and after the training period were measured by one nationally registered radiologist. The coefficient of variation of the DXA machine is 1.0% (5).

3.3. Calcium Intake and Calcium Supplements & Statistical Analyses

The participants completed a three-day dietary record with the food-weighing method before and at the end of the training period. The diet records were conducted on a total of 3 days: 2 weekdays and one weekend day. The diets were analyzed with software (Eiyokun Ver. 3.0; Kenpakusha, Japan) that is based on a standard food database. SPSS software version 25 (IBM, USA) was used for all analyses. Statistically significant differences in weight, calcium intake, BMC, and BMD at pre-training versus post-training were evaluated with paired Student's *t*-tests. The statistical significance was set at 0.05, and a two-sided test was used.

3.4. Leg-Raise Training

The leg-raise training began with the participant in a supine position with the knees bent to approximately 90 degrees. Over a three-second count, the participant raised both legs vertically from the initial position while extending the knees so that the heels ended directly over the hips. Participants rested for 5 seconds with the legs in this vertical position and then returned to the original position over a three-second count. Each participant performed 10 repetitions of the leg-raise exercise at home, three times per week, for 6 months. In addition, each participant received an explanation of the leg-raise training and practical coaching during the pre-training period. The leg-raise training is easy to perform at home because it does not require changing clothes or special equipment.

4. Results and Discussion

The body weight of participants decreased from pre-training to post-training; however, the difference was not significant (50.3 ± 6.1 vs. 49.4 ± 5.7 kg, P = 0.053). The pre-training calcium intake estimated from diet records that used the food-weighing method was 439.5 ± 168.0 mg, which is well below the recommended Japanese National Dietary Reference Intake of 650 mg/day. A 300 mg oral calcium supplement increased the calcium intake to 720.6 ± 179.5 mg/day. The training rate during the six months was 82%, which means participants did leg-raise training 2.5 times per week on average throughout the period.

Six months of leg-raise training was associated with a significant increase in lumbar spine BMC and BMD in young women. Training had no significant effect on BMC or BMD at any proximal femoral site. The rectus abdominis and the underlying psoas major muscles are the agonist muscles during the leg-raise movement. The psoas major muscle directly connects the trunk and the lower extremities, with its origin in the lumbar spine and its insertion on the lesser trochanter. The leg-raise training applied a load at the lumbar spine that was beyond the mechanical stress experienced during daily life and was sufficient to increase BMC and BMD. High-load resistance training would be beneficial for increasing BMD, mainly in the lumbar spine (6, 7).

Compared with exercises such as jumping from a standing position, which effectively increases BMC and BMD (1, 8) at both the femoral neck and lumbar spine, lifting both legs from a supine position does not produce sufficient stress on the femoral neck region to increase BMC or BMD. During exercises performed in a standing position, the weight of the trunk, upper limbs, and head, as well as ground reaction force (GRF), are always applied as load in the femoral neck region. Even if the mechanical stress is not as great as a high-impact load, but is above a threshold, the stress, even at relatively low loads, will locally strengthen the target bones. The load stimulus produced by the pole push-off movement during six months of Nordic walking increased BMD in the stressed forearm by 3.4% (9).

Axler and McGill (10) calculated the moments applied to the fourth and fifth lumbar joints during abdominal exercises, including leg raises, using a mathematical link segment model and biologically based modeling techniques. According to their calculations, the momentum applied to the fourth and fifth lumbar joints during leg raises with bent knees was 1800 N; this value was 2500 N during leg raises with the lower legs extended.

GRFs of 2.5 $\times$ BW and 4.76 $\times$ BW (during take-off and landing, respectively) in young adults (8, 9) are sufficient to stimulate bone (1). High-impact exercise has a systematic, positive effect on the loaded axial and appendicular bones, indicating that high-impact GRF exercise programs, such as jumping, are specifically effective as site stimuli, not only for the lumbar spine but also for the femoral neck region.

Our study has some limitations, the duration was six months, and the sample size was selected to detect a change of less than 3 % in BMD, so any smaller magnitude or slower onset benefit of less frequent exercise may not have been detected in this study. Further research is thus needed to compare optimal frequencies of exercise over a longer duration. The major strength of this study is the use of a similar unilateral study design, a comparison of different measurement sites within the same participant, which reduces the likelihood that findings have been influenced by confounding factors such as changes in diet or habitual activity. High-impact jump training is effective for increasing BMC and BMD on both the lumbar spine and proximal femur in healthy young women. However, it would also be suggested that even the weight-bearing leg-raise training is effective for keeping the lumbar spine BMC and BMD, with sufficient diet and habitual activities.

In summary, the mechanical stress on the bone was site-specific, and the leg-raise training had an effect on the targeted lumbar spine but not on the proximal femur, confirming that the training only affected the area where the mechanical stress was applied.

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Footnotes

Authors' Contribution: Study concept and design, acquisition of data, T.K., Analysis and interpretation of data, K.K., K.S., T.Y., Y.U. and T.K., Critical revision of the manuscript, Y.U., Statistical analysis, K.K, K.S. and T.K., Study supervision, Y.U.

Clinical Trial Registration Code: Receipt number: R000054635. UMIN ID: UMIN000047928.

Conflict of Interests: Nothing to declare.

Data Reproducibility: The dataset presented in the study is available on request from the corresponding author during submission or after its publication. The data are not publicly available due to it contains personal information, including height, weight, age, and other personally identifiable information, including medical history and menstrual cycles. All data are presented as averages because when informed consent was taken, it was clearly stated that personal data would not be released under any circumstances.

Ethical Approval: Suzuka University of Medical Science Ethics Committee Approval No. 200501.

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Informed Consent: All participants signed informed consent forms that described the study's objectives.

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