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Effect of Vibration Intervention on Leg-press Exercise

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Abstract**—**Many studies have emphasized the importance of resistive exercise to maintain a healthy human body, particular in prevention of weakening of physical strength. Recently, some studies advocated that an application of vibration as a supplementary means in a regular training was effective in encouraging physical strength. Aim of the current study was, therefore, to identify if an application of vibration in a resistive exercise was effective in encouraging physical strength as that in a regular training. A 3-dimensional virtual lower extremity model for a healthy male and virtual leg-press model were generated and synchronized. Dynamic leg-press exercises on a slide machine with/without extra load and on a footboard with vibration as well as on a slide machine with extra load were analyzed. The results of the current indicated that the application of the vibration on the dynamic leg-press exercise might be not greatly effective in encouraging physical strength, compared with the dynamic leg press exercise with extra load. It was, however, thought that the application of the vibration might be helpful to elderly individuals because the reduced maximum muscle strength appeared by the effect of the vibration may avoid a muscular spasm, which can be driven from a high muscle strength sometimes produced during the leg-press exercise with extra load.

Keywords**—**Resistive exercise, leg-press exercise, muscle strength.

I. Introduction

THE beneficial effects of resistive exercise on physical and mental health are well known [1]-[4]. Recently, many studies have emphasized the importance of resistive exercise to maintain a healthy human body, particular in prevention of weakening of physical strength [5]. Fortunately, it has been proven that resistance training programs can alleviate deterioration of the muscular system. Reference [6] researched to determine the efficacy of resistance, functional, or functional plus resistance training and concluded the benefits of exercise are dependent on tasks performed during training. Reference [7] examined the dose-dependent effect of resistance training on balance performance and reported that resistance training improves balance in healthy because resistance training improves balance, particularly using a low load, high velocity regimen with initial lower muscle strength and slower contraction. And, reference [8] investigated about the positive and negative effects of a progressive resistance strengthening program and informed that progressive resistance strength training was a feasible fitness option for some people with multiple sclerosis.

However, increase in training load increase the odds of injury [9]. And, fatigue resulting from overtraining was likely to have a negative impact on the performance. Another method for muscle strengthening that recently has been used on healthy persons is vibration training. It is practiced on a vibrating platform where the person is standing in a static position or moving in dynamic movements. And, studies have shown that sound effect on exercise merged with whole or local body vibration. Reference [10] examined the effects of whole body vibration training and showed that whole body vibration training was an effective short-term training methodology for inducing improvements in knee-extensor explosiveness. More marked effect on muscle strength after vibration training was shown when the training intensity was progressive [10]-[11]. These studies demonstrated the beneficial effect of vibration training on muscle strength. And, if vibration training has a similar effect as resistive training it could be an alternative training method. However, positive effects on muscle performance were recorded in some but not all studies. Reference [12] concluded vertical vibration-stimulus did not induce changes in the performance and balance tests.

Most of these studies demonstrated the beneficial effect of vibration training on muscle strength after vibration training performed by resistance training. On the other hand, these methods are not suitable to evaluate the effects of vibration exercise synchronized with resistive exercise. For the quantitative evaluation of vibration exercise on muscular-skeletal system, the current study investigated an

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application of vibration simultaneous with resistive exercise by using 3-dimensional multi-body dynamic analysis. A representative motion of resistive exercise movements with squat equipment was chosen and analyzed.

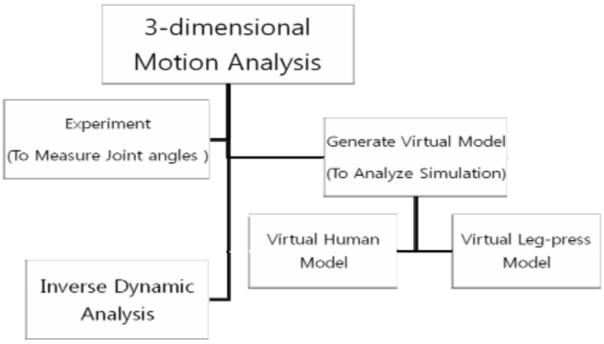

Fig. 1 Process flow chart to 3-dimensional motion analysis

II. 3-Dimensional Motion Analysis

A. Procedures to 3-Dimensional Motion Analysis

The muscle characteristics of a squat motion were evaluated 1) by measuring the range of motion on an experiment, 2) 3-dimensional lower extremity muscular skeletal virtual model was generated and 3) changes of dominant muscle strengths were analyzed during the squat motion (Fig. 1).

B. Measuring the Range of Motion

The training program performed a lower-extremity-training program consisting of unloaded (0 kg), loaded (70 kg) dynamic exercise and loaded (70 kg) exercise with vibration (amplitude: 10 mm displacement, frequency: 20 Hz). A healthy male subject (21-yeal-old, 177.8 cm, and 77 kg) completed lower extremity exercises that included high squat motion (knee angle between 0° and 120°). The hip, knee, and ankle angle was measured on sagittal plane during the lower extremity exercises (Fig. 2).

C. Virtual Human Model

A 3-dimensional virtual lower extremity model for a healthy male (21-yeal-old, 177.8 cm, and 77 kg) was generated by using BRG.LifeMOD (Biomechanics Research Group, Inc., USA)(Fig. 3). The lower extremity model consisted of 4 bones (lower torso, femur, fibula, and foot), 3 joints (hip, knee, and ankle) and 12 muscles (gluteus maximus, gluteus medius, iliac, rectus femoris, biceps femors, vastus medialis, vastus lateralis, adductor magnus, semitendinosus, tibialis anterior, gatrocnemius, and soleus muslce).

D. Virtual Leg-press Model

A simple virtual leg-press model for a commercial product (POWER GYM, Korea) by using MSC.ADAMS (MSC Software Corp., USA) was generated and synchronized with the virtual lower extremity model. Constraints for contact area between the virtual human and leg-press model were created.

E. Inverse Dynamic Analysis

Dynamic leg-press exercise on a slide machine with/without 70 kg extra load and on a footboard with vibration as well as on a slide machine with 70 kg extra load were analyzed according to the experimental data (hip, knee, and ankle angle) by using 3-dimensional multi-body dynamic software, MSC.ADAMS. Rectus femoris, vatus lateralis and vastus medialis as dominant muscles of interest in leg-press exercises were chosen and presented on result.

III. Result

The current study defined 12 muscles on lower extremity to analyze the lower-extremity-training program. Normally, rectus femoris, vastus lateralis, and vastus medialis generated high muscle strengths among the muscle strengths from all defined lower extremity exercises (Fig. 4). The results

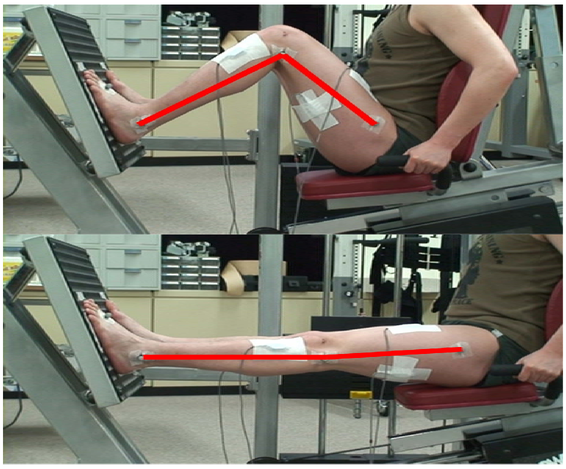

Fig. 2 A range of motion to perform a leg-press exercise

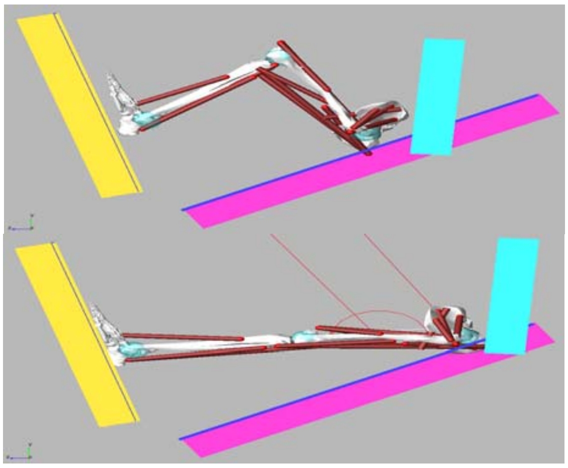

Fig. 3 A synchronized 3-dimensional virtual human lower-extremity and leg-press model

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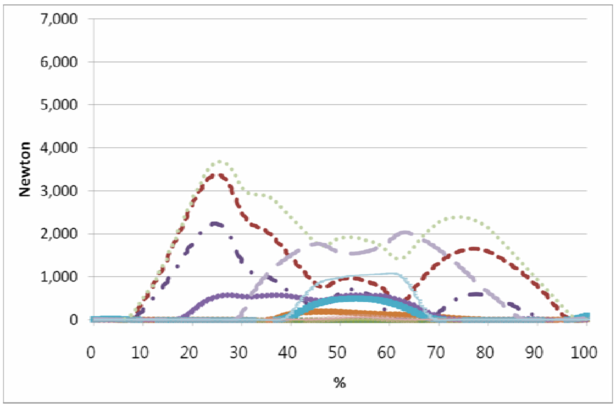
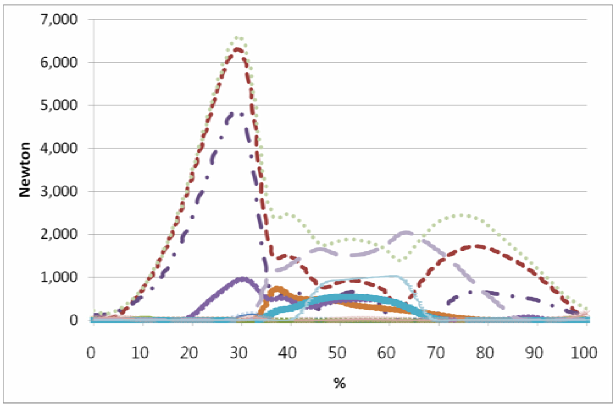
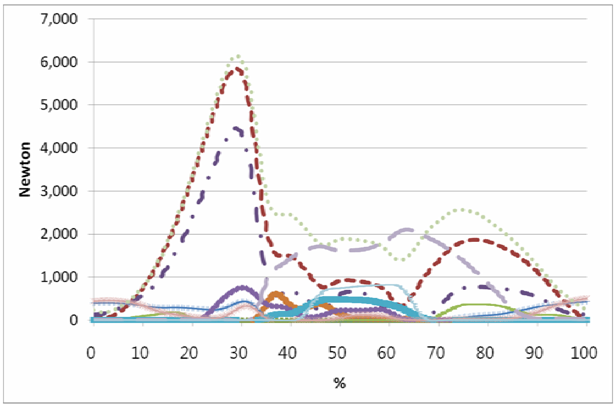


(a) Muscle strengths generated by the exercise without extra load



(b) Muscle strengths generated by the exercise with extra load



(c) Muscle strengths generated by the exercise with extra load and vibration

Fig. 4 Muscle strengths for lower-extremity muscles generated by (a) the exercise without extra load, (b) the exercise with extra load, and (c) the exercise with extra load and vibration

presented a cycle of leg-press exercise that start of the knee extension (0%), maximum knee extension (50%), and the back to the start position (100%). Normally, high muscle strengths were generated at a slide machine began to move (25%) and stopped to move.

TABLE I
MAXIMUM MUSCLE STRENGTHS FOR MAIN LOWER EXTREMITY MUSCLES GENERATED BY THE EXERCISES DEFINED IN THE CURRENT STUDY (UNIT: N)

	Maximum muscle strength		
	Rectus Femoris	Vastus Lateralis	Vastus Medialis
Without Extra Load	3381.84	3685.22	2243.78
With Extra Load	6306.30	6601.21	4910.29
With Extra Load and Vibration	5858.93	6144.60	4466.77

The results showed remarkable enhancement in both the exercise with extra load and the exercise with extra load and vibration. And, vastus lateralis exercising with extra load generated the highest muscle strength. Muscle strengths from an exercise with extra load presented more increase muscle strengths than from the exercise without extra load and the exercise with extra load and vibration. The muscle strengths of the exercise with extra load and vibration, as unexpected, couldn't show increase over the muscle strengths of the exercise with extra load in any of the lower extremity muscles.

IV. DISCUSSIONS AND CONCLUSIONS

Generally, age-related decline in muscle strength might be an early indicator of balance deficits and fall risk, even in non-frail adults [7]. In addition, lower extremity muscle weakness as well as balance impairment was major independent intrinsic contributors to falls [13]. One factor that could explain the impaired walking ability characterized by flexion in the knees and hips is weakness of the quadriceps muscles [14]. Therefore, the primary goal of providing a training stimulus that maximizes performance potential and minimizes the negative consequences of training.

This is the first and pilot study to investigate the effects of vibration training on muscle strength during dynamic training. Our study was unsuccessful to show an important benefit of any of the vibration training program on most aspects of muscle strength. The results indicated that the application of the vibration on the dynamic leg-press exercise might be not greatly effective in encouraging physical strength, compared with the dynamic leg-press exercise with extra load. It was possible that this analysis was not challenging enough to detect effects of training. It was, however, thought that the application of the vibration might be helpful to elderly individuals. Increase in training load, particularly during the pre-season training phase, increase the odds of injury [10]. And, reductions in training load during the early competition training phase could reduce the odds of injury without compromising agility performances. Thus, the reduced maximum muscle strength appeared by the effect of the vibration might avoid a muscular spasm, which can be driven from a high muscle strength sometimes produced during the leg-press exercise with extra load. Moreover, the exercise with extra load and vibration could induce the same stimulus of the resistive exercise with extra load then the reduced risk of the injury.

Vibration training is a safe and efficient strength training method. The results of this study indicated that vibration training had great potential for application. Further research is needed to investigate the influence of vibration training on various groups of subjects and diverse conditions of vibration.

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