EFFECTS OF THE EXTERNAL MUSCLE SYSTEM ON THE FUNCTION OF HAMSTRINGS

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The purpose of this study was to develop a device which can simulate the function of the hamstrings and increase these muscles' strength. By wearing it during daily training, one can train the hamstrings according to the specific needs of each sport event. Fifteen subjects were involved in the study and the external muscle system was examined by using EMG and kinetics methods. The results showed that there was an increasing trend in jumping performance and muscle co-contraction ($p<0.1$) during running; There were significant differences ($p<0.05$): in the first peak force between high loading and none and in the second peak force between low, medium, high loading and none. Thus we believe the system can be used in training sessions. By wearing the system during training, athletes can train muscles when performing movements unique to sport events.

KEY WORDS: ground reaction forces, EMG, co-activation, treadmill, training method.

INTRODUCTION: The hamstrings are typical double-joint muscles which are crucial in many sports such as sprint running, jumping and cutting. Many researchers have proved that the hamstrings play an important role at the end of swing phase and at the beginning of the touchdown phase during sprint running (Wiemann, 1990; Liu, 1993; Hunter, Marshall & McNair, 2004). Among high-speed sports, there is a high injury occurrence and recurrence of injury of the hamstrings (Worrell, 1994; Garrett, 1996; Thelen, Chumanov, Best, Swanson & Heiderscheit, 2005; Bryan Dixon, 2009). Therefore, a training method for the hamstrings has been introduced and developed.
Several studies have been conducted to examine the effectiveness of modern strength training methods for the hamstrings and some methods have been proved to strengthen and protect the hamstrings (Askling, Karlsson & Thorstensson, 2003; Clark, Bryant, Culqan, & Hartley, 2005). However, existing methods are too general to apply in specific sports training. The purpose of this study was to develop a device which can simulate the function of hamstrings and increase their strength. By wearing it during daily training sessions, one can train the hamstrings according to the specific needs of each sport event and protect the muscles from injury throughout the training session.

METHODS: The subjects were fifteen healthy male students (age 19.9 ±1.5 years; height 178.6 ±5.3 cms; mass 68.8 ±7.1 kg) who volunteered to participate in the study. All subjects had no injury within the previous six months.
A Gaitway Ⅱ dynamometer treadmill system (2813M01-A20, sampling frequency 250Hz) and an EMG system (Biovision, sampling frequency 1200Hz, amplification factor 1000) were used in this study to get these datas at the same time. The external muscle system included two kneecaps, one waist belt and some elastics ropes: one end of the elastic rope should be fixed to the waist belt, which is at the semitendinosus' origin; another two ends of the elastic rope should be fixed to the bottom of kneecap, which is at semitendinosus' insertion point (Figure 1).
All subjects ran on a treadmill at a speed of 16km/hr. Subjects performed the CMJ and running with and without the external muscle system. The elastic loadings of this system were low, medium and high. Tested variables included counter movement jump height (CMJ), vertical ground reaction forces (get the first peak force at touch down and the second peak force during push off) and co-activation of the semitendinosus and the rectus femoris during running.
We used independent sample t-tests in SPSS13.0 to analyze the above data (significance level: $p<0.05$).

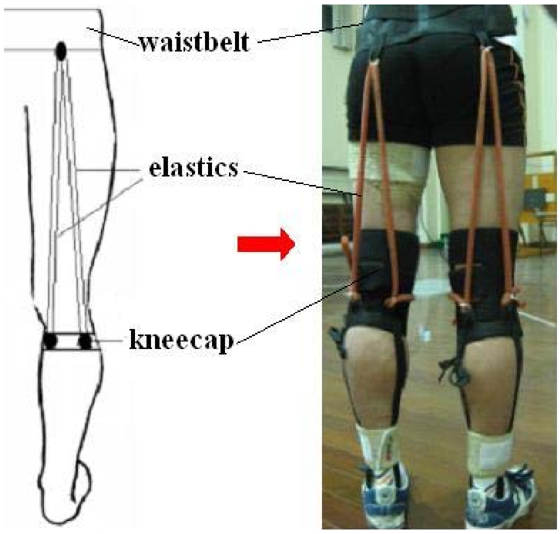

Figure 1: The demonstration of external muscle system.

This study analyzed the co-activation of hamstrings and the rectus femoris with different elastic loadings during stance phase, the computational formula is shown as following, antagonistic muscle was hamstrings, agonistic muscle was the rectus femoris:

$$Co - activation = \frac{IEMG_{\text{antagonistic muscle}}}{IEMG_{\text{agonistic muscle}}}$$ (Kubo, Kawakami & Fukunaga, 1999)

RESULTS: Jump height increased (Figure 2) when the elastic loads increased from none to low as well as from low to medium, then decreased when the elastic loads increased from medium to high.

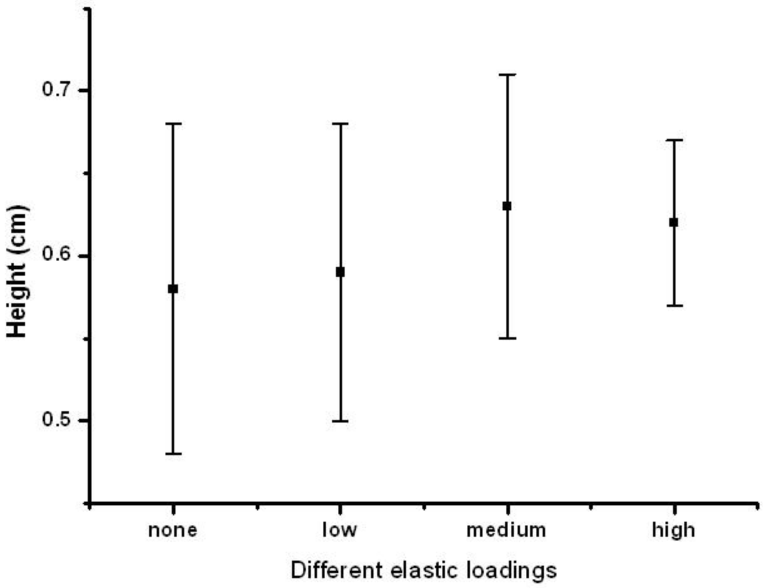

Figure 2: Changes in CMJ height with different elastic loading intensities (no significant difference, P<0.1).

The results indicated that the first peak force and the second peak force of the ground reaction forces increased as the elastic loading intensity of the external muscle system increased (Table 1).

Table 1: The results of GRF with different elastic loading intensities (BW).

	None	Low	Medium	High
The first peak force	2.61±0.29	2.72±0.23	2.78±0.15	2.87±0.20*
The second peak force	2.43±0.38	2.68±0.26*	2.73±0.24*	2.79±0.26*

1) in the first peak force,*P<0.05, between high loading and none; 2) in the second peak force, *P<0.05, between low, medium, high loading and none.

The study analyzed the co-activation of the semitendinosus and the rectus femoris under different elastic loading intensities during the stance phase. Results showed that the co-activation increased as the elastic loading intensity changed from none to low and from low to medium, then decreased as the intensity changed from medium to high (Figure 3).

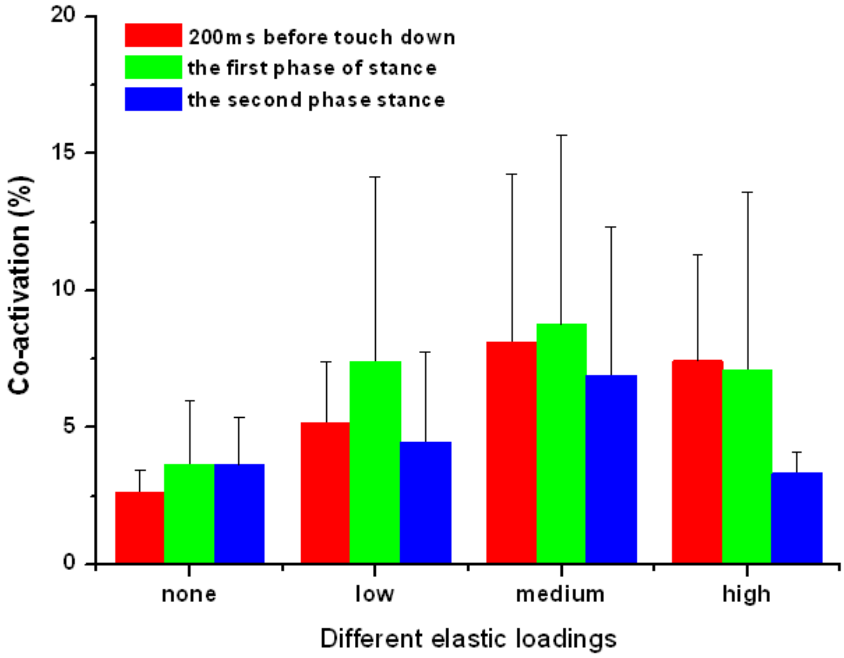

Figure 3: Co-activation of the semitendinosus and the rectus femoris with different elastic loadings (no significant difference, P<0.1).

DISCUSSION: The results can conditionally verify the effects of the external muscle system, which can be summarized in two aspects; muscle strength enhancement and muscle coactiviation.

Muscle strength enhancement: From no elastic loading to medium intensity loading, CMJ height increased as the elastic loading intensity increased. Theoretically, the hamstrings have to resist the external force as the loading is burdened, so more potential energy can be stored at the CMJ squat phase. Thus more work is done at the toe-off phase. In other words, the combination of posterior thigh muscles and the external muscle system helps subjects to store more energy and to jump higher.

Another theory which can explain the force enhancement function of the external muscle system is the “Lombard’s Paradox” (Lombard & Abbott, 1907). Wiemann’s musculoskeletal model clearly interpreted the “Paradox” and showed that the posterior thigh muscles can extend the knee with the help of the quadriceps (Wiemann et al. 1990). Thus, when the hamstrings are loaded with the external muscle system, the increasing strength can induce larger knee extension force and can further lead to subjects’ higher jumping height. It can also explain the kinetics results in our study that the second peak force of the GRF increased as the external loading increased. Because the external system can induce the knee extension and let subjects to create larger push ground force.

Muscle co-activation and injury prevention: Co-activation of the antagonistic muscles can lead to the antagonistic muscles co-contraction (Izquierdo, Aguado, Gonzalez, Lopez & Hakkinen, 1999) which can further increase joint stiffness. According to the results in our

study, it can be included that during low to medium intensity elastic loading, the external muscle system can increase joint stiffness and thus increase joint stability. However, further research is needed to examine the effect of the external muscle system on injury prevention, because it is only under certain range of stiffness, can ankle stability be improved (Baratta, Solomonow, Zhou, Letson, Chuinard & D'Ambrosia, 1988).
No similar device has been introduced or tested in previous study. However, literatures have widely demonstrated the effectiveness of strength training. As the strength training was mostly asked to be done before or after training session, the external muscle system is a device which can be used during the training session. To understand its long-term effect, further research is warranted.

CONCLUSION: The external muscle system with low and medium intensity elastic loading can increase jumping height (no significant difference), co-activation (no significant difference) and the vertical ground reaction forces ($P<0.05$). This device can be used by both athletes and patients (to increase their muscle strength so as to achieve better performance or to help themselves recover). whatever the users are, the main point is to select the proper loading and training time specifically to each individual. The loading should be determined by the kind of training the users needed. And the traning time should be determined with regard to the principles of motor learning, such as the time a person needed to cause neural re-programme through training. In future studies, researchers should focus on these two aspects.

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