RELATIONSHIP BETWEEN MUSCULAR OUTPUTS AND THE HORIZONTAL PERTURBATION IN THE EARLY PHASE OF BENCH PRESS MOVEMENT UNDER STABLE AND UNSTABLE CONDITIONS

Sentaro Koshida[1], Koji Miyashita[2], Kazunori Iwai[3], Aya Kagimori [4] and Yukio Urabe[5]

Faculty of Health Sciences, Ryotokuji University, Urayasu, Japan[1]
Research Institute of Life and Sciences, Chubu University, Kasugai, Japan[2]
Hiroshima National College of Maritime Technology, Hiroshima, Japan[3]
Ryukoku University Training Centre, Fushimi, Japan[4]
Graduate School of Health Sciences, Hiroshima University, Hiroshima, Japan[5]

We demonstrated the relationship between the change rates of muscular outputs and horizontal perturbation under stable and unstable conditions in dynamic bench press movement. Twenty-seven male collegiate athletes attended the study. We used a tri-axis accelerometer attached to the barbell shaft to obtain the acceleration data in the bench press and computed peak force output, rate of force development (RFD), and horizontal acceleration trajectory length for 0.2 seconds after the initiation. Significant reduction was found in the peak force output and RFD under stable and unstable conditions, but not in the horizontal acceleration trajectory length. Significant correlation was found between the change rate of RFD and the horizontal acceleration trajectory length under stable and unstable conditions (*r=0.55, P<0.01*).

KEY WORDS: instability resistance training, coordination, accelerometer

INTRODUCTION: It has been suggested that resistance training exercise under unstable conditions (also known as instability resistance training) may improve trunk stability. However, its benefit on athletic performance improvement remains a matter of debate because of significant loss of muscular outputs under unstable conditions. (Behm et al, 2002; Anderson et al, 2004; Koshida et al, 2008).

Previous literature indicates that the loss of muscular outputs under unstable conditions is attributed to altered neuromuscular coordination during the movement. Anderson et al (2004) reported that the force output in chest press movement was significantly decreased, but EMG activity of the prime movers was maintained. The authors explained that the unchanged EMG activity may be due to greater postural and stabilization roles in the prime movers. Konecki et al (2001) also reported that the motor contribution of the wrist muscles was decreased when the external object became unstable in the push movement. The result suggested that greater joint stabilization requirement may affect the muscular outputs in dynamic movements. Based on those previous findings, we anticipated that the degree of perturbation in the other planes which are not engaged in a desired movement may be related to the loss of muscular outputs during instability resistance training exercise. However, to our best knowledge, how the perturbation is related to loss of muscular outputs under unstable conditions is little quantified. Therefore, the purpose of the present study was to demonstrate how the change of muscular outputs correlates with the change of horizontal perturbation in the dynamic movement by using a tri-axis accelerometer.

METHODS: Data Collection: Twenty-seven male collegiate athletes (age, 21.5 ± 1.9 years; height, 171.2 ± 4.6 cm; weight, 79.0 ± 12.8 kg) volunteered to participate in the study. All the participants had experienced moderate to extensive resistance training for at least 12 months. The participants executed 3 sets of single bench press movements as quickly as possible under stable and unstable conditions. Previous studies have reported that the maximal power output in bench press movement was observed when using the weight of 45% to 55% of 1 repetition maximum (1RM)(Mayhew et al, 1997). Therefore, we used a weight of 50%1RM for the test. We used a tri-axis accelerometer (Microstone Co., Saku, Japan) attached to the center of the barbell shaft to obtain the acceleration data in the bench press movement (200Hz). A flat bench provided the stable condition. The participant's feet were placed on the flat bench to minimize the influence of lower extremity on postural control. The experimental setting of the unstable condition is shown in Figure 1. Two inflatable rubber discs were placed underneath the upper thoracic and buttock areas provided the unstable condition.

Data Analysis:
We calculated peak force output (N) based on Newton's second law. Rate of force development (RFD; N/s) was computed by the equation below:

RFD (N/s)
= {Peak force output(N) – [g ×Barbell weight(N)]} / TTP(s)
Where: *g:* gravitational acceleration, TTP: time to peak force from the onset of movement

Moreover, the acceleration trajectory length on the horizontal plane assuming the representative variables of horizontal perturbation was calculated for 0.2 seconds after initiating the movement (Figure 2). The greater the horizontal acceleration trajectory length becomes, the greater perturbation is assumed.
The change rates of these variables (%) under the two conditions were also computed by the equation below:

Change rate (%)
= [(The value in the unstable condition- the value in the stable condition)
/ the value in the stable condition] ×100

We used a paired t test with Bonferroni correction to compare the muscular outputs between the two conditions. In addition, we had a Pearson coefficient analysis performed to demonstrate the relationships of the differences in the outputs and horizontal acceleration between the two conditions. Statistical significance was set as $P<0.05$ in this study.

RESULTS: The mean value (±SD) of 1 RM was 85.0±13.4kg; therefore, the participants used the average weight of 42.5 ±6.7kg in the experiment. The mean values of maximum force outputs in the bench press under stable and unstable conditions were 565.1±104.6N and 559.9±148.0N respectively (Figure 3A). The mean values of RFD were 1323.5±605.1N/s under the stable condition and 1038.0±434.2N/s under the unstable condition. Maximum force output and RFD under the stable condition were significantly greater than those under the unstable condition. However, the horizontal acceleration trajectory lengths were not significantly different between the stable and the unstable conditions.

There is significant correlation between the change rate of RFD and that of horizontal acceleration ($r=0.55$, $P<0.01$)(Figure 4) ; however, no significant correlation was found between the change rate of peak force output and that of the horizontal acceleration trajectory length.

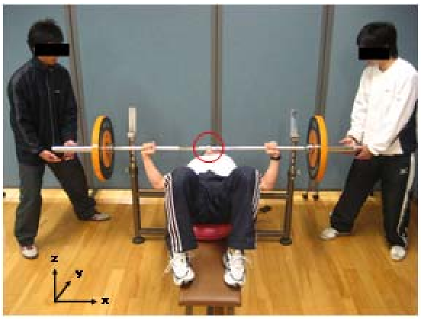

Figure1. The experimental setting of the unstable condition: A red circle represents the position of the accelerometer. Three arrows represent the xyz coordinate in the study

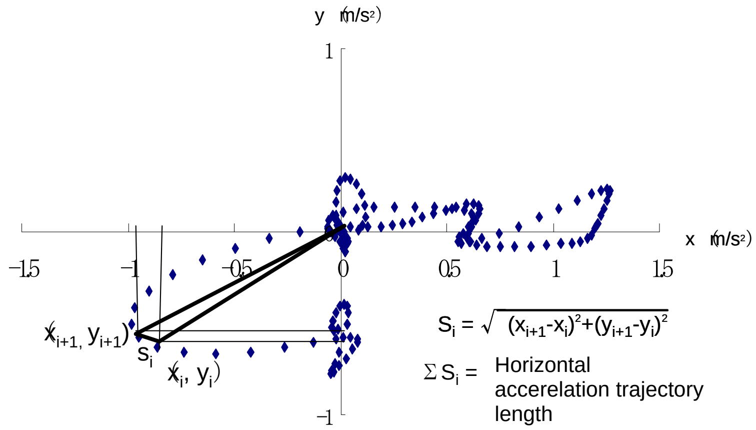

Figure2. Calculation method of horizontal acceleration trajectory length

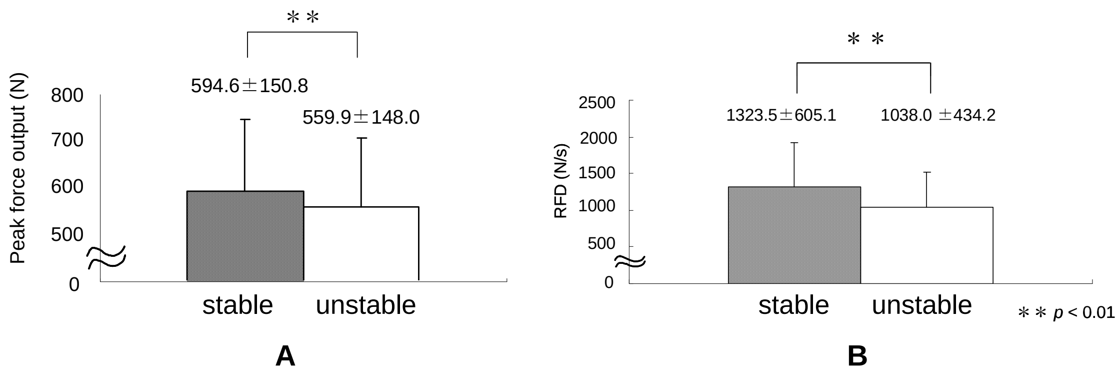

Figure 3. The comparisons of (A) peak force output and (B) RFD between the two conditions

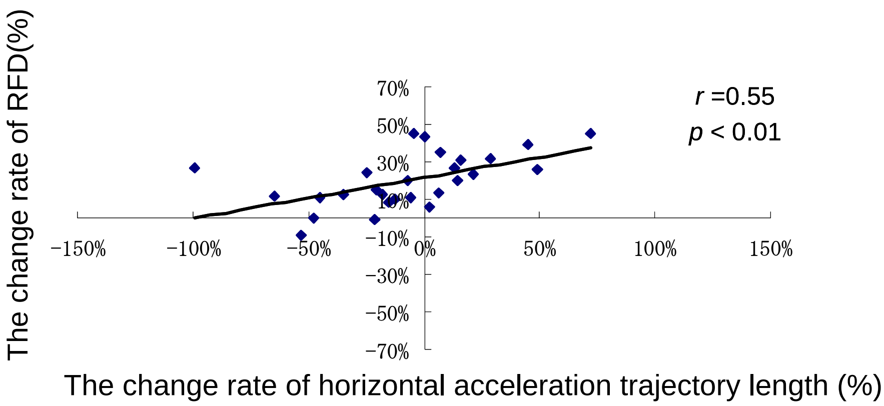

Figure 4. The scatter diagram of the change rates of RFD and horizontal acceleration trajectory length

DISCUSSION: The results showed that the peak force output in the unstable condition was lower than that in the stable condition. Koshida et al (2008) reported that peak force output in dynamic bench press with the weight of 50%1RM on the Swiss ball was significantly lower than that on the flat bench. The current result supports the previous finding. In bench press movement, regardless of static or dynamic movements, significant reduction of peak force output is observed under unstable conditions. RFD was also decreased under the unstable condition when compared to that under the stable condition. In previous studies, the efferent neuromuscular drive during muscle contraction is reported to be a factor associated with RFD value (Aagaard et al, 2002). The neuromuscular coordination altered by the given instability may have led to the RFD reduction as well as the peak force output reduction.

The difference in the horizontal acceleration trajectory length between the stable and the unstable conditions was not statistically significant in this study. It has been accepted that postural control was prioritized to force production. Our result supports the findings.

A moderate correlation was found only between the reduced rates of RFD and the horizontal acceleration trajectory length in this study. The study of Anderson et al (2004) suggested that prime movers may function as stabilizers under unstable conditions. In addition, previous studies have shown that postural and joint stabilities under unstable conditions were reinforced by muscle co-contraction of antagonistic muscle. We speculated that those changes of neuromuscular patterns might be associated with the RFD reduction under the unstable condition. Interestingly, there was no significant correlation between the reduction rates of peak force output and the perturbation. Approximately 2.5% of the small change rate of the peak force outputs might affect the result.

The result suggests that excessive stabilization activity might decrease RFD and that the instability resistance training could aim at improving muscular outputs by better coordinating force production with postural and joint stabilization. Some of resistance training exercises such as bench press on a flat bench and most of machine exercises do not require much of stabilizing activity during the movements. Because actual sports movements require the whole body to be stabilized during dynamic movement and a large amount of force to be generated in a very short period of time simultaneously, instability resistance training could be a more functional method for improving muscular outputs in sports activities. However, the significant loss of muscular outputs under unstable conditions was constantly reported; therefore, instability resistance training may not be suitable to induce maximal or submaximal force on limbs.

CONCLUSION: The change of horizontal perturbation caused by unstable conditions may be associated with the reduced rate of force development in the early phase of bench press movement.

REFERENCES:

Behm, D.G., Anderson, K. and Curnew, R.S. Muscle force and activation under stable and unstable conditions. *J. Strength Cond. Res*. 16:416-422, 2002.

Anderson, K., et al. Maintenance of EMG activity and loss of force output with instability. *J. Strength Cond. Res*.18:637-640, 2004.

Koshida, S., et al. Muscular outputs during dynamic bench press under stable versus unstable conditions. J. Strength Cond. 22:1584-1588, 2008.

Kornecki, S., Kabel, A. and Siemienski, A. Muscular co-operation during joint stabilization, as reflected by EMG. *Eur. J. Appl. Physiol.* 83:453-461, 2001.

Mayhew, J.L.,et al. Changes in upper body power following heavy-resistance strength training in college men. *Int. J. Sports Med.* 18:516-520.1997.

Aagaard, P., Simonsen, E.B., Anderson, J.L., Magnusson, P. and Dyhre-Poulsen, P. Increased rate of force development and neural drive of human skeletal muscle following resistance training. *J. Appl Physiol*. 93:1318-1326, 2002.