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［原著］

Electromyographic and Kinematic Trunk Analysis of Boxing during a Dominate Straight Punch

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［Abstract］

The purpose of this study was to compare the surface electro myogram of trunk muscle activity and the three-dimensional kinematics of the trunk between experienced and novice boxers during straight punch with the rear arm. Fifteen university-age males participated in the study. Participants were ranked as experienced (n=8) or novice (n=7). The straight punch was broken into three phases as Preliminary Movements (PM), Thrown Punch (TP), and Returned Punch (RP). The surface electro myogram captured the activity of the rectus abdominis, external oblique, deltoid, and rectus femoris on the dominant side and the internal oblique-transversus abdominis (IO-TrA) and multifidus on both sides. Three-dimensional motion analysis was performed to calculate the horizontal angle of the Acromial line, the ASIS line and the Greater Trochanter of the femur (GT) line. Results of the surface electro myogram of the IO-TrA on the non-dominant side of the novice group during the PM phase were significantly higher than those of the experienced ($p<0.05$). Similarly, the IO-TrA of the dominant side of the novice during the TP phase were significantly higher than that of the experienced ($p<0.05$). In motion analysis, the ASIS line and the GT line were significantly greater in the experienced group compared with the novice ($p<0.05$). The novice group did not allow the entire trunk to rotate, but rather twisted the thoracolumbar vertebrae to throw the punch. Trunk rotation, not trunk twist, is important to the execution of the straight punch.

Keywords：Trunk rotation, Trunk twisting, Boxing, Straight punch, Internal Oblique muscle

Introduction

Published rates of lower back pain in athletes range from 1% to more than 30%[1-3] and are influenced by sport type, sex, training intensity, training frequency, and technique[4-6]. Lower back pain is experienced by 44% of college boxers in Japan. In college boxers with lower back pain, the peak torque of the trunk rotators at the angular velocity of 120 deg/sec is less than that of college boxers without lower back pain[7]. Based on a study of amateur boxers in Japan, directly following the number of injuries to the hands and the head, a large number of people are affected by lower back pain. Hands and the head are exposed to immediate shock in boxing, however, although lower back isn't exposed to immediate shock the injury rate of lower back pain is high in boxing[7]. Compared with experienced college boxers, lower back pain in high school boxers with little experience is much more common[8]. For beginners of boxing, lower back pain is a big problem.

A straight punch is one of the most useful punches in boxing, and it is involved in many attacks.

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Investigators have studied the differences in the movement pattern between beginners and experts[9]. Trunk muscle activity and trunk movement during a straight boxing punch, however, have never been analyzed. The purpose of this study is to analyze trunk muscle activity and trunk movement during a straight punch in experienced and novice boxers, and to evaluate the potential causes of lower back pain in boxers.

Materials and Methods

Subjects. Fifteen males with no history of chronic lower back pain agreed to participate in the study. Mean (± standard deviation; SD) age of the study participants was 20.9 (± 1.6) years, mean height was 171.8 (± 5.7) cm, and mean mass was 63.2 (± 6.0 kg). Participants were ranked as experienced (n = 8) or novice (n = 7) based on their level of boxing experience. Experienced individuals participated in national boxing competitions in Japan while novice individuals had no experience in boxing. The purpose and protocol of the study was explained to each participant who then signed an informed consent form prior to participation. This study was approved by the Ethics Committee of doctoral program in sports medicine, graduate school of comprehensive human Sciences, university of Tsukuba (No. 445).

Straight Punching Movement. Participants were instructed to perform a straight punch with the rear arm (dominant arm) as quickly as possible, as follows: extension of the rear arm as straight and as far as possible from the right-handed or left-handed stance, then immediately return to the starting position. There was no real target, however it was assumed to be the height of the subject's own lower jaw. The leg was not permitted to move forward during the punch. After several times, the next successful straight punch was analyzed. An evaluator with boxing experience confirmed that the proper form was used in performing the straight punch.

For the analysis of this study, the straight punch was broken into three phases: 1. Preliminary Movements: from beginning movement of the body until beginning of arm extension. 2. Thrown Punch: from beginning of arm extension until full extension. 3. Returned Punch: from full extension of the elbow joint until the return to the start position.

Surface Electromyographic System. A surface electromyographic system (SEMG) was used to measure activity of the trunk, deltoid and rectus femoris muscles. Surface electrodes were placed on the dominant side rectus abdominis (RA, 3 cm lateral to an umbilicus), external oblique (EO, midway between the costal margin of the ribs and the iliac crest, approximately 45° to the horizontal), acromial part of the deltoid (DEL, 2cm below to the acrominon), rectus femoris (RF, midway between the anterior superior iliac spine and superior margin of the patella). Surface electrodes were placed on dominant and non-dominant side internal oblique-transversus abdominis[10] (IO-TrA, 2 cm medial and inferior to the anterior superior iliac spine) and multifidus (MF, 2 cm lateral to the spinous process at the L4-5 interspace) (Fig. 1). A reference electrode was placed over the sternum. Before the surface electrodes were attached, the skin was rubbed with a skin abrasive and alcohol to reduce the skin impedance to below 2 k Ω . Pairs of Ag/AgCl surface electrodes (NT-511G; Nihon Kohden Corporation, Tokyo, Japan) were attached, parallel to the muscle fibers, with a center-to-center distance of 2 cm.

Maximum Voluntary Contraction Trials: For normalization of the SEMG data, a maximum voluntary contraction (MVC) trial was performed with each muscle of interest while the SEMG signal amplitude was recorded. Most test positions were consistent with those demonstrated in manual muscle testing reference materials commonly used by

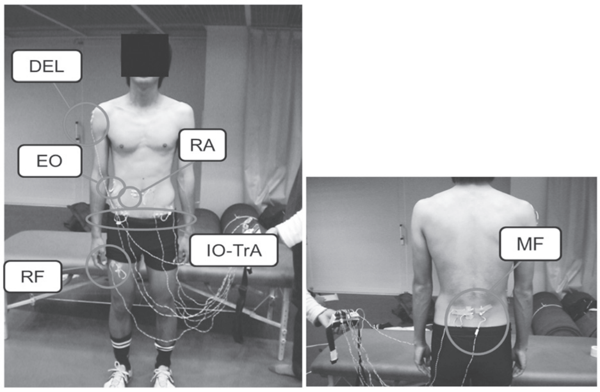

Fig. 1

A surface electro myographic system's setting. Surface electrodes were placed on the rectus abdominis (RA), external oblique (EO), deltoid acromial part (DEL) and rectus femoris (RF) on the dominant side, and internal oblique-transversus abdominis (IO-TrA) and multifidus (MF) on both sides.

physical therapists. New test positons were created for testing the external and internal obliques. Manual resistance was applied gradually, with the maximum amount held for 3 seconds. Correct electrode placement was further confirmed by observing the SEMG signal amplitude during the manual muscle tests.

For the RA, MVC was tested using a partial sit-up with knees flexed, arms folded across the chest, and abdominal muscles flexed. Resistance was then applied to the shoulder in the direction of trunk extension. For the EO on the right side and the IO-TrA on the left side, the subject was in a supine position with knees flexed and arms folded across the chest. The abdominal muscles were flexed and trunk was rotated to the left. Resistance was applied at the shoulders in the trunk extension and right rotation directions. For the EO on the left side and the IO-TrA on the right side, the trunk was rotated to the right with the resistance applied at the shoulders in the trunk extension and left rotation directions. The MVC for the MF was performed with prone trunk extension, with resistance applied to the upper thoracic area in the direction of trunk flexion. The MVC for the DEL on the dominant side was performed with upright shoulder abduction, with resistance applied to the upper arm in the direction of adduction. For the RF on the dominant side, MVC was performed with seated knee extension, with resistance applied to the lower leg in the direction of flexion. Fifteen subjects were given similar verbal encouragements for each of the MVC trials to help ensure a maximal effort throughout the 3 seconds. The subjects were asked after each trial if they thought it required maximum effort. If not, the trial was repeated. MVC trials were performed with 1-minute rest intervals. SEMG data was collected for the 3-second period of the isometric contraction. The MVC was calculated using the 1-second period with the highest signal activity.

Data analysis of SEMG: Raw SEMG signals were sampled at 1000Hz, amplified (Multi Telemeter; WEB5000 Nihon Koden Co, Ltd, Japan), band-pass filtered (20-500Hz), and full-wave rectified using analysis software (AcqKnowledge version3.7.3; Biopac Systems Co, Ltd, Japan). The average-rectified-value (ARV) of electro myographic amplitude for three phases (Preliminary Movements, Thrown Punch, and Returned Punch) of the straight punch was calculated. The mean ARV of MVC trials was used for normalizing SEMG amplitudes obtained during each phase of the straight punch (%MVC). An event synchronization unit was used to match video and SEMG recordings. SEMG was compared between Experience and Novice groups for each of the three phases.

Three-dimensional motion analysis. Procedure and Setting: The straight punch was videotaped, then, a three-dimensional motion analysis was performed. Fig. 2 shows the high-speed video tape recorder (VTR) cameras set-up. Each participant was marked bilaterally with reflective markers placed on the lateral tip of the acromion process, the anterior superior iliac spine (ASIS), and the greater trochanter

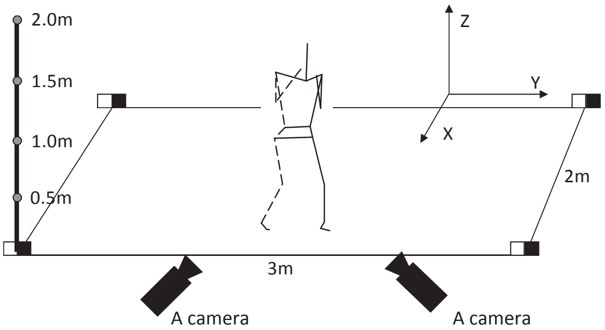

Fig. 2

The high-speed video tape recorder cameras set-up. Reflective markers were tracked individually by two electronically synchronized high-speed cameras

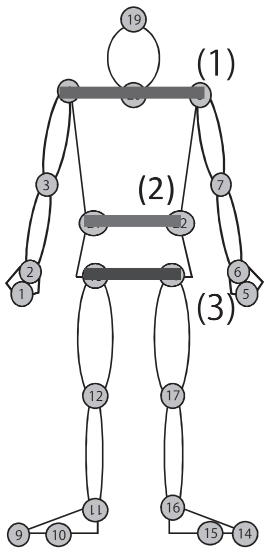

Fig. 3

Reflective markers points. Reflective markers attached to 1) the acromial process bilaterally. The line that connected these points on both sides were called the Acromial line. 2) The ASIS, and the line that connected these points on both sides were called the ASIS line. 3) The greater trochanter (GT), and the line that connected these points on both sides were called the GT line.

of the femur (Fig. 3). Reflective markers were tracked individually by two synchronized 125-Hz high-speed cameras (HSV500C[3], NAC Corp., Japan). The high-speed VTR cameras were positioned to allow for a 3m (L) × 2m (W) × 2m (H) calibrated volume of space. The positions of the reflective markers were calculated with Frame-DIAS Ver.3 (DKH Corp., Japan), utilizing a direct linear transformation method. The three-dimensional coordinate values were smoothened using a Butterworth filter at a cut-off frequency of 15Hz. Two-dimensional coordinates of the measurement point were calculated on a horizontal plane (X-Y coordinate) based on the three-dimensional coordinates.

Calculation of angles 1: Trunk rotation angle. We calculated the trunk rotation angle based on movement of the following lines during the punch as follows: 1) lines connecting both sides of the lateral tip of the acromion (Acromial line), 2) lines connecting both sides of the ASIS (ASIS line), and 3) lines connecting both sides of the greater trochanter of the femur (GT; GT line)[11] (Figure3). Trunk rotation to the non-dominant side during the strike movement of the straight punch was defined as having a positive value, and trunk rotation to the dominant side during the return from the straight punch was defined as having a negative value. The variation in the rotation angle was calculated by adding the maximum angle to the absolute value of the most negative angle. The variation of the Acromial line, the ASIS line, and the GT line was analyzed between groups

Calculation of angles 2: Trunk twisting angle. The Acromial-ASIS angle was calculated by subtracting the maximum value of the ASIS line angle from the maximum value of the Acromial line angle. Next, the Acromial-GT angle was calculated by subtracting the maximum value of the GT line angle from the maximum value of the Acromial line angle. The difference between the Acromial-ASIS angle and the Acromial-GT angle represented the trunk-twisting angle and was analyzed between the two groups.

Statistical Analysis. The two-way analysis of variance was used to calculate the %MVC. A Bonferroni test was used for post hoc analysis. The t-test was used to calculate the maximum rotation angle in three-dimensional motion analysis. An unpaired t test was used to analyze differences in the three-dimensional motion between groups. A P value of less than 0.05 was considered statistically significant, and a P value of less than 0.1 was considered to represent the tendency to differ. All statistical analyses were conducted using Statcel 2 (OMS Ltd., Tokyo).

Results

Surface Electro Myogram. Preliminary Movements phase in Experienced vs Novice: The novice group (129.7 ± 63.8%) was significantly higher than the experienced (29.2 ± 15.6%) in the IO-TrA of non-dominant side during this phase. There were no significant differences in other muscles. (Fig. 4)

Thrown Punch phase in Experienced vs Novice: The novice group (173.0 ± 94.2%) was significantly higher than the experienced (85.1 ± 19.2%) in the IO-TrA of dominant side during this phase. There were no significant differences in other muscles. (Fig. 5)

Returned Punch phase in Experienced vs Novice: The novice group (31.3 ± 10.2%) was lower than the experienced (73.7 ± 89.1%) in the RF during this phase. However, there were no significant differences. (Fig. 6)

Trunk rotation angle. Acromial line angle: The acromial line angle was 85.0 ± 22.0° in the experienced group and 66.8 ± 27.8° in the novice group. Although the acromial line angle of the experienced group was larger than that of the novice, the difference was not statistically significant. (Fig. 7) ASIS line angle: The ASIS line angle was 77.9 ± 24.3° in the experience group and 48.7 ± 20.4° in the novice group. The ASIS line angle was significantly greater in the experienced group compared with the novice. (Fig. 7)

GT lines angle: The GT line angle was 69.1 ± 25.6° in the experienced group and 38.5 ± 16.2° in the novice group. The GT line angle was significantly greater in the experienced group compared with the novice. (Fig. 7)

Acromial-ASIS angle: The Acromial-ASIS angle

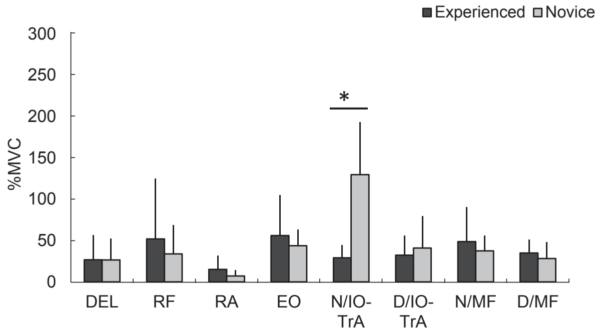

Fig. 4

Surface electromyographic value of preliminary movements phase in experienced vs novice. The novice group was significantly higher than the experienced in the IO-TrA of non-dominant side during this phase. *: $p < 0.05$

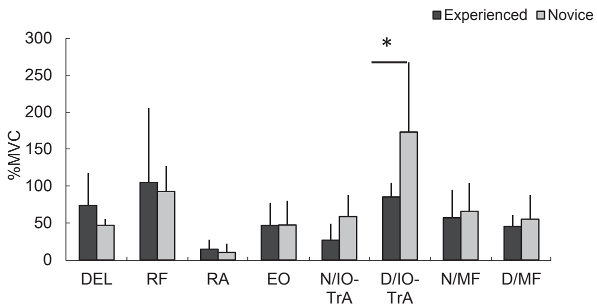

Fig. 5

Surface electromyographic value of thrown punch phase in experienced vs novice. The novice group was significantly higher than the experienced in the IO-TrA of dominant side during this phase. *: $p < 0.05$

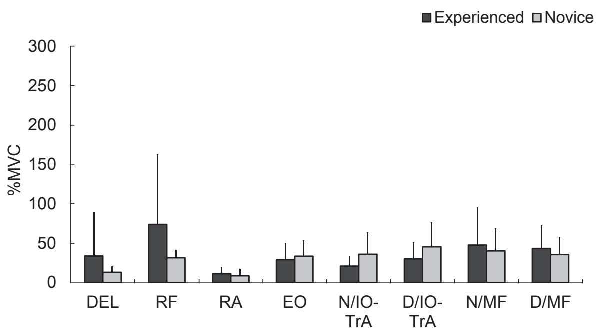

Fig. 6

Surface electromyographic value of returned punch phase in experienced vs novice. There were no significant differences.

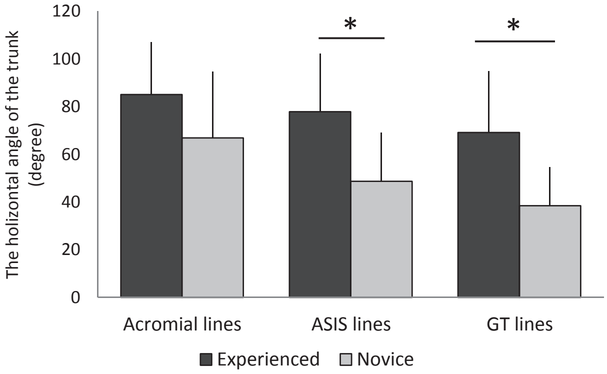

Fig. 7

Trunk rotation angle of the three-dimensional motion analysis. The ASIS and GT line angles were significantly greater in experienced compared with novice. *: $p < 0.05$

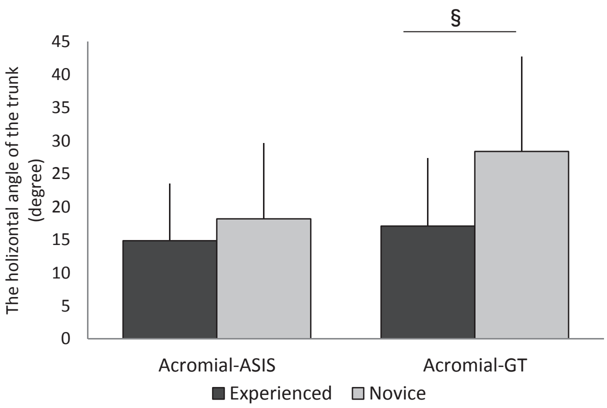

Fig. 8

Trunk twisting angle of the three-dimensional motion analysis. The Acromial-GT angle of Novice tended to be larger than that of Experience. § : $p < 0.1$

was 14.8 ± 8.7° in the experienced group and 18.2 ± 11.5° in the novice group. Although the Acromial-ASIS angle of the novice group was greater than that of the experienced, the difference was not significant. (Fig. 8)

Acromial-GT angle: The Acromial-GT angle was 17.1 ± 10.2° in the experienced group and 28.4 ± 14.3° in the novice group. The Acromial-GT angle of the novice group tended to be greater than that of the experienced ($p=0.09$, Fig. 8).

Discussion

During the execution of a straight punch of the dominant arm, using surface electro myogram, this study found that the IO-TrA of non-dominant side of the novice group during the preliminary movements phase was significantly higher than those of the experienced group. Similarly, the IO-TrA of the dominant side of the novice group during the thrown punch phase was significantly higher than that of the experienced group. Before throwing the punch, the novice group twisted their trunk in the opposing direction. Additionally, during the thrown punch phase, the novice group twisted their trunk to same direction of the punch. The result of the three-dimensional motion analysis's results show that the novice group tended to have a greater Acromial-GT angle than the experienced group. The novice group did not allow the entire trunk to rotate, but rather twisted the thoracolumbar vertebrae to throw the punch. The ipsilateral TrA and IO contract together to rotate trunk[12]. TrA contraction occurs on both sides during trunk rotation, however, the contraction of the TrA on the rotating side is higher than the opposite side during Thrown Punch phase. The increased muscle activity of the TrA-IO of the novice group during the Thrown Punch phase combined with twisting of the thoracolumbar vertebrae may be the cause of lower back pain.

The RF contractions of the experienced group throughout the punch were more frequent than those of the novice group during SEMG. However, there was no significant difference between groups. In addition, the trunk rotation angles (i.e., the ASIS and GT line angles) of the experienced group using three-dimensional motion analysis were significantly greater than those of the novice group. That is, the experienced group punched using lower limbs as well as rotating the hip joint but, did not twist the thoracolumbar vertebrae. Toyoshima, et al.[9] examined how to perform a straight punch using the dominant arm. A significant correlation was observed between the waist movement distance and the maximum speed of the waist as well as punching power. The extent of waist movement in the previous study equaled the amount of trunk rotation in the present study. Trunk rotation, not trunk twist, is important to the execution of the straight punch.

The function of trunk muscles during the performance of integrated kinetic chain activities, such as throwing or kicking, is transferring torques and angular momentum [13-14]. This suggests that trunk muscles serve the same purpose during a punch. The importance of this function is seen as being pivotal for efficient maximization of force generation and minimization of joint loads in all types of activities[13]. In addition, trunk stability training for enhanced health, rehabilitation, and athletic performance has received renewed emphasis[15]. Specific training practices aimed at targeting the trunk stabilizing muscles are an important consideration not only for activities of daily living or rehabilitation of lower back pain, but also for athletic performance[15]. In order to prevent lower back pain in athletes, it is important that novice athletes acquire collect movement technique as well as undergo trunk stabilization training.

This study was limited to the straight punch performed in the air without a target. When the impact applied to the body by a target is present, a different response by the trunk muscles is expected. However, the forces generated by impact were not evaluated in this study and will require further research.

Conclusion

Trunk muscle activity and trunk rotation during a boxing straight punch was compared between experienced and novice boxers. In SEMG, the IO-TrA of the novice boxers during the straight punch was significantly higher than those of the experienced boxers. In three-dimensional motion analysis, the experienced boxers punched rotating the hip joint. In contrast, the novice boxers twisted the thoracolumbar vertebrae to throw the punch. It is important that appropriate movement technique and trunk stabilization exercises are taught to novice boxer in order to prevent injuries.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication on this artice.

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References

1) Videman T, Sarna S, Battie MC, Koskinen S, Gill K, Paananen H and Gibbons L. 1995. The long-term effects of physical loading and exercise lifestyles on back related symptoms, disability, and spinal pathology among men. *Spine* 20: 699-709.

2) Hickey GJ, Fricker PA and McDonald WA. 1997. Injuries to elite rowers over a 10-yr period. *Med Sci Sports Exer* 29: 1567-1572.

3) Granhed H and Morelli B. 1988. Low back pain among retired wrestlers and heavyweight lifters. *Am J Sports Med* 16: 530-533.

4) Dreisinger TE and Nelson B. 1996. Management of back pain in athletes. *Sports Med* 21: 313-320.

5) Kujala UM, Kinnunen J, Helenius P, Orava S, Taavitsainen M and Karaharju E. 1999. Prolonged low-back pain in young athletes: a prospective case series study of findings and prognosis. *Eur Spine J* 8: 480-484.

6) Johnson AW, Weiss CB Jr, Stento K and Wheeler DL. 2001. Stress fractures of the sacrum. An atypical cause of low back pain in the female

athlete. *Am J Sports Med* 29: 498-508.

7) Izumi S, Miyakawa S and Miyamoto T. 2007. The evaluation and comparison of the physical characteristics of the college boxing players with/without low back pain. *Jpn J Phys Fitness Sports Med* 56: 203-214.

8) Izumi S, Kaneoka K, Miyamoto T, Hiura M, Hangai M and Miyakawa S. 2009. A questionnaire survey to the amateur boxing injuries in Japan. *Jpn J Clin Sports Med* 17: 225-231.

9) Toyoshima T, Tanaka E and Nakano S. 1991. Effect of lumbar movement on punching force in boxing. *Jpn J Phys Fitness Sports Med* 40: 626.

10) Hodges P and Richardson C. 1997. Contraction of the abdominal muscles associated with movement of the lower limb. *Phys Ther* 77: 132-142.

11) Sasaki H, Furuya Y, Ajiro T and Hirokawa R. 1997. A biomechanical study of an attacking frontal KENDO stroke: Comparison between an 8th Dan and 3th Dan. *The Tokai J Sports Med Sci* 9: 34-44.

12) Cresswell AG, Grundström H and Thorstensson A. 1992. Observations on intra-abdominal pressure and patterns of abdominal intra-muscular activity in man. *Acta Physiol Scand* 144: 409-418.

13) Kibler WB, Press J, and Sciascia A. 2006. The role of core stability in athletic function. *Sports Med* 36: 189-198.

14) Willardson JM. 2007. Core stability training: applications to sports conditioning programs. *J Strength Cond Res* 21: 979-985.

15) Behm DG, Drinkwater EJ, Willardson JM and Cowley PM. 2010. The use of instability to train the core musculature. *Appl Physiol Nutr Metab* 35: 91-108.