MUSCULAR RECRUITMENT DURING REAR HAND PUNCHES DELIVERED AT MAXIMAL FORCE AND SPEED BY AMATEUR BOXERS.

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Six male competitive amateur boxers (mean ± SD age: 24.6 ± 3.3 years; height 1.82 ± 0.05m; mass: 73.3 ± 19.0 kg) participated in electromyography during delivery of boxing punches to a dynamometer. A linear model of recruitment of the muscles under investigation applied best in the case of maximum force punches delivered to the body. The importance of the rectus femoris gastrocnemius and biceps femoris muscles in the initiation of punch delivery was evident. Punch forces delivered for maximal force were greater than those delivered for maximum speed. The force was 38% greater when a maximum force punch to the head was delivered relative to that delivered for maximum speed. This was associated with increased activity of 27% in the large rectus femoris muscle involved in rear leg extension.

KEY WORDS: Boxing, EMG, impact, jab, muscle.

INTRODUCTION

Effective coaching and training underpin sports participation and competitive sports performance. In combat sport effective technique and muscular training are key considerations. The ability in amateur boxing to deliver punches effectively for both maximum force and also with speed are important considerations (Dyson et al. 2005) The ability to coach and train appropriately to deliver forceful rear hand punches is critical to success under the rules of competitive amateur boxing. Much of the impact force of the rear hand punch is considered to originate from the drive of the rear leg (Hickey, 1980).
The aims of this study were to identify the muscular recruitment sequence of key muscles (part of an anticipated chain sequence) relevant to punch performance during rear straight punches delivered at maximal force and speed to a body and head target. In addition differences in the level of peak muscular activity of the rectus femoris, which is likely to be of importance in the achievement of a forceful rear hand punch to the head, were considered when delivery was for either maximal force or maximal speed.

METHODS

Six male competitive amateur boxers (mean ± SD age: 24.6 ± 3.3 years; height 1.82 ± 0.05m; mass: 73.3 ± 19.0 kg) gave their informed written consent before participating in the study. Subjects wore 0.284 kg Top Ten competition gloves over their normal hand bandages, and adopted a lead left hand and rear right hand boxing style. Electromyography of eight muscles on the rear (right) hand side of the body was carried out. The muscles selected and their action are detailed in table 1.

Table 1. Muscles investigated using electromyography and their actions.

Muscle	Code	Muscle action in punch delivery.
Gastrocnemius	G	Plantar flexion of foot and knee flexion.
Biceps Femoris	BF	Hip extension and knee flexion.
Rectus Femoris	RF	Hip flexion and knee extension.
Upper Trapezius	T	Elevation of the scapula
Anterior Deltoid	AD	Arm flexion and horizontal adduction.
Biceps Brachii	BB	Elbow flexion and supination of the forearm.
Flexor Carpi Radialis	FCR	Wrist flexion and wrist abduction.
Triceps Brachii	TB	Elbow extension.

Electrode sites were prepared for electromyography (EMG) by cleansing the skin with isopropylalcohol swabs, shaving body hair when necessary, and lightly abrading the skin surface with Medicotest disposable abraders before application of Medicotest N-50-E disposable electrodes. Two electrodes were applied over the belly of each muscle along the same direction as the muscle fibres and a reference was placed on a close bony prominence (e.g. clavicle; elbow). Electrodes from each muscle were attached to a four kilo-ohm preamplifier and all were taped to the skin surface to prevent any movement during the dynamic boxing task, taking care not to restrict the natural movement of the subject during boxing performance. The preamplifiers were connected to a MIE Medical Research Ltd. eight channel radiotelemetry transmitter with aerial. The differential preamplifiers had a gain of 4000, with a balance input of 10 mΩ, a common mode rejection ratio of 110 dB and a signal to noise ratio of -50 dB. The frequency pass band was 6 to 330 Hz (3 dB point).
Prior to data collection each 20 minute self-selected warm-up comprising stretching, jogging and striking hand held coaching pads was performed. The height of the boxing dynamometer manikin, which was to be the target during each boxing trials, was matched to each subject's shoulder height from the floor. Following habituation, each subject was given 30 seconds to throw straight rear hand punches at maximal speed or force in turn to the head of a calibrated boxing dynamometer (Smith et al. 2000). Punches were thrown either singularly or in two/three punch combinations in a prescribed sequence from an audio cue (Akai, AJ-W248). Punch force data were sampled at 330 Hz and recorded using punch data acquisition software specified to run within Provec 5.0 software (MIE Medical research Ltd, Leeds, UK). Typically 19-20 punches were thrown by each hand during a punch sequence with movement recorded on a Panasonic video camcorder.
Electromyography data was sampled for 15 seconds using Myodat 3.0 software during each data collection period and then stored to the computer hard disc for subsequent analysis. For each subject, six punches were chosen from the middle phase of the punch sequence and the main horizontal uniaxial component of impact force recorded for the qualitative muscular recruitment analysis. The integrity of the raw EMG for each selected punch was inspected, and if good then the linear enveloped EMG was processed. A sequence of muscle recruitment, based on the assumption of a linear recruitment model for the eight muscles, was determined for the maximal force and speed conditions for each subject and the group. The model utilised an increment of one for the position (within eight possible ones) a muscle was maximally recruited within a series of 1 to 8 for each subject.
Relative activity levels of the rear hand right rectus femoris muscle in four punches delivered for maximal force and for those delivered for maximal speed were determined with related triaxial punch force data.

RESULTS

The mean (±SE) uniaxial punching forces to the body for maximum force was 3244 ±48 N and for maximum speed was 2256 ±44 N and to the head 3956 ±110 N and 2459 ±61N respectively. The linear recruitment of punches delivered to the body as shown in figure 1 commenced with the initial recruitment of the quadriceps muscle rectus femoris which extended the rear leg at the knee.

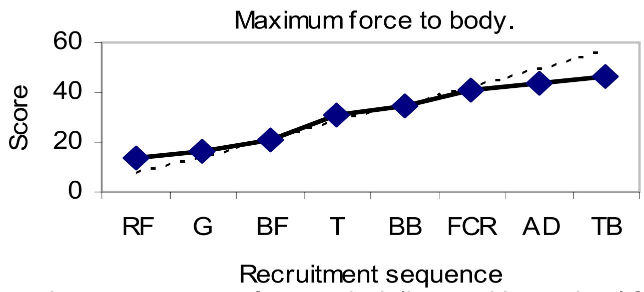

Figure 1. Muscular recruitment sequence for punch delivery with maximal force to the body.

This extension of the rear leg also involved the plantar flexion action of the gastrocnemius muscle in the calf and hip extension action of the biceps femoris of the hamstring group. Muscle recruitment then involved the trapezius muscle in the upper back followed quickly by the shoulder and arm muscles. The contraction of the biceps brachii muscle to bend the elbow and supinate the forearm preceded the peak activity of the other muscles under investigation acting on the shoulder and wrist joints. The linear recruitment sequence model fitted well with closer coupling demonstrated in the arm muscles.

In the case of punches to the body delivered with maximum speed the linear model was not as appropriate with more boxers recruiting the leg muscles later (as indicated by the position above the theoretical linear line) and the upper body muscles earlier in the sequence (see figure 2). The peak activation of the triceps brachii in extending the arm and flexor carpi radialis in maintaining wrist flexion occurred relatively much earlier when punches were delivered for maximum speed to the body.

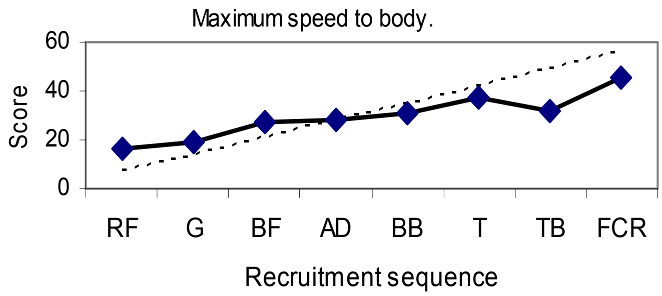

Figure 2. Muscle recruitment sequence for punch delivery with maximal speed to the body.

For punches delivered with maximal force and speed to the head the gastrocnemius was the first muscle to be recruited as plantar flexion of the foot occurred. Figure 3 shows that in the case of punches delivered for maximum force this was followed by the rectus femoris and biceps femoris with extension of the leg at the knee and hip respectively. The linear model then applied with successive recruitment of the upper body trapezius and anterior deltoid muscles and upper arm muscles biceps brachii as the elbow flexed and then peak activation of the triceps brachii as the arm extended with the wrist maintained in position for the strike.

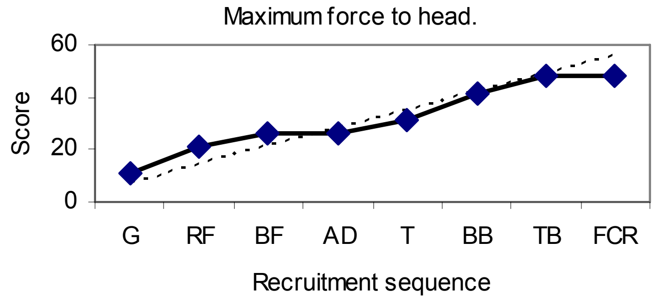

Figure 3. Muscular recruitment during deliveries with maximum force to the head.

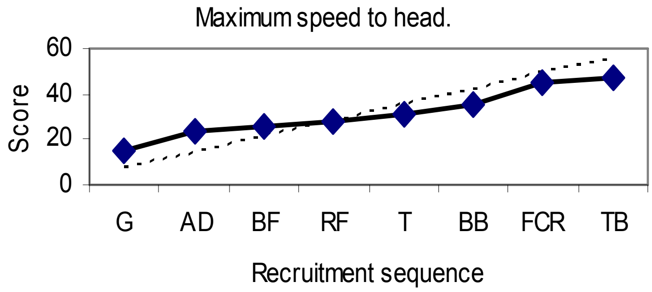

Figure 4. Muscular recruitment during maximum speed punches to the head.

In the case of deliveries to the head with maximum speed there was evidence of more association in the recruitment of upper thigh and upper body muscles in the initiation of the

action within the group of boxers (see figure 4). Again the peak activity of the triceps brachii and flexor carpi radialis were closely coupled in the final phase of the punch delivery. When punch delivery was optimized for maximum speed the muscular recruitment was more variable within the group of boxers, as indicated by the distance from the linear line.
The increased mean force of delivery when a punch to the head was delivered with maximal force relative to maximal speed was 1587N equivalent to an additional 38% force delivery. This was associated with an increased level of activity in the rectus femoris muscle of 27% as shown in table 2.

Table 2. Relationship (mean±SD) between the increased force and rectus femoris muscle activity when head punches were delivered for maximum force rather than speed.

	Punch force (N)	Muscle activity (μV)
Maximum force	4202 ± 1037	1248 ± 306
Maximum speed	2614 ± 591	910 ± 256
Difference	1587 ± 515	338 ± 139

DISCUSSION

Valentino et al. (1990) considered differences in the level of muscular activity during boxing and reported notable recruitment of deltoid muscles when a jab (or straight rear hand) punch was performed compared to an upper cut. This research has demonstrated the significance to punch force generation of a linear recruitment of muscles originating from the legs, trunk, shoulders and arms in sequence has been demonstrated in this research. This supports the importance of a boxer having the correct 'stance' and 'on-guard' position in order to throw effective punches (Hickey, 1980). The relative importance of leg extension at the ankle, knee and hip involving the gastrocnemius, rectus femoris and biceps femoris muscles was notable especially in forceful punch delivery. This work supports the approach that boxing coaches should prioritise the development of sequential muscular recruitment when coaching the technical requirements of rear hand punching.

CONCLUSION

A linear model of recruitment of the muscles under investigation applied best in the case of maximum force punches delivered to the body with the importance of early recruitment of the rectus femoris, gastrocnemius, and biceps femoris muscles in the initiation of punch delivery evident particularly when punches were delivered with an aim of maximum force. The punching force to the head was 38% greater when maximum force was a priority relative to when delivery was for maximum speed, and this was associated with increased activity of 27% in the large rectus femoris muscle involved in rear leg extension.
Maximum punching force and speed starts with the recruitment of muscles in the legs and a pathway of force travels through the human body to the point of impact. Coaches should consider focusing on developing such muscular recruitment sequence patterns, especially with young boxers.

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