弓道における引分け動作の筋活動様式

Muscle Activity Patterns in the Hikiwake Movement of Kyudo

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Abstract

Kyudo (Traditional Japanese Archery) is one of the traditional sports of Japan. Some stages constitute the shooting movement. In particular, drawing the bow is the most important movement, and is called *daisan* and *hikiwake*. The purpose of this study was to compare the muscle activity patterns for a second before *daisan* phase finish, and during *hikiwake* phase, by the skill level. Eight elite (E) and eight novice (N) players in *Kyudo* participated in the experiment. Each subject performed 24 shots. EMGs were recorded from three muscles in both sides of the body: middle part of deltoid, infraspinatus and triceps brachii. During *daisan* phase the joint of left elbow is extended, and during *hikiwake* phase the joint of shoulder is extended and the joint of elbow is flexioned gradually to pull the bow, concerning right upper limb. On these movements, the muscle of infraspinatus activity in E showed increase or stable patterns. The present results on muscle activity pattern in infraspinatus suggest that E used dorsal muscle effectively to draw a bow.

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I. Introduction

Kyudo is a traditional Japanese sport. Since a correct shooting style is considered to result in the hitting of the target, when teaching technique, the development of shooting style should be emphasized. Although the technique is taught based on ancient stereotypes inherited from predecessors, until now they have hardly been verified scientifically. Moreover, even in the Kyudo Kyohon (Kyudo Teaching Manual) [All Japanese kyudo leagues ed. (1990)] many abstract phrases can be found, occasionally it is sometimes difficult for a novice to understand its contents. Mori (1998) stated about instruction of kyudo that a learner needs to master the right rational and purposeful shooting technique, which suited the purpose of shooting a bow. Also for that reason, instruction which has a scientific basis, rather than a sensuous teaching expression and groundless coaching, is required. This research was done in order to acquire a scientific view.

In previous studies on Kyudo, many have focused on the equipment [Hosoya et al. (1994), Kosa et al. (1975)] or hanare, "the releasing of the arrow" [Hosoya et al. (1997a,b), Inagaki (1972,1973,1981)]. In electromyographical studies on movement at the time of shooting the bow, it has been reported that the extensor muscle group is predominantly used and that predominantly active muscles may differ depending on the level of skill [Kamei et al.

(1971), Karasawa (1976)]. However, in the above-mentioned research, the time series of muscle activity in the movements leading up to the shooting of the bow were shown but not elaborated on. Kyudo is a sport that utilizes the elastic feature of the bow in order to hit the target. To make optimum use of this feature, it is necessary to carry out a detailed study of the muscle activity involved in the process of drawing the bow.

The movements that draw a bow are roughly divided into eight paragraphs of "syahou-hassetsu". After each movement is completed there is a period of motionlessness before proceeding to the next step. Furthermore the movements involved in shooting the bow are extremely slow and for the total movement to be completed 20-30 seconds are necessary. "Syahou-hassetsu" especially involved in the 4 main steps leading up to the bow being shot are: uchiokoshi, "raising the bow in the front," daisan, "the preliminary move that sets up the draw," hikiwake, "the bow being pulled into full draw," and kai, "completion of the draw," all of which culminate in hanare, the release of the arrow from the bow. The movements concerning directly on-target are hanare and kai in which elastic energy is stored in a bow by drawing. It seems however, that the drawing movement itself, which is a stage before kai and hanare, is difficult for a novice. The movement of drawing the bow is called hikiwake, but the preceding movement that sets up the draw is called daisan. In daisan, both wrists are raised to face-level and the bow is pushed open by extending the left elbow with resisting the elasticity of the bow. As for hikiwake, while maintaining the extended position of the left elbow, the bowstring is drawn by the right hand. Usually, after raising both arms around the overhead front, it is difficult to push a bow with the left hand and to pull a bowstring with the right hand. Moreover, as the left hand pushing a bow is non-dominant hand for a majority, the power to push is weaker than the power to draw. So, for a smooth movement, the left elbow joint is extended and then fixed. Hikiwake movement is a dynamic motion drawing the bow apart with the left and right. It has been reported when completing of hikiwake the tension of a bow becomes fixed, and static muscular contraction is performed [Kamei et al. (1971)]. Since it shifts to hikiwake smoothly at the time of the completion of daisan, preparation -activity should be made. Therefore, the muscle activity was investigated during the one-second period before completion of daisan (i.e., during the one-second period before initiation of hikiwake) and during hikiwake. We expected that beginners activate the shoulders and right wrist muscles too much, and cannot use extensor muscles effectively like veterans.

Based on the above-mentioned process leading up to the bow being shot, the aim of this study is to carry out a comparison of the forms of muscle activity seen at different skill levels by referring to the almost motionless stage right before the start of hikiwake and one-second before completion of daisan, as well as the hikiwake movement itself, based on the electromyograms of Kyudo veterans and beginners.

II. Methods

1. Subjects

The subjects consisted of 16 females divided into two groups, the elite group (E), (aged 38.5 ± 8.6, trained 9.8 ± 5.4 years, and usually uses the bow whose drawing weight is 13.3 ± 1.0 kg) and the novice group (N), (aged 18.6 ± 1.1, trained 1.9 ± 0.1 years, and usually uses the bow whose drawing weight is 11.6 ± 0.8 kg), each comprising eight members. Members in the elite group had obtained stage four or above of the Kyudo proficiency test, while those in the novice group were level one or lower.

2. Procedure

Each subject was facing a practice target and shot arrows with the same bow of which draw weight was 12 kg (**Fig.1**). Since the same arrow was used in all shots, the arrow was removed from the target after a shot ended. The target with a diameter of 36 cm was put on a 180 cm distance from the subject so that the arrow surely hit it. Four shots were made into one-set. The subject released a total of six sets, i.e., 24 arrows. The break for about 5 minutes was taken at the interval of sets.

The EMG (electromyography) was recorded by the surface bipolar lead method using a multi-telemeter system (Nihon Koden Multi -Telemeter System WEB-5000, high cutoff frequency 1 kHz, time constant r = 0.03 s) focusing on the main muscle groups thought to be involved in daisan and hikiwake, namely the left and right infraspinatus, the middle part of the deltoid muscles, and the caput longum part of the triceps brachii [Kamei et al. (1971)]. The infraspinatus act as the external rotation and horizontal extension of the shoulder joint. About identification of infraspinatus, it was checked by the motion of the shoulder joint used as agonist. The muscles that work to horizontal adduction of a shoulder joint are infraspinatus and teres minor. Although these muscles exist in the depths of the body, infraspinatus is shown a little in a surface compared with teres minor. So the measurement of EMG was possible for this muscle. Moreover, the middle part of the deltoid muscles and the caput longum part of the triceps brachii are the agonist extending horizontally shoulder joints, and elbow joints, respectively. EMG electrodes (Ag/AgCl disc electrode; 0.5 cm in diameter) were placed on the skin above each muscle belly. These sites were prepared first by lightly abrading the area and cleaning the skin with alcohol. The distance between two electrodes was approximately 2 cm.

Furthermore, a video camera (FUJIX-8 F610) was placed in front of the subjects to videotape their movements during the shooting of the bow. A circuit was created to calculate the time for hanare and a coated protection glove (yugake) was fixed to the right hand.

The EMG and hanare signals were recorded in a computer (Macintosh Power Book 2400c/180) using an MP100 (BIOPAC Systems, Inc.) at a sampling rate of 1 kHz. A synchronizer (OSTEC, TFS-01) was used to synchronize these signals and video images.

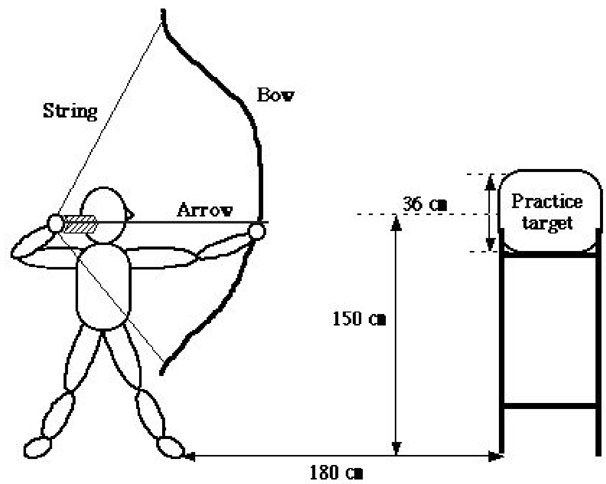

Fig.1 The relationship of the subjects to the target.

3. Method of analysis

From the video images, the start and completion of each movement were obtained. The starting point of daisan was taken to be the point when the left elbow began to be extended, while completion of daisan, as well as commencement of hikiwake was considered to be the point where the right hand began to pull the bowstring back (**Fig.2**). Completion of hikiwake was taken to be the point where the arrow reached the cheek at mouth level.

From the EMG, the integral values (iEMG) were calculated. Based on the study by Clarys et al. (1990), for each muscle type, the one -second period before completion of daisan was divided into five intervals (I-V), and the iEMG for each interval was calculated as a percentage of the total one-second period iEMG to give the %iEMG (**Fig.3**). As a result, it will become 100 percentages if the value of %iEMG in five intervals (I-V) is totaled. For hikiwake, the whole movement was divided into five intervals (I-V), and %iEMG was calculated as daisan was. The four best shots used for analysis were chosen by scoring "good" of the following two points: 1) The subjects judged their shot in three stages "good", "ordinary", and "bad". 2) The shot by which the arrow stuck in the target was parallel to the ground was judged to be "good". The group type (E, N) and interval (I-V) were taken as factors for the %iEMG of daisan and hikiwake and a two-way ANOVA was performed. Fisher' s PLSD was adopted as a post-hoc test.

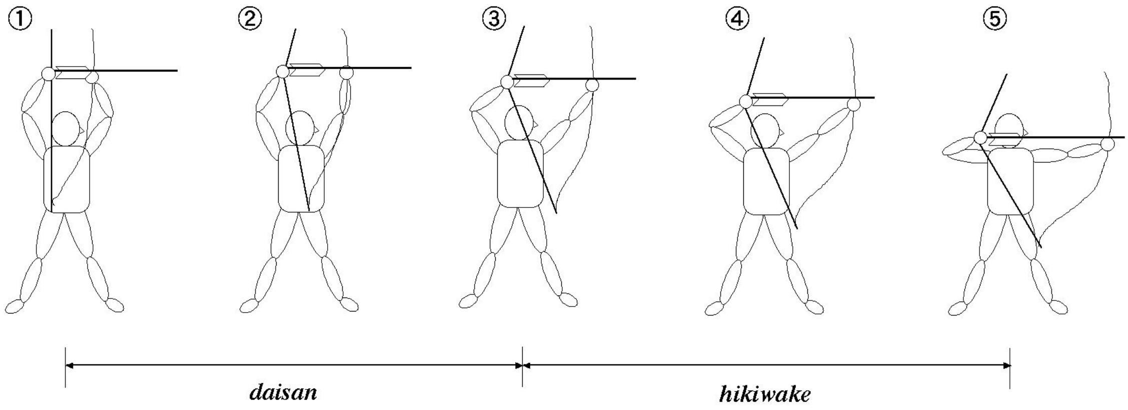

Fig. 2 The movement from the beginning of daisan to completion of hikiwake.

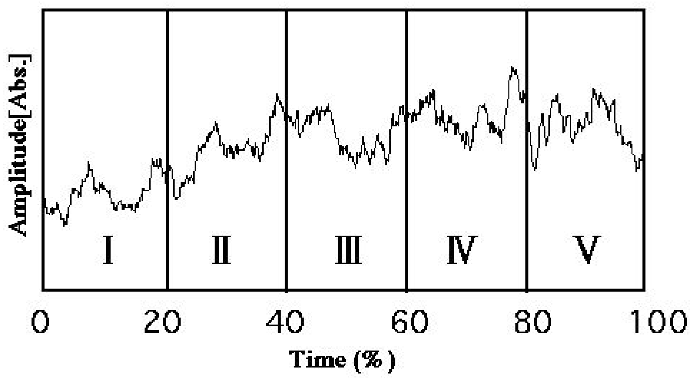

Fig. 3 Method of EMG analysis.

III. Results

The durations of shooting movements in both groups are shown in **Table 1**. For the absolute values, although each movement time did not have a significant difference between the two groups, the time of daisan in group N tended to be shorter than in group E ($p < 0.1$). The relative value for each duration, on the other hand, was calculated as a percentage of the total durations of uchiokoshi, daisan, hikiwake, and kai. During daisan, the relative time of group N was significantly shorter than that of group E. For the time of hikiwake, there was no difference between group E and group N in both absolute and relative values.

1. Muscle activity at the time of shooting the bow

As shown in **Fig.4a**, the EMG for group E was typical of that at the time of shooting the bow. At first, during uchiokoshi, to raise the upper arm laterally, a continual electrical discharge occurred from both the right and left central deltoid regions. In daisan, from the posture taken in uchiokoshi, the left elbow was extended and the bow was pushed open. In order to be able to resist the elasticity of the bow, a strong electrical discharge could be seen from the left deltoid and triceps muscle. Furthermore, during the latter part of the movement, a steadily rising electrical charge was emitted from the right infraspinatus. During the next stage of hikiwake, in order to be able to extend the bowstring further with the right hand, the right central deltoid and right triceps regions were also active. Moreover, during this period, both the left and right infraspinatus, situated dorsally, were also seen to be active, while all muscle activity was maintained during kai.

Fig.4b shows typical muscle activity pattern in group N. Compared with group E, different patterns were observed in the activities of infraspinatus and deltoid. First, large activities of bilateral infraspinatus were seen in the first half of uchiokoshi. Second, about the right deltoid, it began to work from the time of uchiokoshi, it applied to kai and is discharging very strongly. Moreover, the discharge of the left deltoid gradually increased from daisan and it was discharging strongly from the second half of hikiwake to the end of kai.

Table 1 Durations of shooting movements in seconds. Inside parentheses is the relative duration in the total time of uchiokoshi, daisan, hikiwake, and kai. *, significantly different from the group E, $p < 0.05$.

	Uchiokoshi	Daisan	Hikiwake	Kai
group E	5.56 ± 1.08 (29.07 ± 3.06)	5.38 ± 0.97 (28.12 ± 3.05)	5.30 ± 0.90 (27.96 ± 4.10)	2.86 ± 0.11 (14.85 ± 3.91)
group N	5.55 ± 1.40 (31.05 ± 4.09)	4.22 ± 1.24 (23.43 ± 3.67*)	5.23 ± 1.45 (29.23 ± 5.23)	2.85 ± 0.76 (16.29 ± 4.62)

(unit: s)

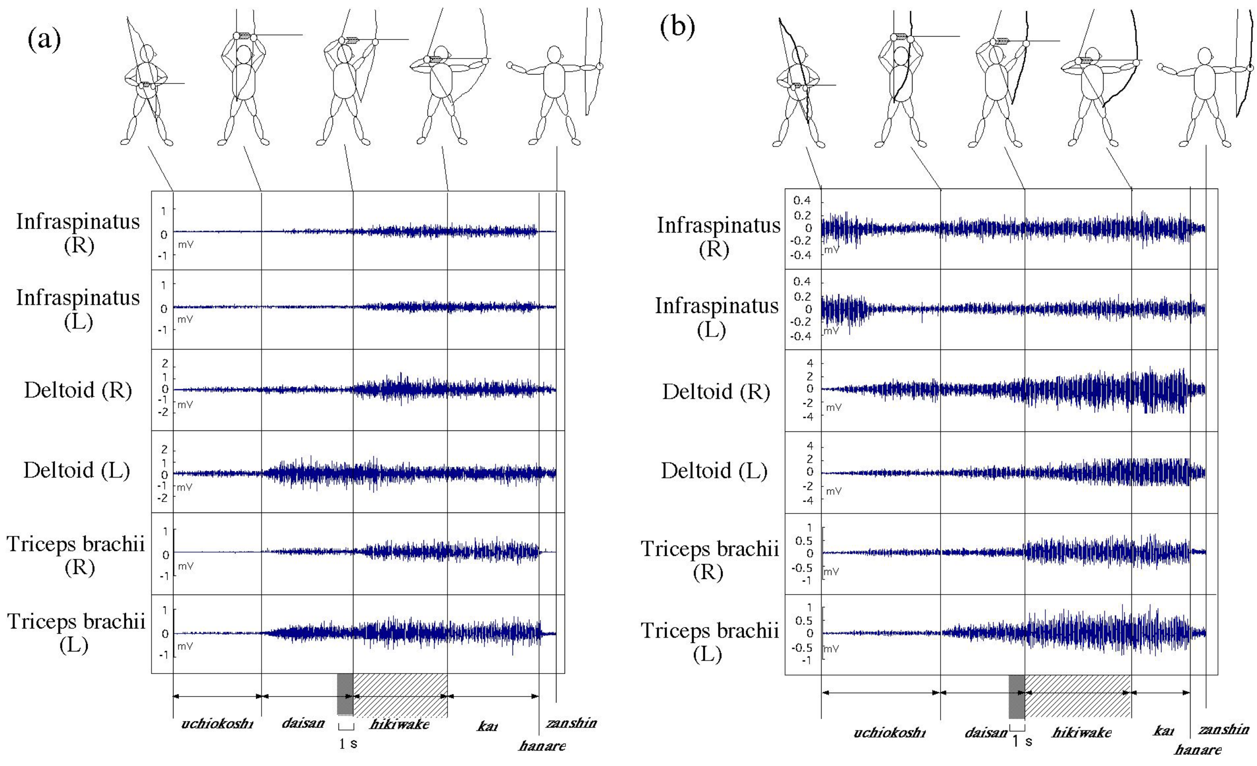

Fig. 4 A typical EMG at the time of shooting the bow (a) Group E (b) Group N.

2. Muscle activity patterns during the one-second period before completion of daisan

Fig.5 shows the forms of activity in each muscle group during the one-second period before completion of daisan. Overall, a difference could be seen in the form of group E and group N in both the left and right infraspinatus and the left triceps. The forms of muscle activity in both groups are explained below. Furthermore the result of ANOVA test was summarized in **Table 2**.

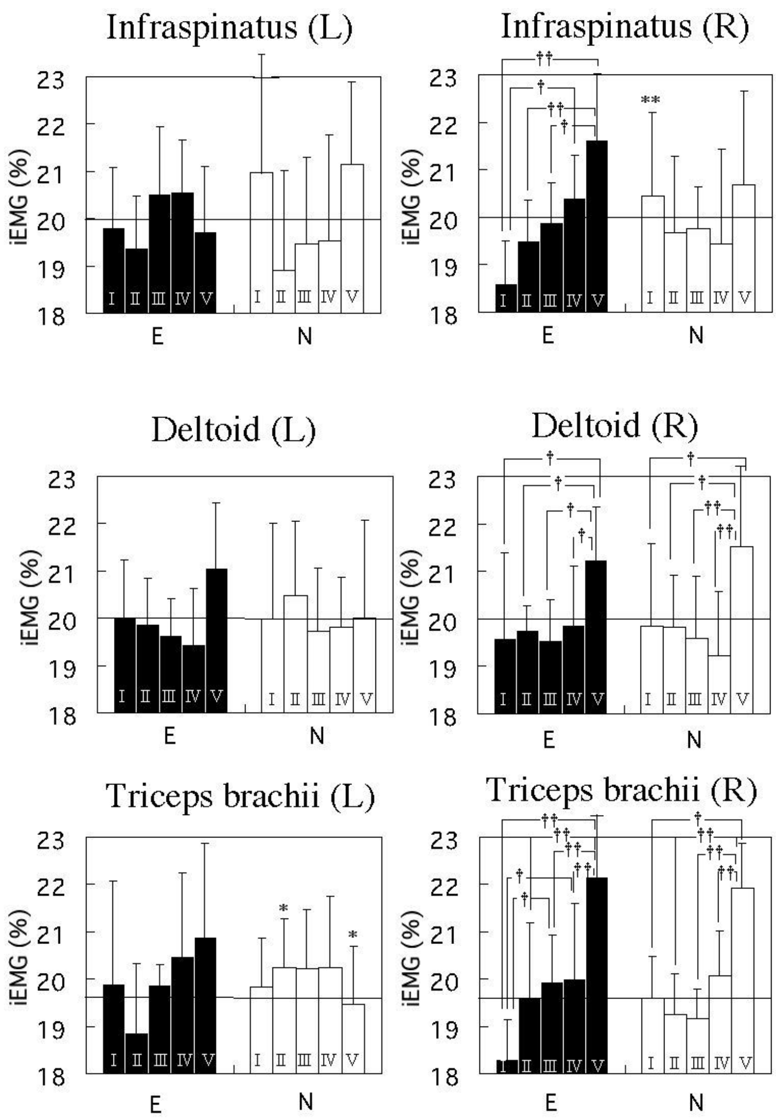

Fig. 5 Muscle activity patterns in each muscle group one second before completion of daisan. Asterisks indicate results of post-hoc test and the significant difference from the group E; *: $p < 0.05$, **: $p < 0.01$, and between intervals; †: $p < 0.05$, ††: $p < 0.01$.

Table 2 Summary of 2-way ANOVA test on forms of muscle activity during the one-second period before completion of daisan.

	Factor		
	Main effect		Interaction
Parameter	Group	Interval	Group*Interval
Infraspinatus (L)	NS	NS	NS
Infraspinatus (R)	NS	$p < 0.01$	$p < 0.05$
Deltoid (L)	NS	NS	NS
Deltoid (R)	NS	$p < 0.001$	NS
Triceps brachii (L)	NS	NS	$p < 0.01$
Triceps brachii (R)	NS	$p < 0.001$	NS

NS indicates that the finding was not significant, while *p* values are included for significant results ($p < 0.05$).

1) Infraspinata

For the %iEMG of the five intervals, there was almost no difference between group E and group N with regard to the left infraspinatus. Furthermore, the results of the ANOVA revealed that there was no significant main effect or interaction between the groups and the interval. However, with regard to muscle activity in group N, two main tendencies were seen, namely, muscle activity tended to either decreases or fluctuates greatly as the intervals progressed.

Next, a difference was seen between the groups in the form of the activity of the right infraspinatus. In group E as the intervals progressed, activity increased, while in group N, no pronounced change could be seen throughout the five intervals. However, as with the left infraspinatus, either a decrease in activity or a large fluctuation in activity was observed.

ANOVA showed a significant main effect of interval (F [4,70] = 3.335, p<0.01) and a significant interaction between group and interval (F [4,70] = 2.702, p<0.05).

2) Central deltoid region

In the central region of the left deltoid, a large increase in activity was seen in the fifth interval (interval V) of group E, while almost no fluctuation was seen in group N. On the other hand, with regard to the right deltoid, a large increase in activity was seen during interval V in both groups. ANOVA showed a significant main effect of interval (F [4,70] = 5.532, p<0.001).

3) Triceps

With regard to the triceps, a general increase in muscle activity was seen in the left triceps in group E, while activity in group N remained almost constant throughout the five intervals period. ANOVA showed a significant interaction between group and interval (F [4,70] = 3.698, p<0.01).

With the right triceps, both groups should a large increase in activity during interval V, and a significant main effect of the interval was seen (F [4,70] = 10.247, p<0.001).

3. Muscle activity patterns in hikiwake

Muscle activities in hikiwake are shown in **Fig. 6**. Overall, a difference was seen between the two groups in the activity of the infraspinata and central deltoid region. The form of each muscle activity for groups E and N are discussed below. Furthermore the result of ANOVA test was summarized in **Table 3**.

1) Infraspinata

In both groups similar activity was seen on both the left and right infraspinatus. In group E, however, with the exception of interval I, almost constant values were obtained, while in group N a decrease in values was seen as hikiwake came close to completion. ANOVA showed both a significant main effect of interval (F [4,70] = 12.630, p<0.001) and a significant interaction between group and interval (F [4,70] = 3.036, p<0.05) on the left infraspinatus. For the right infraspinatus, a significant interaction was shown between group and interval (F [4,70] = 7.255, p<0.001).

2) Central deltoid region

For the muscle activity of the central deltoid region, with the exception of interval I, almost constant values were obtained on both sides in group E, while in group N, an increase was seen as each interval progressed. However, no significant interaction of group and interval was seen on either side, but a significant main effect of the interval was obtained (Left: F [4,70] = 8.349, p<0.001, Right: F [4,70] = 9.428, p<0.001).

3) Triceps

Similar changes in the triceps were seen on both the left and right side. In other words, on the left side, with the exception of interval I, similar muscle action was seen, and as the intervals progressed, the action increased, giving a significant main effect of the interval (F [4,70] = 11.176, p<0.001). In contrast, on the right side an increase in muscle activity was seen as the intervals progressed, and a significant effect of interval was obtained (F [4,70] = 29.716, p<0.001).

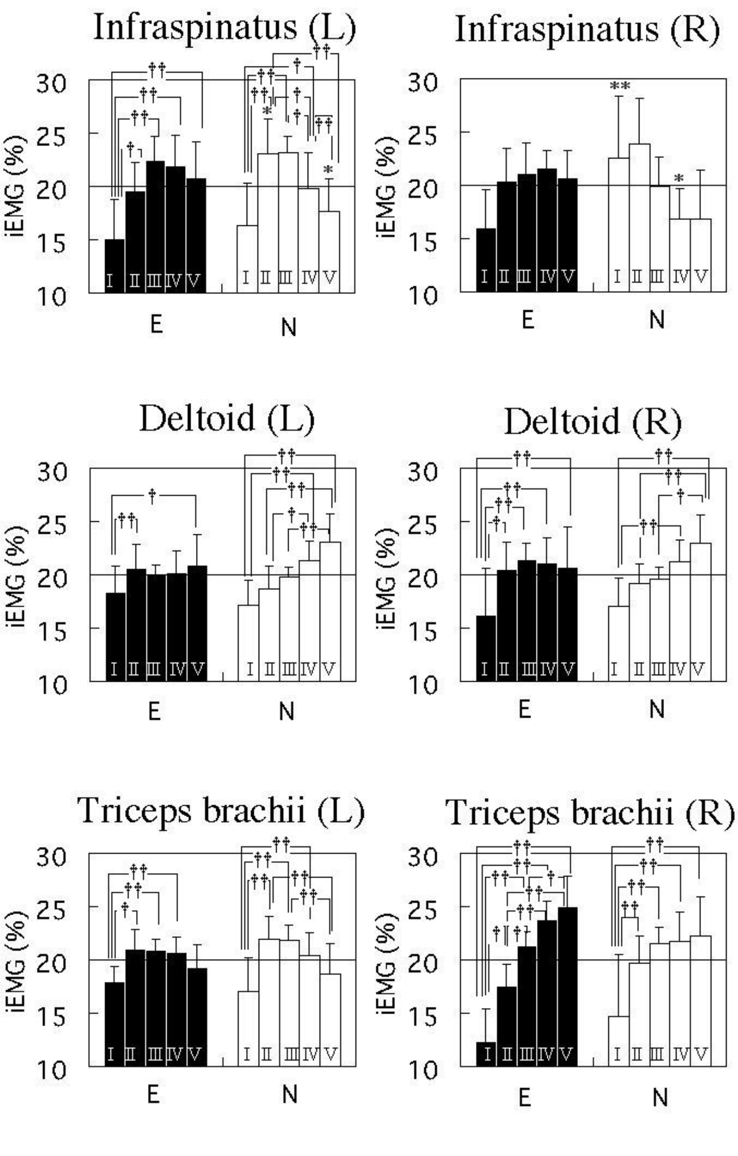

Fig. 6 Muscle activity patterns in each muscle group during hikiwake. Asterisks indicate results of post-hoc test and the significant difference from the group E; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, and between intervals; †: $p < 0.05$, ††: $p < 0.01$.

Table 3　Summary of 2-way ANOVA test on forms of muscle action during hikiwake.

	Factor		
	Main effect		Interaction
Parameter	Group	Interval	Group*Interval
Infraspinatus (L)	NS	$p < 0.001$	$p < 0.05$
Infraspinatus (R)	NS	NS	$p < 0.001$
Deltoid (L)	NS	$p < 0.001$	NS
Deltoid (R)	NS	$p < 0.001$	NS
Triceps brachii (L)	NS	$p < 0.001$	NS
Triceps brachii (R)	NS	$p < 0.001$	NS

NS indicates that the finding was not significant, while p values are included for significant results ($p < 0.05$).

IV. Discussion

1. Validity about the analysis method of EMG

The muscle activity during one-second before completion of daisan activates statically, and is in the state of the preparation of hikiwake. Therefore, probably there will be no problem in dividing this stage into five and analyzing EMG.

Expediently, hikiwake movement was also equally divided into five intervals (I-V), and EMG was analyzed. In this analysis method, the left and right infraspinatus muscle activities differed between group E and group N. Furthermore, the time of hikwake movement was almost the same between both groups. However, it is not clear whether the speed at which each subject carries out the movement is the same. Therefore, in hikiwake, although the fine difference between groups might have gone undetected for other muscles than infraspinatus, we could recognize muscle activity patterns for each group.

2. Movement of the shoulder joint during drawing the bow

The process of shooting the bow consists of many continuous movements. However, during daisan, hikiwake and kai, as the movement progresses, more strength is necessary to resist the restoring force of the bow and bowstring. In particular, in order to maintain the state of the bow being pulled into full draw, kai, a few seconds of isometric muscular exertion takes place, leading to hanare. In order to be able to proceed to a mechanically stable kai with little vibration, it is necessary to draw the bow smoothly during daisan and hikiwake.

Furthermore, as well as the above-mentioned actions, the movement of the elbow and shoulder joint is also important. Above all, the horizontal extension of the shoulder joint plays the most decisive role. The reason for this is that while during daisan the main action is that of the extension of the left elbow, during hikiwake, through symmetrical horizontal extension of the shoulder joint, the bow can be pulled out even further. The shoulder joint is an extremely mobile, multi-axial ball and socket joint allowing three-dimensional movement (extension, abduction/adduction, inner rotation /external rotation). Because of this, achieving motor control to stabilize the shoulder joint is difficult, and it is considered a ready expression of the difference in level of skill of the player.

In this study, there will probably be a difference in the form between expert and novice players evident from the video picture. In expert players, without a left shoulder joint moving in daisan not much, the left hand with a bow was calmly slid to the ground and parallel, and was extending the left elbow joint. Moreover, in order to maintain the elastic energy produced by pushing a bow with the left hand, expert's right hands were hardly changing from the position, which set up both hands in front of the forehead. The muscle around a right shoulder seemed not to be used in excess then. Both shoulder joints were abducted at an angle of 90 degrees, which was seen to be changeless. In such a state, hikiwake was completed by working equally the left-hand side that pushed a bow, and the right-hand side that pulled a bowstring.

On the other hand, in the novice players, a left shoulder joint also moved at the same time as extension the left elbow joint. Moreover, the distance of the right hand and forehead cannot be kept constant. This might mean that an arrow was not parallel to the straight line which connected the acrominal processes of right and left, and the tip of an arrow might turn to the right, i.e., bodily front, rather than the target which is aiming. As such, the shoulder on either side may be symmetrically located neither by sagittal plane nor frontal plane, and the movement direction of a shoulder joint on either side may not be the same. Moreover, it seemed that most beginners' players exercise their muscle around the right wrist too much.

In this study, the main active muscle groups involved in the movement of shooting the bow: the infraspinata situated in the trunk of the body, the triceps situated in the upper arm, and the central deltoid region, operating the movement of extroversion to extension of the shoulder joint, are measured. From an anatomical point of view, the infraspinatus originates in the fossa infraspinata of the shoulder blade and stops at the greater tubercle of the humerus and reinforces the shoulder joint capsule [Nakamura and Saito (1996)]. The central deltoid region starts from the acromion and has an area of stoppage in the central exterior humerus.

With regard to the caput longum of the triceps, it begins in the infraglenoid tubercle of the shoulder blade and stops at the olecranon, working two joints. All of these muscles are concerned with movement of the shoulder joint and are considered to play an important role in the drawing of the bow.

Therefore in this study, with regard to these muscle groups, the percentage change of muscle activity during the preparation period for hikiwake, namely the one-second period before completion of daisan was analyzed.

3. Differences in the muscle activity patterns with regard to skill level

Although analysis of operation had not been carried out, the reproducibility of operation seems an important skill in *Kyudo*. Since the durations of uchiokoshi, daisan, and hikiwake had mastered the almost the same and fixed rhythm, group E is conjectured that reproducibility of movement is also high. Moreover, in both the groups, the durations of uchiokoshi, daisan and hikiwake had no significant difference between the shots, and group N may also have the reproducibility of a beginner. In this study, the drawing weight of the bow is 12 kg. Although this weight is close to the drawing weight of use for subjects of group N, the load is large and there is a possibility that a joint movable region is limited for them.

Below, average muscular activity pattern of the group E and group N is considered.

1) Muscle activity patterns one-second period before completion of daisan

In this study a noticeable difference was seen in the right infraspinatus and the left triceps with regard to skill level. First of all, with regard to the infraspinata, while the final one-second of the activity of the left infraspinatus is almost constant in veterans, it is unstable in beginners. While daisan involves extending the elbow to push open the bow, at the same time to avoid the opened bow being returned to it original position, the right hand, which holds the bowstring is not moved, and the transition to hikiwake is made. In this state, the stress put on the muscles of the right side gradually increases. Consequently, the muscular activity levels in interval I differed significantly between groups. In veterans, the action of the right infraspinatus increases, while in beginners, like the left infraspinatus, it is unstable, and the fact that beginners cannot exercise stable muscle power with regard to the power of the bow is demonstrated.

Next, when looking at the triceps, it can be seen that, as with the right infraspinatus, an increase in muscle activity in veterans tends to exist. Put simply, this increase in muscle activity is due to the extension of the left elbow. However, it can be considered that by strengthening the elbow joint leading to increased muscle activity and fixation of the shoulder joint, a smoother transition to the next movement of hikiwake can be obtained. Anatomically, the triceps are divided into three heads, the infraglenoid tubercle of the shoulder blade, the posteromedial humerus, and the posterolateral humerus, each having a different region of origin and ending in the olecranon [Nakamura and Saito (1996)]. In particular, the caput longum, which starts from the infraglenoid tubercle of the shoulder blade, operates two joints and supports the extension and adduction of the shoulder joint. In this study, the EMG was derived from the caput longum, which was instrumental in the movement of the shoulder joint, and it can be inferred that it stabilized the shoulder joint and elbow to counteract the bowstring returning to its original position. Therefore, in Group N, it is guessed that reduction of muscular activity is not suitable in interval V.

2) Muscle activity patterns in hikiwake

The main movement of hikiwake is the horizontal extension of the shoulder joint. In veterans for the left and right infraspinatus, with the exception of the first interval, almost constant values were obtained and the movement was stable. From this it is known that in veterans the infraspinata become stabilized early on in the hikiwake movement and remain stable until it is finished, leading to the horizontal extension of the shoulder joint. In contrast, in group N, it is inferred that significant decreases in the last interval of the left side and the fourth interval of the right side are not desirable. In advanced research it has been reported that the dorsal muscles are the main muscles used in the drawing of the bow [Kamei et al. (1971), Karasawa (1976)] and the results of this study support this.

On the other hand, it can be inferred that since the muscle activity of beginners decreases in the latter half, when the process of hanare is reached, the strength exercised at the beginning of hikiwake is reduced.

Regarding the deltoids, as with the infraspinata in veterans, with the exception of the first interval, almost constant values were obtained. From this it can be inferred that upon drawing the bow, horizontal extension of the shoulder joint is most important, and in veterans during hikiwake, the middle part of both the left and right deltoids are activated early on in the movement leading to adequate extension of the shoulder joint.

Next, with regard to the triceps, in order to further extend the elbow during daisan, it may be thought that no large difference was seen between the groups. However, with regard to the right triceps in the veteran group, a large increase in muscle action was shown as the intervals increased. In hikiwake, the right elbow is inflected. Despite this, the fact that muscle activity increased in veterans demonstrates that hikiwake occurs with the shoulder joint being central to it. In other words, as with the one-second period before completion of daisan, the triceps are instrumental in moving the shoulder joint and are assumed to work to stabilize the shoulder joint and elbow so that the force of the bow drawn by the dorsal muscles, such as the infraspinata, does not return to its original position.

With regard to the hikiwake movement above, the movement of the left and right infraspinata, in particular, took place in an early stage and simultaneously maintained stability. As a result, the dorsal muscles are used early on in the movement emphasizing the importance of simultaneous activity on both sides to extend the shoulder joint horizontally.

4. The importance of the dorsal muscles in shooting the bow

In this study it is indicated that during daisan and hikiwake, the activity of the infraspinata is extremely influential to performance through the drawing of the bow. When the bow is being drawn, it is necessary to extend the shoulder joint horizontally, both left and right in a uniform manner. For this to occur, the muscles working to extend the shoulder horizontally must be stable on both sides at the same time. However, since the shoulder joint is the most mobile of the joints, it is difficult for beginners to stabilize the shoulder joint and draw the bow.

In this study the importance of the activity of dorsal muscles during the shooting of the bow, and in particular during daisan and hikiwake is shown. By applying these results to teaching, it may be possible to have beginners, or those at a low level who only use the power of their arms to draw the bow, develop a more stable movement in an early stage and also reduce the burden on the muscles involved in the movement of the elbows and wrists.

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