SPATIAL AND TEMPORAL MOVEMENT PATTERNS OF THE SHOULDER JOINT IN BALLET DANCERS TO EXPRESS THE FLATTERING SWAN

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The purpose of this study was to characterize both spatial and temporal patterns of the shoulder joint movement in the upper limb motion when ballet dancers are performing the flaps of swan wings. Twenty-three expert female dancers (Dance group) and 21 inexperienced age-matched females (Control group) participated in the study. Thirty-three reflective markers were attached to the trunk and upper limbs, and then the upper limb motion in the "Swan Lake" was captured with 8 optical cameras. The spatial and temporal characteristics of movement pattern of angular displacements with time were calculated to compare between groups. As a result, the shoulder joint movements of each group showed different movement pattern especially in horizontal flexion/extension and internal rotation. Therefore, the internal rotation of shoulder joint in arm downward movements and horizontal extension of shoulder joint in arm upward movements would be one of the fundamental skills to perform the swan wings expression.

KEY WORDS: motion analysis, expression, arm kinematics, dancer, ballet.

INTRODUCTION: In some artistic athletic movements and dance movements, arms might play a role to add aesthetical characteristics. In rhythmic gymnastics and figure skating, artistic aspects are included in the criteria for evaluation (Uratani 2014). In ballet, dancers have to perform their movements, especially with arms to express emotion or a role on the stage. In previous study, it was reported that trained dancers can express different emotion such as joy, sadness and anger in the upper limbs with different kinematic characteristics (Sawada et al., 2003). Therefore, it is supposed to be important to understand biomechanical characteristics of arm movements with expression in dancers to enhance performance. However, As far as we know, no study has examined the biomechanical characteristics of upper limbs movements of ballet dancers.

So the purpose of this study was to characterize the movement pattern of the upper limb motion especially for the shoulder joint when ballet dancers are performing the flaps of the swan wings in Swan Lake by comparison with the movement patterns of age-matched controls.

METHODS: Twenty-three expert female dancers (Dance group: age = 21.0 ± 2.4 year; height = 160.3 ± 5.6 cm; weight = 49.1 ± 3.9 kg; experience = 14.9 ± 3.2 year) and twenty-one age-matched females without any previous dance experiences (Control group: age = 22.8 ± 1.2 year; height = 156.8 ± 5.7 cm; weight = 48.7 ± 4.6 kg) participated in the study.

Thirty-three reflective markers were attached to the head, trunk and upper limbs (forehead, temporal region of head, manubrium, C7, anterior superior iliac spine, center of superior articular process, anterior/ posterior shoulder, center of upper arm, medial/lateral elbow, center of forearm, medial/lateral wrist, metacarpophalangeal joint of index finger, metacarpophalangeal joint of middle finger, metacarpophalangeal joint of little finger and tip of medial finger), and then the motion of the upper limb usually performed by dancers in the "Swan Lake" was captured with 8 optical cameras (Vicon Nexus1.8.5, Vicon Motion Systems Ltd, 250Hz). Each subject performed a total of 12 trials (4 trials * 3 sets) with the sound of the metronome. Subjects took a break of 30 seconds per set. Prior to the experiment, control group were asked to watch the video images of "Swan Lake act2" to understand the motion of the upper limb in this study. No further instructions including verbal instructions were provided to the participants. All subjects provided informed consent in accordance with the University's Institutional Review Board.

Shoulder joint angles (abduction/adduction, horizontal flexion/extension, external/internal rotation) were calculated from the coordinates of the markers. All movement components were defined following the ISB recommendations (Wu et al., 2005). Angular displacement of shoulder joint in three directions were set 0-degree in anatomical position and averaged. The trajectories of average angular displacements indicated on the 3-dimensional Cartesian coordinate system were compared between groups (Dance group vs. Control group).

RESULTS: Figure1 to 3 showed the group ensembles of spatial and temporal characteristics of shoulder joint angles in each group. The broken line indicates a 0-degree for each axis. The movement pattern of Dance group was represented by bold line, Control group was indicated by thin line. Those figures were made from the same 3-dimensional figure with the shoulder joint angle in the three dimensions as each axis of the figures: i.e. abduction/adduction, horizontal flexion/extension and external/internal rotation.

Figure 1 showed the relationship between shoulder abduction/adduction and horizontal flexion/extension. Both groups showed similar trends of shoulder joint angle in each direction. However, on the other hand, Dance group showed larger shoulder internal rotation than that of the Control group, while the Control group moved their upper limbs only in external rotation (Figure 2). Figure 3 showed the relationship between external/internal shoulder rotation and horizontal flexion/extension. Dance group showed the same degree of range of motion in the maximal shoulder joint angle of horizontal flexion and extension. Moreover, the maximal shoulder joint angle of horizontal extension in Dance group was larger than that of Control group during arm upward movements, while the maximal shoulder joint angle of horizontal flexion in Dance group was smaller than that of Control group in arm downward movements. Thus, the shoulder joint movements of each group showed different movement pattern especially in horizontal flexion/extension and internal rotation.

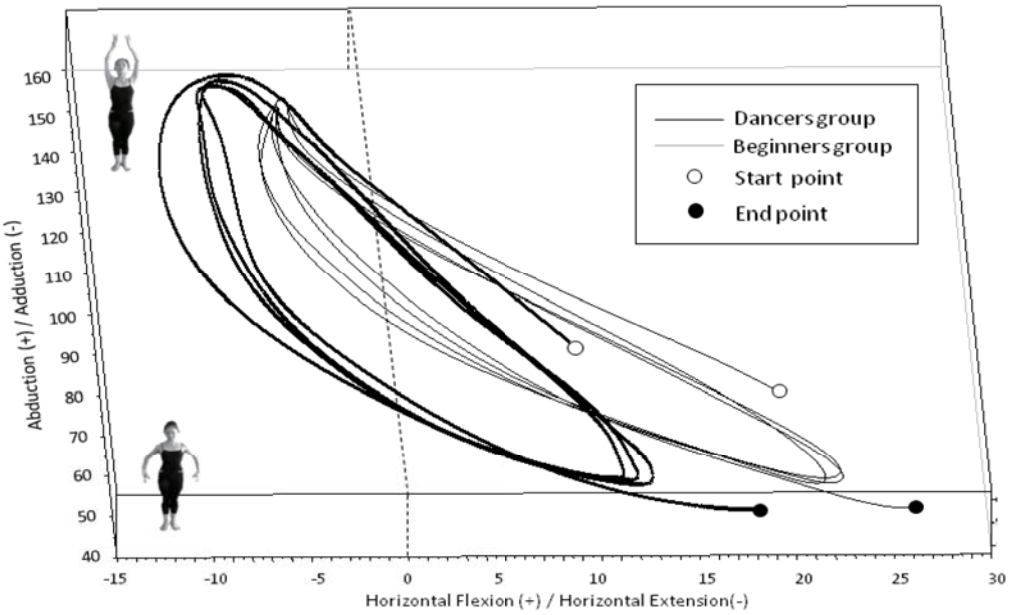

Figure 1: The relationship between horizontal shoulder flexion/extension and abduction/adduction in each group.

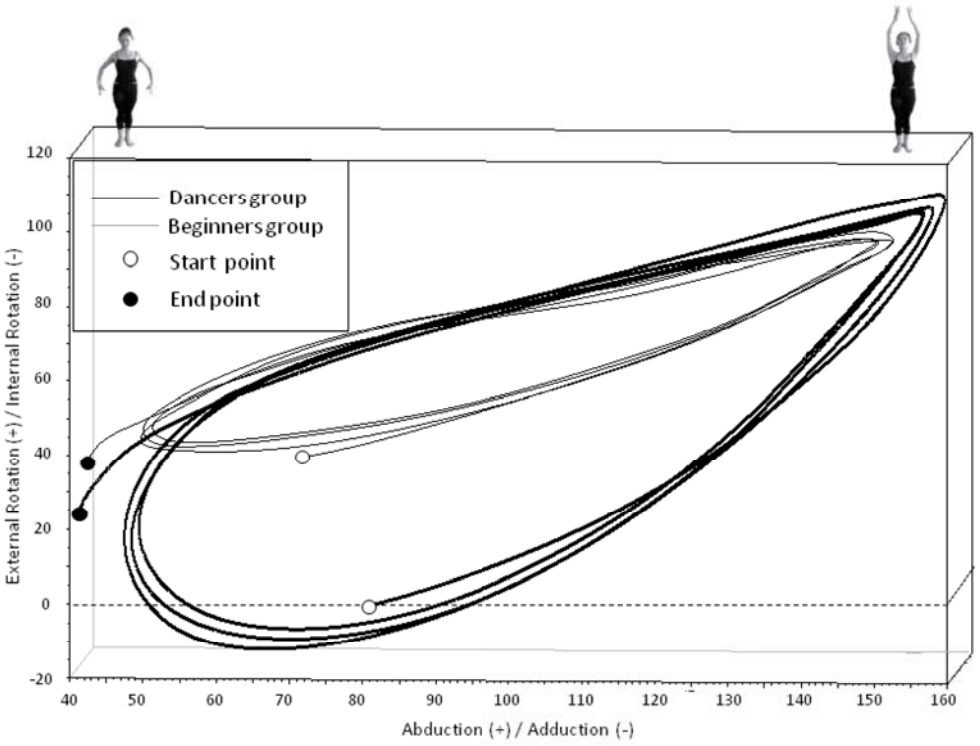

Figure 2: The relationship between shoulder external/internal rotation and abduction/adduction in each group.

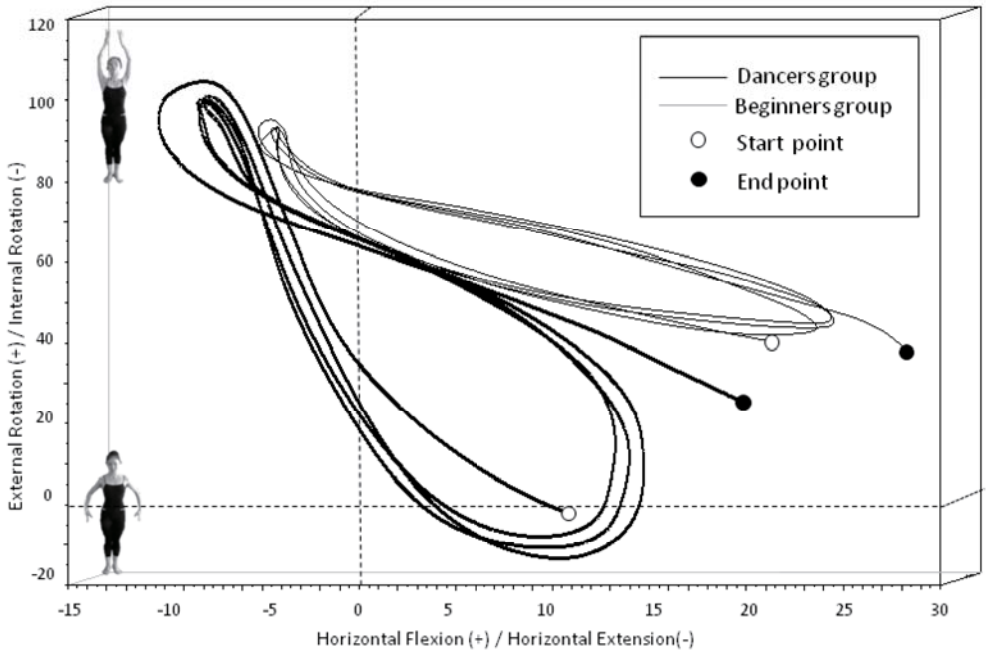

Figure 3: The relationship between shoulder external/internal rotation and horizontal flexion/extension in each group.

DISCUSSION: Our study had two major findings. Firstly, Dance group showed larger shoulder internal rotation than that of the Control group. Secondly, the maximal shoulder joint angle of horizontal extension in Dance group was larger than that of Control group in arm upward movements, while the maximal shoulder joint angle of horizontal flexion in Dance group was smaller than that of Control group in arm downward movements.

Nakagawa *et al.*(1989) reported that external rotation occurred with abduction and horizontal flexion in normal movement of the shoulder. However, the internal rotation of the shoulder joint in Dance group occurred with the abduction of the shoulder joint. We consider that Dancer could move the upper limb in the internal rotation, in order to express the flaps of swan wings by long succession of practice. These results suggest that the internal rotation of the shoulder joint was an important role of performing the swan wings expression by the arms.

In this study, the motion of the upper limb was accompanied with the thumb facing anteriorly. Furthermore, ballet dancer is required to control the scapula elevation during the movement of upper limbs. As for the second result, it is considered to be difficult for dancers to move their shoulder in horizontal extension during arm upward movements. Therefore, the internal rotation and horizontal extension of shoulder joint in arm upward movements would be a necessary skill to perform the swan wings expression. In addition, it is common knowledge that the scapula motion occurs in concert with the movement of the upper limbs (Nakagawa *et al.*, 1989; Tanaka *et al.*, 1994; Ludewig *et al.*, 1996). Based on this fact, further study is needed to examine the scapula motion of ballet dancer with their shoulder movements.

CONCLUSION: In this study, the spatial and temporal characteristics of movement patterns of Dance group were examined by comparison with Control group. As a result, Dance group showed larger shoulder internal rotation than that of the Control group, while the Control group moved their upper limbs only in external rotation. Moreover, the maximal shoulder joint angle of horizontal extension in Dance group was larger than that of Control group in arm upward movements, while the maximal shoulder joint angle of horizontal flexion in Dance group was smaller than that of Control group in arm downward movements. Therefore, the internal rotation and horizontal extension of shoulder joint in arm upward movements would be one of the fundamental skills to perform the swan wings expression.

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