Difference of COM-COP Inclination Angle while Performing Ballet Turn (*pirouette en dehors*) in Novice and Experienced Dancers

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SUMMARY

*Pirouette*, whole body rotation, is an important task in ballet. However, the learning process of *pirouette* is prolonged and easily leading to injury. Thus, the purpose of this study was to evaluate the difference between novice and experienced ballet dancers while performing *pirouette in en dehors*. There were five phases in *pirouette*, preparatory, double-leg support, single-leg support in pre-swing, single-leg support in mid-swing, and ending phases. The experienced dancers had longer duration but smaller center of mass (COM)–center of pressure (COP) inclination angle in pre-swing phase than novice dancers. The experienced dancers also had less push-off force in double-leg support phase. Thus, proper force exertion and without hasty pattern are suggested to novice dancers while performing *pirouette in en dehors*.

INTRODUCTION

Ballet is a performing art. Dancers practice ballet techniques hardly to achieve particular aesthetic requirement. *Pirouette*, whole body rotation in single-leg support, is one of the techniques used very often. Dancers often start to practice the turning task around age of ten and improve the skill through continuous efforts. The method to improve the turning skill includes observing demonstration in ballet teachers, imitating the movement pattern by guesswork, and practicing repeatedly via trial-and-error. However, the ineffective learning process prolongs the practice time, thus the fatigue and injury may occur. Ballet teachers also sense of powerlessness in teaching a high-skilled movement. Thus, to verify the difference in postural control between novice and experienced dancers while turning is necessary for dancers and dance educators.

The relationship between COM and COP had used to clarify the postural stability [1]. The COM-COP inclination angle was also used to detect the postural stability between elderly and young population in obstacle crossing [2]. Therefore, the purpose of this study was used to COM-COP inclination angle and other biomedical parameters to verify the difference in postural control while performing ballet turns between novices and experienced ballet dancers.

METHODS

Subjects
Six female dancers participated in this study, 4 experienced dancers in the experienced group (E group; age: 21.3 ± 4.6 years old; ballet experience: 12.3 ± 1.9 years; height: 166.7 ± 6.5 cm; weight: 54.5 ± 12.7 kg) and 2 novice dancers in the novice group (N group; age: 13.0 ± 0.0 years old; ballet experience: 4.5 ± 3.5 years; height: 162.7 ± 8.0 cm; weight: 47.8 ± 2.5 kg). Dancers in the experienced group had self-reported ability of *pirouette* at least two revolutions. Subjects in the novice group had self-reported ability in *pirouette* at least one revolution but did not achieve two revolutions. Dancers will be excluded if they have lower extremity injury that limited their performance and vestibular problems.

Instrumentation

Three-dimensional (3-D) videographic data was collected while each subject executing tasks. The 3-D acquisition system with eight Eagle CCD cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) was used to collect the real-time 3-D trajectory of the makers on each subject at sampling rate of 200 Hz. The markers were placed on each subject followed by a modified Helen-Hays marker set. Two Kistler force plates (Kistler Instrument Corp., Winterthur, Switzerland) was synchronized to record the ground reaction force signals at 1000 frames per second. The customized wood plates (size: 0.8 m*0.6 m*0.4 m) were mounted on each force plate to expand the working area. The vinyl floor, which was the usual material of floor using in ballet classroom, was well attached on the wood plate to mimic the environment of real ballet classroom.

Data reduction and analysis

All participants performed one revolution, and dominant leg support with *en dehors* (left leg support with turning in clockwise direction or right leg support with turning in counter-clockwise direction). The *pirouette* task had five phases, preparatory, turning with double-leg support, turning of single-leg support in pre-swing, turning with single-leg support in mid-swing, and ending phases (Figure 1).
The COM-COP inclination angle was calculated both in anterior-posterior (AP) and medial-lateral (ML) directions relative to trunk during pirouette (Figure 2). The parameters of COM-COP inclination angle for analyzed were maximum anterior and posterior angle in AP direction, and range of inclination angle in AP and ML direction of each phase. The variables of interest were the duration in each phase, peak ground reaction force (GRF, normalized by body weight (BW)) on supporting leg and gesture leg in double-leg support phase, and the parameters of COM-COP inclination angle in each phase. The parameters of COM-COP inclination angle were the maximum anterior and posterior angle, and range of inclination angle in AP and ML directions. The non-parametric analysis, Mann-Whitney test, was used to detect differences between groups in the duration, peak GRF, and parameters of COM-COP inclination angle in each phase. The statistical significance was set at 0.05. All statistical analyses were performed using SPSS 17.0 (SPSS for Windows, Chicago, IL, USA).

RESULTS AND DISCUSSION
The experienced dancers had greater total movement time than novice (E: 2.22 ± 0.39 s; N: 1.61± 0.43 s; p = .032). The difference should result from the pre-swing phase because no significant difference was found in other four phases. In the pre-swing phase, dancers must transfer their COM from double-leg support to single-leg support, which was critical for pirouette. The experienced dancers may carefully transfer their COM to align with COP in the vertical direction than novice. This result to a degree was consistent with the results of maximum anterior of COM-COP inclination angle in the same phase (Table 1). The greater anterior inclination angle was found in the novice group than experienced group. The novice dancers may use a hasty pattern in this phase to transfer COM in the AP direction. Thus, the novice dancers may overshoot the COM over COP, and cause a greater anterior COM-COP inclination angle. This may result from excessive push-off force prior to pre-swing phase (double-leg support phase).

Novice dancer had greater push-off force in the gesture leg in double-leg support phase than experienced group (E: 0.83 ± 1.20 BW; N: 1.18 ± 0.26 BW; p=0.007). We suggested that the excessive push-off force in the gesture leg causes COM to overshoot anteriorly than COP. The novice group also had significantly greater AP inclination angle during double-leg support phase. The major movements in double-leg support phase were upper extremity and trunk rotation motion. The motion should be based on the proper postural control so that the energy transferring through upper extremities could be smoothly and efficiently to control the unstable trunk.

CONCLUSIONS
There were several differences of postural control between novice and experienced ballet dancers while performing pirouette, especially in the phases of double-leg support and single-leg support in pre-swing phases. Based on current findings, proper push-off force in the gesture leg and without hasty pattern in these two phases were suggested to novice dancers. However, this was only preliminary finding, and this study continues to recruit more participants for further analysis.

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