What do synergies do for “beauty” in ballet performance?

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INTRODUCTION

- Professional dancers perform “beautiful” movements on a stage by regulating stability properties of important body mechanics such as the center of mass (COM), head position, etc. Since, the ballet performances require moving and holding body segments at specific positions, the changes in stability properties during the sequence of statical and dynamical sub-actions may be a key factor for manifesting “beauty” in ballet performance.

- Recently, the computational method for the stability properties, so-called “synergy”, has been introduced, which quantifies the patterns of co-variation between the involved elements to a particular performance (e.g., joint angles to whole boy COM). Current study attempts to quantify synergy indices for the stabilization of the whole body COM for the high quality performance of professional ballet dancers during passe- arabesque.

METHODS

I. SUBJECTS

- Four female professional ballet dancers (ballet careers: 19.5 ±2.87yrs; height: 165.5±3.84cm; weight: 47±4.69kg; age: 26±2.74yrs) and 4 amateur dancers (ballet careers: 5.8±2.86yrs; height: 164.7±4.32cm; weight: 52.8±5.5kg; age: 24.7±2.05yrs) participated in this study.

II. EQUIPMENT

- Motion capture : 8 infrared cameras (Oqus 500, Qualisys, Sweden) and sampled at 100 Hz.

III. EXPERIMENTAL PROCEDURES

- All participants were performed 10 repetition of required movement leading from the ballet 5th position to passé and arabesque (Figure 1).
- The instructor controlled all trials to be performed with the same music a time signature of 3/4 and 96 beat/min (~30sec).

(A) 5th position (B) Passe (C) Arabesque

Figure 1. Arabesque sequence: (A) 5th position, (B) Passé, (C) Arabesque.

IV. ANALYSIS

1. Performance error - Mean standard deviation (MSD)

- MSD: Mean standard deviation (MSD) of whole body COM position data for professional and amateur dancers during passe- arabesque movement

2. The whole body CoM stabilization strategies index (ΔV)

- Uncontrolled manifold (UCM) analysis was performed to analyze synergistic patterns in elemental variables (segment angles) for the stabilization of the whole body COM position.
- The geometric model for the computation of COM trajectory was composed of 11 segmental angles including the left and right foot, shank, thigh, trunk, upper arm, and lower arm (Black, D. P. et al.,2007).
- The variances of time series within two subspaces, V_{UCM} (UCM space) and V_{ORT} (ORT space).
- The synergy index (ΔV) was quantified by the equation (Scholz et al., 2003).

$$\Delta V = \frac{V_{UCM}/DOF_{UCM} - V_{ORT}/DOF_{ORT}}{V_{TOT}/DOF_{TOT}}$$

DOF_{UCM} = DOF of UCM, DOF_{ORT} = DOF of ORT, DOF_{TOT} = Total DOF

RESULTS AND DISCUSSION

I. Performance error

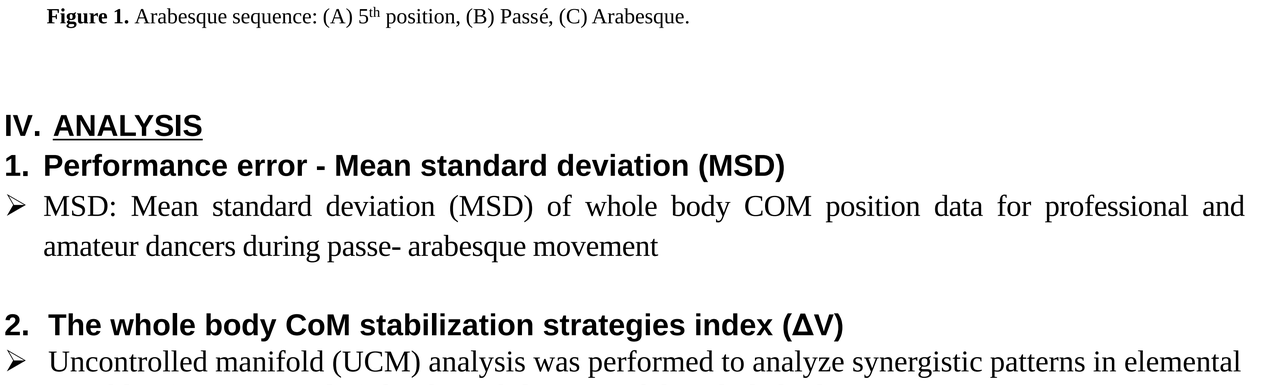

Figure 2. Mean standard deviation (MSD) of whole body COM position data for professional and amateur dancers during passe-arabesque movement in anterior-posterior direction (sagittal plane) (A), medial-lateral direction (frontal plane) (B), and vertical direction (transverse plane) (C). X-axis represents the time normalization of the total performance.

- <Figure 1> shows the performance variability of the professional and amateur dancers in the anterio-posterior(A-P), medial-lateral(M-L), and vertical(VT) direction.
- The professionals dancers showed lower variability than that of amateur dancers. This means that the ability of the professional dancers to perform movements was excellent.
- Especially in A-P direction, it shows a tendency to large differences between the two groups (Figure 1-A).

II. The whole body CoM Stabilization strategy

- In the A-P direction, the stability control strategy through UCM analysis showed differences between two groups in passe- arabesque phase (P1).
- The two groups showed similar solution space (index in UCM variance) (Figure 2-A), but the amateur dancers showed a large error with large ORT variance (Figure 2-B).
- ΔV calculated as the difference between the variance UCM and ORT indicated that the professional dancers are using a coordination of segment angles to stabilize the whole body COM during weight shift phase (P1).
- For ballet aesthetics in arabesque, it is necessary to control in the A-P direction because the gesture legs must be raised to the backward of the body 90 degrees and the upper body must be kept parallel to the gravity line during weight shift (Pedersen, 2006).
- Therefore, this result suggests that the control in A-P direction can be proposed as a strategy for successful arabesque performance.

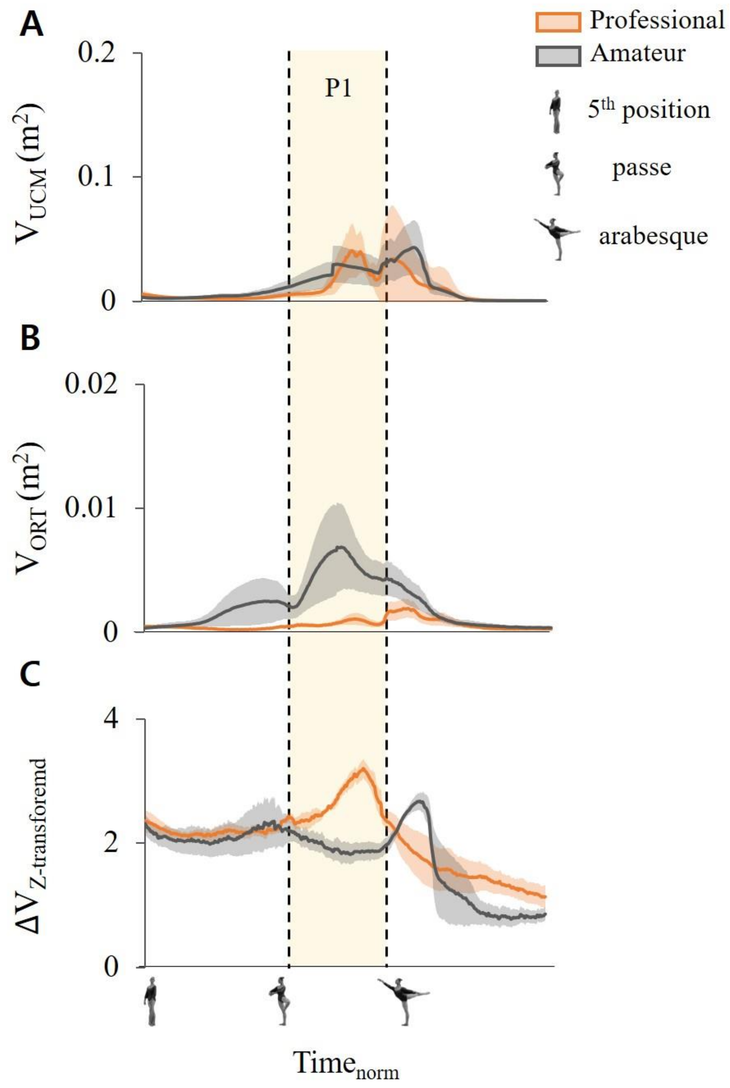

Figure 3. The whole body CoM stabilization strategies index calculated from UCM analysis. Variance UCM with good variability(A), Variance ORT with bad variability (B) and index of synergy with ΔV (C). P1 is the section between dotted lines that is the passe-arabesque phase with weight shift. X-axis represents the time normalization of the total performance.

CONCLUSION

- The current study showed that professional dancers control their strategies with synergistic patterns for whole body CoM stabilization during high quality performance.

REFERENCE

Black, D. P., Smith, B. A., Wu, J., & Ulrich, B. D. (2007). *Uncontrolled manifold analysis of segmental angle variability during walking: preadolescents with and without Down syndrome.* Experimental brain research, 183(4), 511-521.

Pedersen, C., Erleben, K., & Sporring, J. (2006). *Ballet balance strategies. Simulation Modelling Practice and Theory*, 14(8), 1135-1142.

Scholz, J. P., Kang, N., Patterson, D., & Latash, M. L. (2003). Uncontrolled manifold analysis of single trials during multi-finger force production by persons with and without Down syndrome. Experimental Brain Research, 153(1), 45-58.

ACKNOWLEDGEMENT

- This work was supported in part by the Ministry of Science and the National Research Foundation of Korea (NRF-2019R1F1A1061871), the Creative-Pioneering Researchers Program through Seoul National University (SNU), and the Nano Material Technology Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (No .2016M3A7B4910552).