Biomechanical Comparison of Waltz Movements of a World Competitive Ballroom Dance Champion Couple and Ordinary Dancers

Yasuyuki Yoshida[1], Arunas Bizokas[2], Katusha Demidova[2], Shinichi Nakai[3], Rie Nakai[3], Mio Suzuki[1] and Takuichi Nishimura[1]

[1]*Artificial Intelligence Research Center, National Institute of Advanced Industrial Science and Technology, 2-4-7 Aomi, Koto-ku, Tokyo, Japan*

[2]*Non-affiliated*

[3]*Dance Jordin, 2-3-13 Sunnou, Ota-ku, Tokyo, Japan*

1 OBJECTIVES

The waltz is a popular ballroom dance worldwide. Competitive dance consists of Latin American and ballroom dances. Ballroom dance includes waltz, tango, Viennese waltz, slow foxtrot, and quickstep. The salient characteristic of ballroom dances is the closed hold position, with close interaction between dancers.

Some earlier studies have examined ballroom dance. Only one report (Prosen, 2013) describes a study of biomechanics. Prosen (2013) compared Viennese waltz movement skills of highest-ranked and lowest-ranked couples at an international competition. However, the movements of a current world competitive ballroom dance champion couple are going to be examined in this study. Results from comparing the movements of the world competitive ballroom dance champion couple and ordinary dancers can provide beneficial information for dancers of diverse age and skill groups including elderly recreational dancers acting as preventive health care. Furthermore, the findings of the highest quality of dance movements are applicable for preventing injury, improving performance and promoting health in society.

This study was conducted to investigate and compare the world competitive ballroom dance champion couple with ordinary dancers, specifically examining interaction during waltz movements.

2 METHODS

2.1 Preliminary Experiment for Error

2.1.1 Participants

As ordinary competitive dancers, one man (1.64 m body height; 48 kg body mass) and one woman (1.51 m; 50 kg) participated.

2.1.2 Instruments

Male dancer waltz movements were recorded at 240 Hz using an Xsens system (MVN, Xsens Technologies, Netherlands) (Faber, 2016; Robert-Lachaine, 2017), which comprises 17 inertial measurement units (IMUs) attached to the feet, shanks, thighs, pelvis, sternum, head, upper arms, forearms, and hands (Figure 1). A portable optical motion capture system (Bicam; Crescent, Japan) consisting of two cameras with tracker software (Vicon Bonita; Vicon Systems, UK) was used at 240 Hz.

2.1.3 Setup

Song title ‘Without You’ was selected for waltz to play at 29 bars per minute from the album ‘Ballroom Symphony’ (Casa Musica, Germany).

To construct a rigid body 23-link MVN model, the segment lengths of participants were input into the software (MVN Studio; Biomech 2018). To reduce soft tissue artefacts, the IMUs were set by a purpose-built suit. The IMUs for the feet bound by straps over shoes (Figure 1). Subsequently, the upright posture (N-pose) and walking movements were recorded for the MVN model calibration. The Bicam system was

Yoshida, Y., Bizokas, A., Demidova, K., Nakai, S., Nakai, R., Suzuki, M. and Nishimura, T.
Biomechanical Comparison of Waltz Movements of a World Competitive Ballroom Dance Champion Couple and Ordinary Dancers.
In *Extended Abstracts (icSPORTS 2018)*, pages 6-9

also calibrated. Four reflective markers were set on the head of the male dancer.

2.1.4 Protocol

The ballroom dance steps for the waltz were employed with the music as a trial.

(1) Preparation Step (123123)

(2) First Half of the Natural Spin Turn (123)

The man and woman danced together using a closed hold position. The trial was repeated ten times.

Figure 1: The IMUs were set with a purpose-build suit (left). The IMU was strapped over a shoe (right).

2.1.5 Data Analysis

The timing of maximum preparation, first and second step lengths were picked up using the position data of the foot and the toes from the Xsens system. The position of the head corresponding to the timing of the maximum step lengths was picked up from both Xsens and Bicam systems. Subsequently, the head displacement was calculated using the Pythagorean theorem. The displacement of both systems were compared.

2.2 Experiment

2.2.1 Participants

The current world competitive ballroom champion couple, one man (1.85 m body height; 76 kg body mass) and one woman (1.72 m; 59 kg), participated in this study. As described in the preliminary experiment section, ordinary competitive dancers participated: one man and one woman. No participant had any history of lower limb injury or neurological disorder. They wore their own ballroom dance shoes. The study adhered to guidelines set out by the National Institute of Advanced Industrial Science and Technology

2.2.2 Instruments

Two Xsens IMUs sets were used for the dancers. During dancing together, the IMUs acted in synchronization.

2.2.3 Setup

A ballroom dance studio was used for the experiment. The same waltz song as that used for the preliminary experiment was used.

2.2.4 Protocol

The ballroom sequence dance steps for the waltz were used with the music as a trial.

(1) Preparation Step (123123)

(2) Natural Spin Turn (123123)

(3) Second half of Reverse Turn (123)

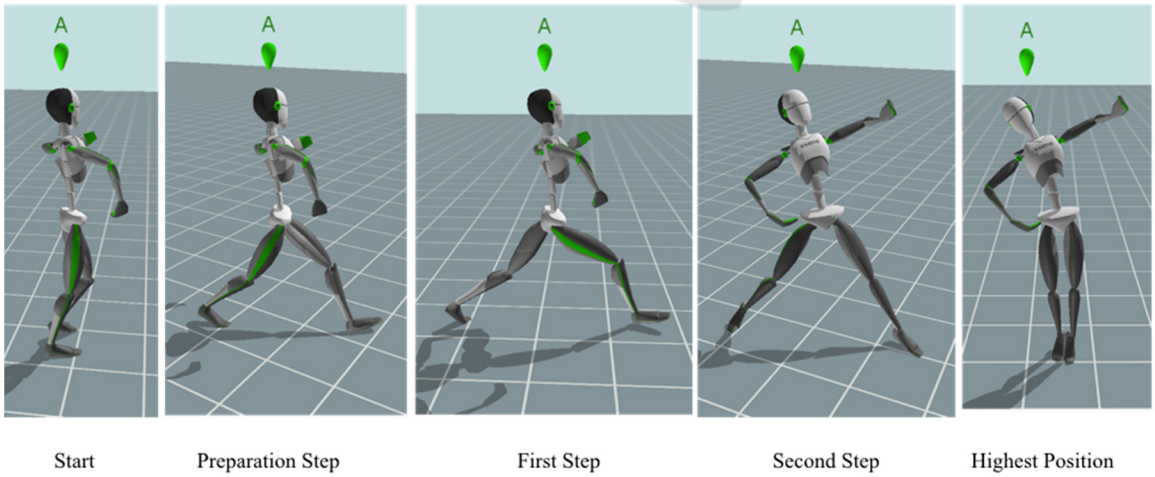

Figure 2: Sequence of the first half of the natural spin turn with preparation step.

First, the man danced alone. Then the woman danced alone. Finally, they danced together using a closed hold position. The trial was repeated five times.

2.2.5 Data Analysis

For each trial, the records of the preparation step to the first half of natural spin turn were used for additional analysis (Figure 2). The position, velocity, and joint angle were calculated using MVN software. Furthermore, step lengths were calculated using the position data of the feets.

3 RESULTS

Table 1 presents results of the errors between the Xsens and BICAM systems. Errors for the preparation step, first step, and second step lengths were approximately 0.01 m during the first half of natural spin turn including preparation.

Table 2 shows the step lengths of the preparation step, first step, and second step during the first half of the natural spin turn including preparation. For comparison pair dancing and dancing alone, the step length of the second is similar to that of the first step for the champion male dancer in pair dancing condition. Comparison of step lengths between the champion male dancer and the ordinary male dancer revealed that the step length normalized by height and leg length for the champion male dancer is greater than that of the ordinary male dancer in both pair dancing and dancing alone conditions.

Figure 3 depicts an example of the pelvis height normalized by body height during the first half of natural spin turn including preparation. The end of data is the highest position of the pelvis. Figure 3 above presents a comparison of the champion male dancer and the ordinary male dancer. At around zero to 0.5 s. the height of the ordinary male dancer was lower than that of the champion male dancer. After that, the height of the champion male dancer was lower than that of the ordinary male dancer. Figure 3 below presents a comparison of pair dancing and dancing alone for the champion male dancer. The height of the pair dancing is lower in the first half than dancing alone.

Table 1: Mean and standard deviation of measurement errors for head displacement with Xsens and BICAM systems.

	Preparation Step (m)	First Step (m)	Second Step (m)
mean	0.0132	-0.0114	0.0124
SD	0.0148	0.0196	0.0168

4 DISCUSSION

Precision accuracy compared with optical motion capture systems for IMUs is one difficulty of this study problem (Zhang, 2013; Blair, 2018). For that reason, measurement errors were evaluated in the preliminary experiment. In some earlier studies, segment angles were evaluated. However, the errors for displacement were not addressed. The errors of this study were approximately 0.01 m. Therefore, the results advocate the use of IMUs to quantify ballroom dance movements.

Distinct interaction during pair dancing was found in the second step for the first half of the natural spin turn. In addition, the longer step length might be an important skill for competitive ballroom dancers. The first half of natural spin turn, as in the first half of natural turn, is a common step for both competitive dancing and recreational dancing.

Rise and fall (Alex, 2002) is a fundamentally important movement in waltz dancing. Comparing a champion male dancer with an ordinary male dancer, the movement range of pelvis height of the champion

Table 2: Mean and standard deviation of step lengths during the first half of natural spin turn including preparation.

			Preparation Step (m)	First Step (m)	Second Step (m)	Preparation Step (%Height)	First Step (%Height)	Second Step (%Height)	Preparation Step (%Leg Length)	First Step (%Leg Length)	Second Step (%Leg Length)
Champion male dancer	Pair	mean	1.03	1.21	1.18	55.91	65.29	63.97	108.88	127.15	124.57
		SD	0.03	0.03	0.02	1.61	1.54	1.29	3.14	3.00	2.51
	Alone	mean	0.97	1.23	1.06	52.23	66.36	57.47	101.71	129.22	111.91
		SD	0.01	0.04	0.03	0.59	2.29	1.40	1.15	4.46	2.72
Ordinary male dancer	Pair	mean	0.73	0.84	0.96	44.34	51.22	58.55	88.62	102.37	117.04
		SD	0.02	0.02	0.02	1.23	1.08	1.46	2.45	2.17	2.93
	Alone	mean	0.70	0.86	0.83	43.03	52.38	50.86	86.02	104.70	101.65
		SD	0.03	0.01	0.04	1.72	0.73	2.27	3.44	1.47	4.54

male dancer is larger. In addition, comparison of pair dancing and dancing alone reveals that the pelvis was lower for pair dancing in the first half. Another interaction of pair dancing was apparent for pelvis lowering movement.

An important imitation of this study is the number of participants. Therefore, future studies must examine greater numbers of participants. Findings of this study might be beneficial for people of many age and skill groups including elderly people and highly ranked competitive dancers for preventing injury, improving performance and promoting health.

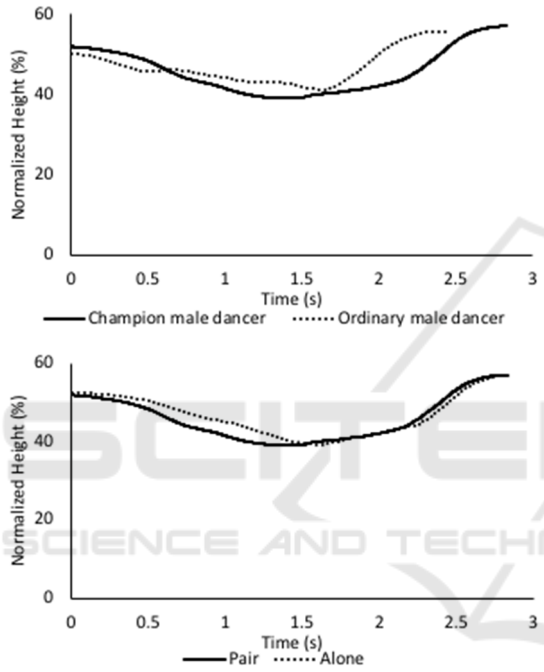

Figure 3: Pelvis height during the first half of the natural spin turn with preparation. The champion male dancer and the ordinary male dancer (above). Pair dancing and dancing by himself with the champion male dancer (below).

ACKNOWLEDGEMENTS

This paper is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

REFERENCES

Alex, M., 2002. 'Ballroom Dancing', Routledge.

Blair, S., Duthie, G., Robertson, S., Hopkins, W. & Ball, K., 2018. 'Concurrent validation of an inertial measurement system to quantify kicking biomechanics in four football codes', *Journal of Biomechanics*, vol.73, pp.24-32.

Faber, G. S., Chang, C. C., Kingma, I., Dennerlein, J. T. & van Dieën, J. H., 2016. 'Estimating 3D L5/S1 moments and ground reaction forces during trunk bending using a full-body ambulatory inertial motion capture system', *Journal of Biomechanics*, vol. 49, no. 6, pp. 904-912.

Prosen, J., James, N,, Dimitriou, L., Perš, J. & Vučković, G., 2013. 'A Time-Motion Analysis of Turns Performed by Highly Ranked Viennese Waltz Dancers', *Journal of Human Kinetics*, vol. 37, pp. 55-62.

Robert-Lachaine, X., Mecheri, H., Larue, C. & Plamondon, A., 2017. 'Accuracy and repeatability of single-pose calibration of inertial measurement units for whole-body motion analysis', *Gait & Posture*, vol. 54. pp. 80-86.

Zhang, J. T., Novak, AC., Brouwer, B. & Li, Q., 2013. 'Concurrent validation of Xsens MVN measurement of lower limb joint angular kinematics', *Physiological Measurement*, vol. 34, pp. N63-N69.