Trajectory Analysis of the Natural Turn Movement Used in Ballroom Dance

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ABSTRACT

The aim of this study is analysis of short term demonstrations of the natural turn movement used in ballroom dance by trajectory analysis of video data. A high speed digital camera (1/240 s per frame) was sufficient to resolve the minute differences between the movement of a professional dancer and an amateur dancer. The analysis of video data using the two-dimensional trajectory analysis software confirmed that attaching light emitting diode (LED) lamps to the neck, elbow, waist, and knee was an effective method for determining the precise position of body parts. The trajectory data revealed a clear accent in the movement of the professional dancer, unlike the case of the amateur dancer. Further, the neck position and trunk angle of the professional dancer was very stable. The movement of a couple (male and female) was also analyzed. This revealed that the movement of the upper part of the dancer's body was strongly affected by the existence of the partner. Our study demonstrates that a simple video analysis is an effective method to improve ballroom dance movements and that this method can be used even in a small dance studio.

Keywords: *video analysis, two-dimensional, natural turn, education*

INTRODUCTION

Ballroom dance is a popular sport with a long history dating back to the 12th century (Raymond et al., 2005; Wyon et al., 2007; Hopper et al., 2011). From children to the elderly and from professionals to amateurs, the variety in the population of ballroom dancers is large. In 2011, dancing became a compulsory subject at junior high schools in Japan. Therefore, the development of convenient educational methods that can be used even at junior high schools or small dance studios, and not only at large institutions, is an important research subject. In fact, it is impressive that dance, as a form of exercise, is taught at a very large number of small dance studios. Thus, designing new educational methods that only require small and low-cost equipment is probably an effective approach to facilitate the application of these methods to small studios.

Competitive ballroom dance is an important field in dance sport. It is an official event at the World Games and is supported by the International Olympic Committee. There are many competitive ballroom dance events for not only professional dancers but also amateur dancers. These competitions provide motivation to a wide range of dancers. In competitive ballroom dance, precise movements are required to obtain high scores. If a method can verify proper dance movements in detail, it would be useful for training competitive ballroom dancers.

The progress in video recording techniques has drastically changed the training methods of various sports (Chen et al., 2009; Yu et al., 2009; Duarte et al., 2010; Chang and Lee, 1997). In particular, video analysis of baseball and football has been used extensively over the last ten years (Bebie & Bieri, 2000; Thomas, 2007; Chen et al., 2010). Further, some reports have focused on trajectory analysis using the video data, especially in baseball (Theobalt et al., 2004; Graham, 2007; Chen et al., 2008) and football (Yu et al., 2006; Ren et al., 2009). By precisely visualizing the trajectory of the movements, improvements in the movements can be easily realized. Although the advantages of video analysis and trajectory analysis using video data are obvious, we could not find any studies that applied such methods to ballroom dance. Only a few very recent papers have demonstrated the analysis of ballet movements using video (Wyon et al., 2011).

In this work, we analyzed in detail the movement of the natural turn, which is one of the basic ballroom dance movements, by two-dimensional (2D) trajectory analysis. In particular, we focused our analysis on a short period of movement (3 s) that was recorded by a commercially available high speed camera (1/240 s per frame), and analyzed using 2D video analysis software. The use of light-emitting diode (LED) lamps to pinpoint the neck, elbow, waist, and knee positions was demonstrated to improve the accuracy of the analysis.

MATERIALS AND METHODS

Test subjects: Two Japanese adult men (Subject 1 and 2) and a Japanese adult women (Subject 3) performed the natural turn movement as test subjects. Subject 1 (S1), subject 2 (S2), and subject 3 (S3) hold a professional standard C, amateur standard C, and amateur C license, respectively, and the licenses were authorized by the Japan Ballroom Dance Federation (JBDF). S1, S2, and S3 had 7, 2, and 2 years of ballroom dancing experience, respectively. This study was approved by the Institutional Human Experimentation Committee. The informed consent was obtained from all the subjects by documents.

Recording of movement: The natural turn movements performed by S1 and S2 were recorded with a digital camera (EXILIM EX-FH25, CASIO Co., Tokyo, Japan) as AVI format files. The shutter speed was 1/240 s per frame. The movement duration was 2.5 to 3 s. To check for reproducibility, five natural turn movements were recorded per subject. Further, the experiment was repeated one month after the first experiment. During the recording, small LED lights (GENTOS LED HELP LIGHT, HC-12SL, SAINT GENTLEMAN Co. Ltd., Tokyo, Japan) were attached at the fifth cervical vertebra (neck), the olecranon (elbow), the fifth lumber vertebra (waist), and on the knee cap (knee) of the subjects during some trials in order to pinpoint the positions of the neck, elbow, waist, and knee.

Trajectory analysis: The positions of the neck, elbow, waist, and knee of each subject were determined using 2D video analysis software (Move-tr/2D 7.0, Library Co., Tokyo, Japan) with the centroid mode (Murase et al., 2011, Murase et al., 2012). The trajectories of each body part were drawn using the same software. The velocity, acceleration, and angle of the trunk of the body were calculated based on the determined positions.

RESULTS

Figure 1 shows the setup used in our experiments. In each experiment, the subject (S) moved from left to right. This movement direction was defined as the *x* axis, and the distance travelled was 300 cm for both a single test subject and a couple. A digital camera was located on the right side of the subject. The distance between the camera and the center position of the subject's course was 250 cm and 310 cm for a single test subject and a couple, respectively. The movements of the subjects were recorded by the camera, and then analyzed using the 2D trajectory analysis software.

A series of snapshots of the natural turn movement are shown in Fig. 2. The movement was completed in almost 3 s, and the video was comprised of a series of still images that were captured 240 times per second. The LED lights attached at the neck, elbow, waist, and knee can be observed as bright spots in each image. Using the 2D video analysis software, the positions of each LED in each image were determined. The positions of the neck and elbow, elbow and waist, and waist and knee were connected with straight lines. The time course of the LED positions and the lines connecting the positions revealed a substantial amount of information.

In order to verify the reproducibility of the analysis, the video recording experiment was performed five times. Figure 3 shows the average trajectory of the five trials. The standard deviation of each data point is indicated by the black bands. The standard deviations of the neck, elbow, and waist movements were rather small for both S1 and S2, as shown in Fig. 3(a) and (b), respectively.

Figure 4 shows the velocity profile of each LED. The velocity is calculated from the derivative of the positions, and thus, detailed characteristics of the velocity profile can be highlighted. The velocities of neck, elbow, waist and knee were repeated increase and decrease even within 3 seconds both in S1 and S2.

To evaluate the fluctuations in the movement of the trunk of the body, an angle analysis was carried out (Fig. 5). For the angle analysis, the neck and elbow positions were connected by a straight line. Then, the angle between this line and a normal to the floor was determined. In both of S1 and S2, the angle was increased according to time, however, the profile was not similar in the two subjects.

Finally, we applied the trajectory analysis to a pair of test subjects as they danced (S2 and S3). In this case, the movement of the female (S3) was monitored. Figure 6 (a)–(c) shows a series of snapshots of S3 without S2. S3 wore LED lights on the left side of her body. Further, similar snapshots of S2 and S3 are shown in Fig. 6 (d)–(f). In this case, both S2 and S3 wore LED lights. The trajectories of the neck, elbow, waist, and knee are superimposed in each picture.

The velocity profile of each LED during the pair dancing is shown in Figure 7. From the data recorded while the pair was dancing, the data representing the movement of S3 (female) are plotted.

DISCUSSIONS

Difference of trajectories between S1 and S2 can be discussed in Figure 2. At the origin (t = 0), in the case of S1 (Fig. 2(a)), the lines between the subject's neck, elbow, waist, and knee were almost perpendicular to the floor, although the subject's elbow was tilted slightly backward. However, in the case of S2 (Fig. 2(b)), position of the elbow was obviously located plane behind the subject's body, and the neck-elbow and elbow-waist angles were almost 90°. The difference between S1 and S2 is clearly visible in the pictures on account of the connecting lines.

At the mid-point of the movement, the elbow and knee locations of S1 and S2 differed. S1's elbow and knee were in front of and behind his body, respectively (Fig. 2(b)), whereas the reverse was true for S2 (Fig. 2(e)). The difference between the time that S1 and S2 reached the mid-point of the movement was only 0.26 s (time taken to reach the mid-point was 1.58 s and 1.32 s for S1 and S2, respectively), and the snapshot clearly illustrates the difference between the movement of S1 and S2.

At the final position, the complete trajectories of the neck and the elbow revealed valuable information. S1's neck followed a very slow arc trajectory, and his neck was tilted slightly downward at the mid-point of the movement. This suggests that S1's neck was almost at a constant height. In contrast, the trajectory of S2's neck was a large arc. This means that S2 squatted lower than S2 in the middle portion of the movement. The above data clearly demonstrate that S2 (amateur license) can identify problems with his movements by comparing his recorded data with the data of S1 (professional license) using this video analysis method.

Figure 3 revealed the reproducibility of the movements of S1 and S2. The averaged data of five times trials showed small standard deviations. This means that the movements of S1 and S2 did not fluctuate significantly across the five individual trials, and thus, each subject shows relatively consistent movements, even for a short movement. Figure 3(c) shows the trajectory of S1's movement that was analyzed using data from the experiment performed without the LED lights. In this case, the standard deviation values were very large, even for the neck, elbow, and waist positions. Clearly, wearing LED lights is an important technique for ensuring that the dance movement is traced accurately.

Figure 4 clearly showed difference of velocity profiles between S1 and S2. In the case of the neck velocity profile (Fig. 4(a)), S1's data contained three clear peaks. In the case of S2, although there were three peaks, the peaks were not clearly distinguishable. This difference likely indicates that S1 exhibited a more prominent accent in his movements even in short movement. Similar results were observed with the elbow data. Although two clear peaks were observed in S1's data, there was one large peak and fluctuations in S2's data. As we mentioned in relation to Fig. 2, S2 positioned his elbow behind his body (Fig. 2(d)), and the elbow pointed downward at the mid-point of the movement (Fig. 2(e)). The fluctuations in the velocity were probably related to the distortion of the trajectory of S2's elbow. For the waist profile, S1's data contained three clear peaks, as observed in the neck profile. This suggests that the movement of the neck and waist of S1 was synchronized, making his trunk movements very stable. The shapes of the neck and waist profiles for S1 were also similar. However, the peaks in the profile of S2's neck and waist were not clearly synchronized. For the knee profile, large differences in the velocity profiles of S1 and S2 were observed.

Figure 5 showed angle analysis during the natural turn movement. In the case of S1, the angle was almost zero at the beginning of the movement. The angle was within 5°until the mid-point of the movement. The angle then increased gradually to 10°by the end of the movement. However, the angle profile of S2 was completely different. The angle was almost 5°at the beginning of the movement. This suggests that the trunk of S2's body was not perfectly vertical i.e., not perpendicular to the floor, at the beginning of the movement. The angle increased to 25°in an undulating manner. The analysis clearly demonstrates the difference in angle of S1 and S2's trunk to the floor.

Figure 6 and 7 showed results of pair dancing. Trajectory analysis was possible even with the pair of subjects dancing, although sometimes, the LEDs on one dancer were hidden by the body of the partner. If perfect detection of the eight lights is expected, additional equipment such as a three-dimensional camera setup may be necessary. However, such a complicated system is beyond the scope of this work because we are trying to conceptualize a simple system that can be applied even at typical small studios.

Velocity analysis of the pair dancing was shown in Fig. 7. For the waist and knee, there is no significant difference between the data from the single dancer and pair of dancers. For the waist data, three clear peaks are observable in both cases (see the arrows in Fig. 7(c) and (g)). Similarly, three peaks are observable in the knee data (see the arrows in Fig. 7(d) and (h)). This indicates that movement of the waist and knee was not affected by the presence of S2.

On the other hand, movements of the neck and elbow were strongly affected by the presence of S2. In the case of the neck movements, when S3 performed the test movement alone, the LED was observed from 0 s to 2.3 s (Fig. 7(a)). The LED was then hidden, which was probably because of her body's rotation. However, when S3 performed the same natural turn movement with S2, the velocity profile changed dramatically (Fig. 7(e)). In this case, the LED was hidden from 0 s to 2 s. This suggests that the lateral angle of S3's neck was strongly affected by the presence of S2.

In the case of the elbow movement, the velocity profiles from 0 s to 1.1 s shown in Fig. 7(b) and (f) are almost the same, and show one small peak. However, the LED was hidden after 1.1 s when S3 danced alone. S3's arm was likely to have been heavily bent when performing alone.

The results suggest that the upper body of S3 was strongly affected by the interaction with S2 although the lower part of her body was not affected. The upper body of S3 was in direct contact with S2, and thus, the angle of the neck and elbow of S3 may have been strongly influenced by the presence of S2. This suggests that exercises with a partner are important to precisely study the ballroom dance movements of a subject.

CONCLUSION

Our results revealed that the characteristics of the natural turn movement used in ballroom dance can be analyzed using a commercially available video camera at a typical small dance studio. By analysis using a 1/240 s shutter speed, very minute differences between two subjects who had professional and amateur licenses could be clearly observed using a trajectory and velocity profile. We believe that this method can be applied in order to provide corrective ballroom dance instructions even at small dance studios and schools.

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FIGURE CAPTIONS

Figure 1

Setup for video recording of the natural turn movement used in ballroom dancing.

Figure 2

Series of snapshots of the natural turn movement. Trajectories of the neck, elbow, waist, and knee are superimposed. (a)–(c) and (d)–(f) are snapshots of the motion of S1 and S2, respectively.

Figure 3

Average trajectories of the five trials. The black bands indicate the standard deviations. (a) S1 with LED lights. (b) S2 with LED lights. (c) S1 without LED lights.

Figure 4

Velocity profiles of the neck, elbow, waist, and knee. (a)–(d) and (e)–(h) indicate velocity profiles of the motion of S1 and S2, respectively.

Figure 5

Angle change of the trunk of (a) S1 and (b) S2.

Figure 6

Snapshots of the natural turn movement. Trajectories are superimposed. (a)–(c) and (d)–(f) show snapshots of the single dancer and the pair dancing, respectively.

Figure 7

Velocity profiles of the neck, elbow, waist, and knee of S3. (a)–(c) and (d)–(f) show profiles corresponding to the single dancer and the pair dancing, respectively.

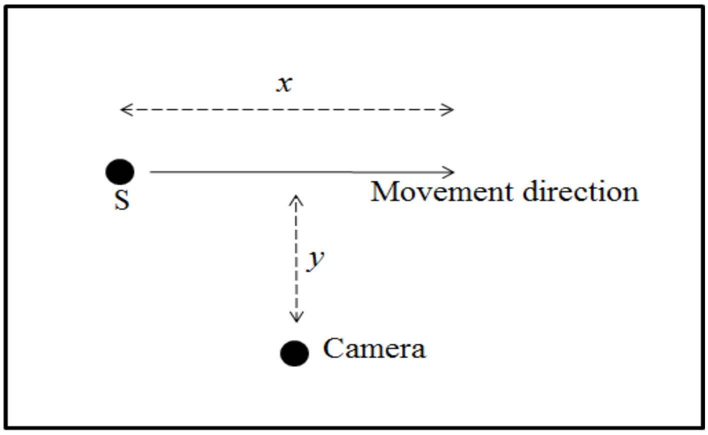


Figure 1 Umemura *et al*.

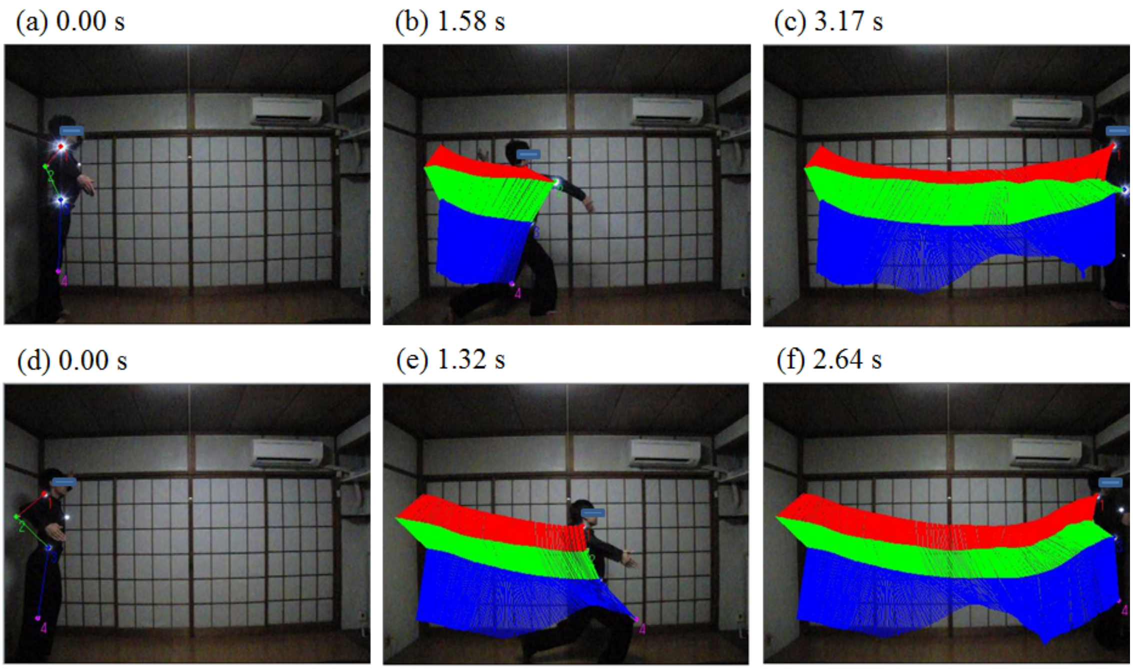
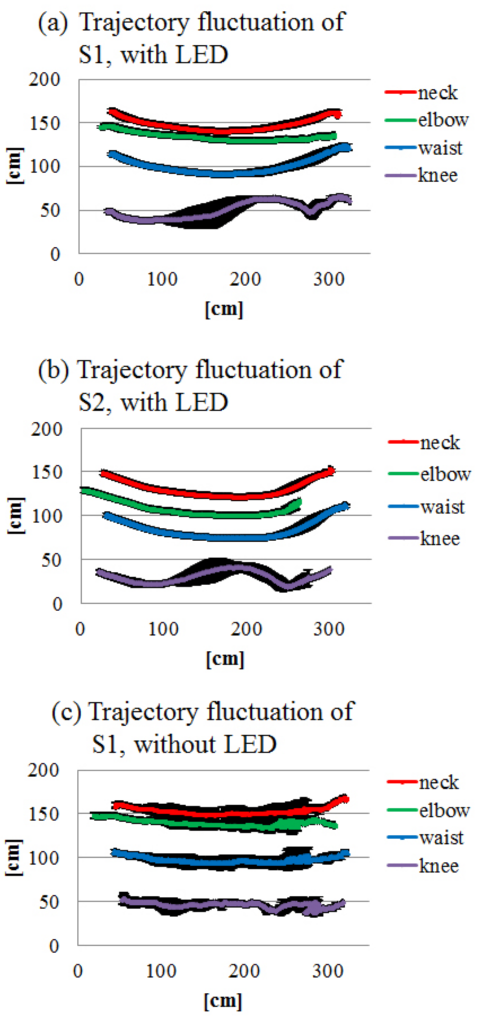


Figure 2 Umemura *et al*.



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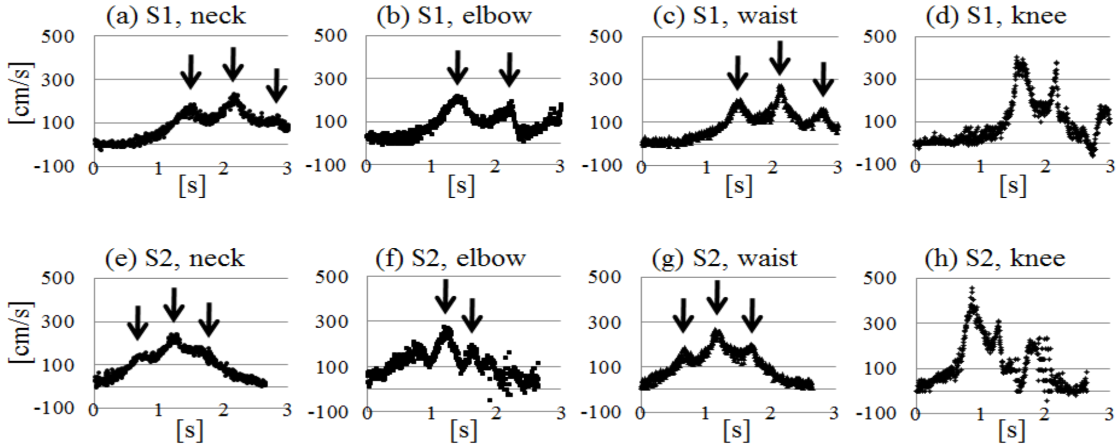

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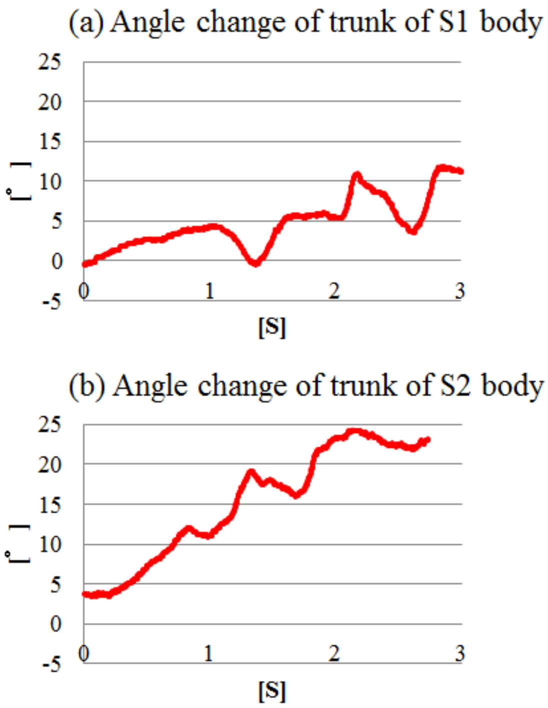

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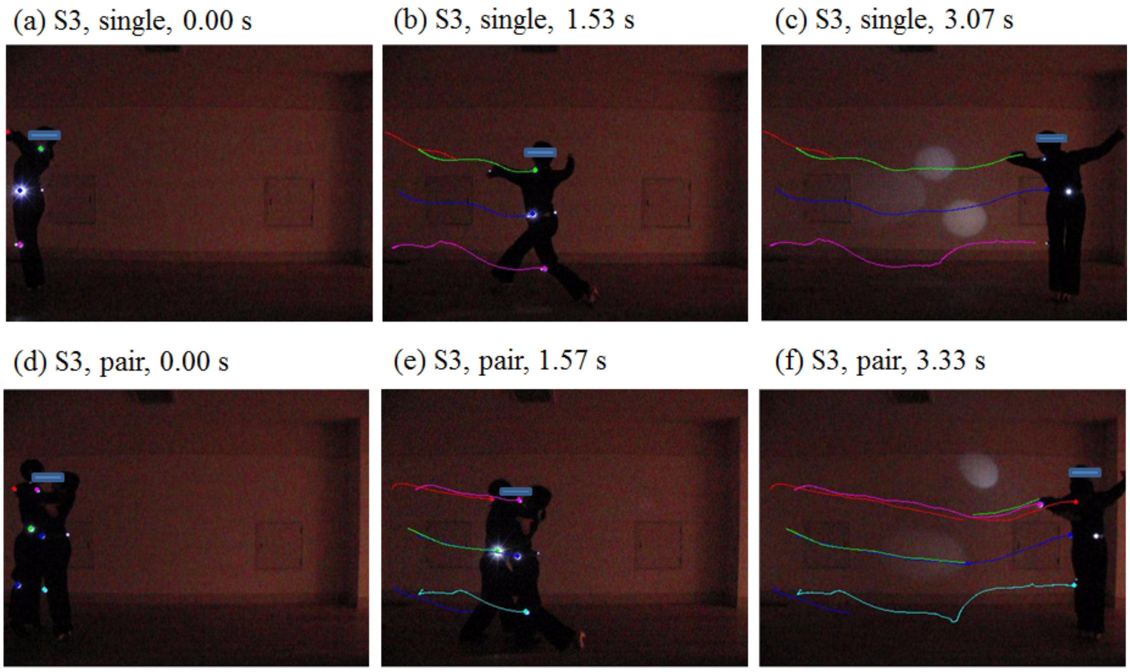

Figure 6 Umemura *et al*.

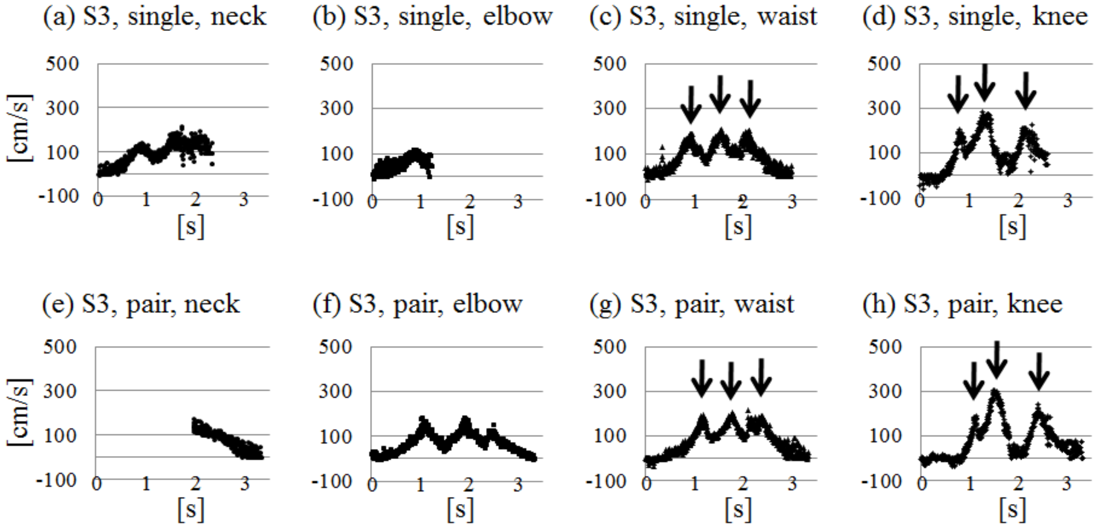

Figure 7 Umemura *et al*.