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Voluntary control of pelvic frontal rotations in belly dance experts

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Introduction

The "hip shimmy" belly dance movement is a rotation of the pelvis around the anteroposterior axis alternating the clockwise and counter-clockwise directions, together with the antiphase coordination of the lower limbs, i.e., alternating knee flexion and extension. Its main features can be characterised by wide and isolated movement of the pelvis in the frontal plane, at different controllable speeds and amplitudes, possibly resulting from underlying control mechanisms that are not observable in more common pedestrian tasks. Kinematic properties of the hip shimmy have been rarely documented in the literature.

Objectives

➤ investigate voluntary pelvic rotations and trunk coordination features :

1. assess whether the amplitude and stability of the frontal pelvic movement can be maximised in certain postural and frequency conditions.
2. characterise how the expected independent control of frontal pelvic from other trunk motions is frequency dependent.

Method

Participants

19 belly dance experts

Age	Height	Weight	BMI	Experience
30.3 ± 6.9 yrs	165.0 ± 0.1 cm	59.5 ± 7.0 kg	21.9 ± 2.3	11.1 ± 5.1 yrs



Experimental procedure

Two-minute standardized warm-up

Rhythmic Motor Task



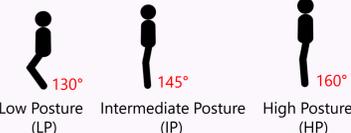
hip shimmy 12 s
widest pelvis amplitude possible in the frontal plane, while minimizing the upper trunk motion

hip shimmy video: <https://youtu.be/atR9YeW5fUc>

9 Conditions

3 postures (knee bending) × 3 frequencies

3 frequencies

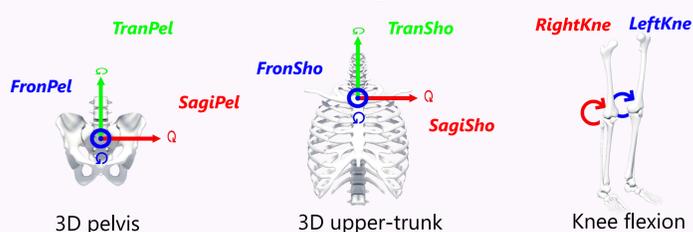


Qualisys optoelectronic system

8 cameras, 20 markers (kinematic data)



Joint Angles



Results

Pelvis : mean performance and variability in the frontal plane

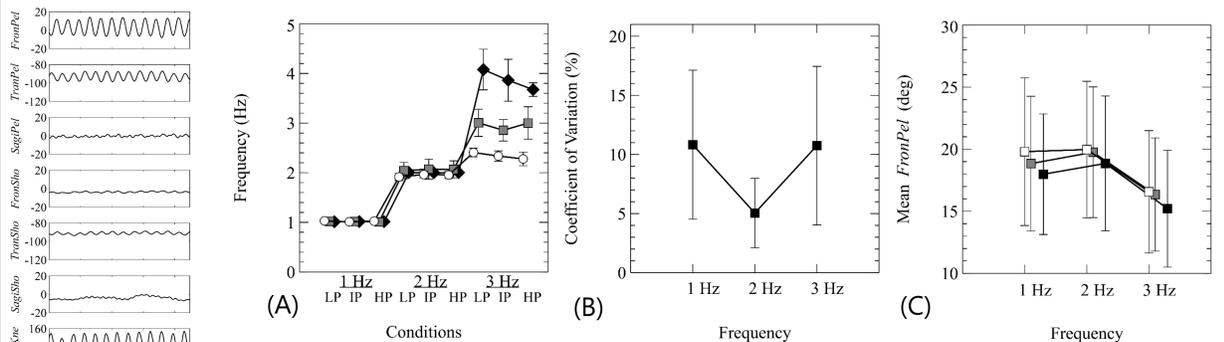


Figure 2.

(A) Mean performed frequency (\pm standard error) of frontal pelvic oscillation as a function of posture and frequency conditions. **Three groups differ at 3 Hz** according to their performance (white circle: F3- group, grey square: F3, black diamond: F3+).

(B) Mean (\pm standard error) coefficient of variation of frontal pelvic frequency as a function of metronome frequency. **It was lower at 2Hz* than at 1 Hz and 3 Hz.**

(C) Mean amplitude (\pm standard error) of pelvic motion in the frontal plane in all conditions as a function of metronome frequency (white square: Low Posture; grey square: Posture; black square: High Posture). **The pelvic amplitude was significantly smaller* in HP than in LP.**

Figure 1.
Joint angles in a hip shimmy trial of one participant (2 Hz, Low Posture)

Trunk coordination mode and stability (CRP)

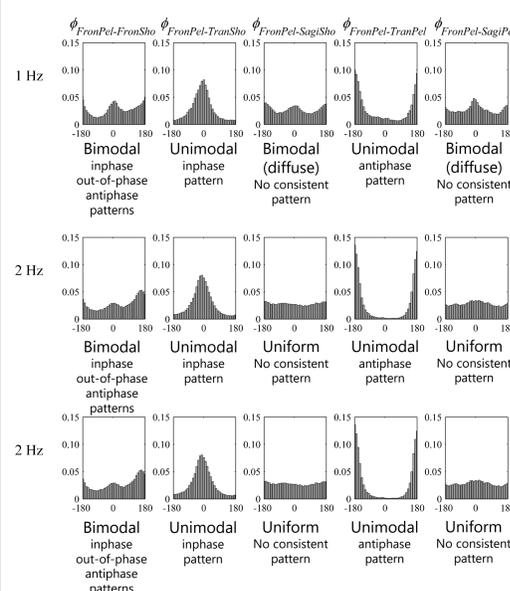


Figure 3.

Proportion (y-axis) distributions of CRP values in the [-180 ; 180] deg range (x-axis), across frequency trials, averaged in all participants.

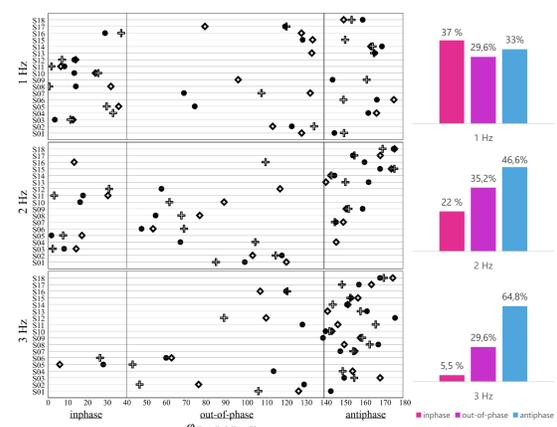


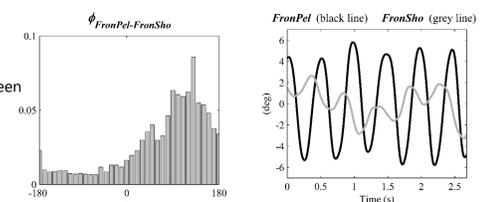
Figure 4.

Mean $\Phi_{FronPel-FronSho}$ (absolute value) of each individual trial in Low Posture (circle), Intermediate Posture (cross), High Posture (diamond), for each frequency condition, in all participants. In each frequency panel, the three trials of one participant are shown on the same horizontal line, ranked from participant S01 to S18 along the ascending y-axis. The associated percentage of trials within each coordination pattern is shown for each frequency. **With increasing frequency, inphase patterns tend to disappear while antiphase pattern become predominant.**

Figure 5.

Example of Out-of-phase pattern coordination between *FronPel* and *FronSho* (S02, 2 Hz, High Posture).

Mean CRP: 103.73 (SD=57.74) deg.



Discussion

- Expert belly dancers performed a higher pelvis amplitude than in gait in the frontal plane [1][2]. Anatomical constraints could explain the posture effect on pelvis amplitude.
- **Dancers are able to separately control amplitudes** of pelvic and upper-trunk oscillations, as the upper-trunk rotations amplitude (< 5 deg) were much smaller than the pelvis (\approx 18 deg).
- **Unpreventable coupling between trunk segments occurred in all frequency conditions:** frontal pelvic rotation induced transverse pelvic rotation, and there was a consistent antiphase pattern between transverse rotations of the pelvis and upper-trunk. These consistent patterns may be due to mechanical and/or anatomical factors, and could reflect the counter-balancing mechanism often described in gait analysis [3][4].
- **Coordination patterns between the pelvis and upper-trunk frontal rotations are frequency dependent:** three stable patterns, inphase, out-of-phase, antiphase were equally distributed among participants at 1 Hz, while the antiphase pattern was predominant at 3 Hz.
- Less temporal variation of pelvic oscillations was observed at 2 Hz than 1 Hz and 3 Hz; thus, 2 Hz could be close to a stable attractor according to the non-linear dynamical systems view. It could well be that pelvic movements performed at 2 Hz resemble a rhythmic movement, but still slow enough for a cycle-by-cycle control, while those performed at 1 Hz are more a succession of discrete movements.
- **Inter-individual differences emerged at 3 Hz.** This frequency seemed more difficult to maintain for half of our participants, who naturally converged into either a higher or a lower frequency. In the non-linear dynamical systems view, 3 Hz could be located in an instability area between two stable attractors. According to Nugent et al. (2017), 3 Hz is a frequency threshold above which dancers spontaneously shift to another *erector spinae* muscle pattern [5].

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