KINEMATICS OF THE LUMBAR SPINE DURING CLASSIC BALLET POSTURES

Veronique Feipel[1], Sandra Dalenne[1], Pierre-Michel Dugailly[1,2], Patrick Salvia[1,2,3] and Marcel Rooze[1,3]
[1]Department of Functional Anatomy, [2]Department of Physiotherapy, [3]Functional Evaluation Centre, University of Brussels, Brussels, Belgium, vfeipel@ulb.av.be

INTRODUCTION

Low-back pain (LBP) and injuries, including isthmic and other vertebral stress fractures, disk disease, Scheuermann's disease, sprains, dynamic instabilities and sacro-iliac pain, are frequent in ballet dancers (Baillon 1983, Micheli 1983, Quirk 1983, Hamilton et al 1989, Sohl & Bowling 1990, Khan et al 1995, Coplan 2002). These problems are attributed to falls, overuse, practice changes, postural and dynamic characteristics of ballet, inappropriate technique or floor surface, as well as muscle balance alterations (Baillon 1983, Micheli 1983, Quirk 1983, Sohl & Bowling 1990, Khan et al 1995). Moreover, hip pathologies also frequently occur in ballet dancers, probably related to postural aspects such as turnout (Sanmarco 1983, Sohl & Bowling 1990, Luke & Micheli 2000, Coplan 2002). These pathologies include femoral neck stress fractures, lesions and inflammatory disorders of musculo-tendinous apparatus, and snapping hip syndrome.

The contribution of trunk motion to ballet movements is intended at keeping the shoulders horizontal. However, in some motions, such as *arabesque* and *développé à la seconde*, it can be hypothesized that lumbar motion may contribute to a higher elevation of the lower limb (Figure 1). The aim of this study was to analyse 3D kinematics of the lumbar spine during ballet movements in expert dancers and to correlate it with limb elevation, shoulder inclination and pathological history.

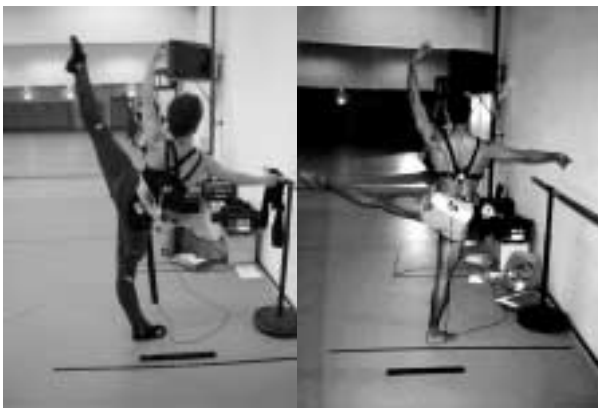

Figure 1: Two dancers in *développé seconde* with different lower limb elevation.

METHODS

Twenty-five professional or semi-professional ballet dancers (17 ♀, 8 ♂, mean age (SD): 21 (4) yrs, 18 professionals of the Royal Ballet of Flanders, 7 last year students of the Stedelijk Instituut voor Ballet in Antwerp, Belgium) were submitted to a self-administered questionnaire and kinematics evaluation.
The questionnaire collected information on ballet practice and position in the company, laterality in certain movements, orthopaedic history, present musculo-skeletal problems and treatments, sports practice, smoking and alimentation habits. Women also replied to question concerning their menstrual cycle and *pointes* experience. Moreover, the lengths of the lower limbs (Anterior Superior Iliac Spine to floor) and thighs (ASIS to apex of patella) were measured using a tape. Lumbar kinematics was sampled using the CA 6000 Spine Motion Analyzer (OSI, USA) mounted using straps at the level of the thorax and the pelvis. The pelvic strap was reinforced by an elastic belt (Figure 1 and 3). The movements tested were *arabesque* (A), *développé à la seconde* at the *barre* (DSB) and without *barre* (DS) and *pied en main* (PM). They were repeated three times to the right and left side. Kinematics parameters considered were the position of the lumbar spine in each final position with respect to reference position, the maximal motion velocity during final position installation and the frequency of oscillation when maintaining the final position (Figure 2).

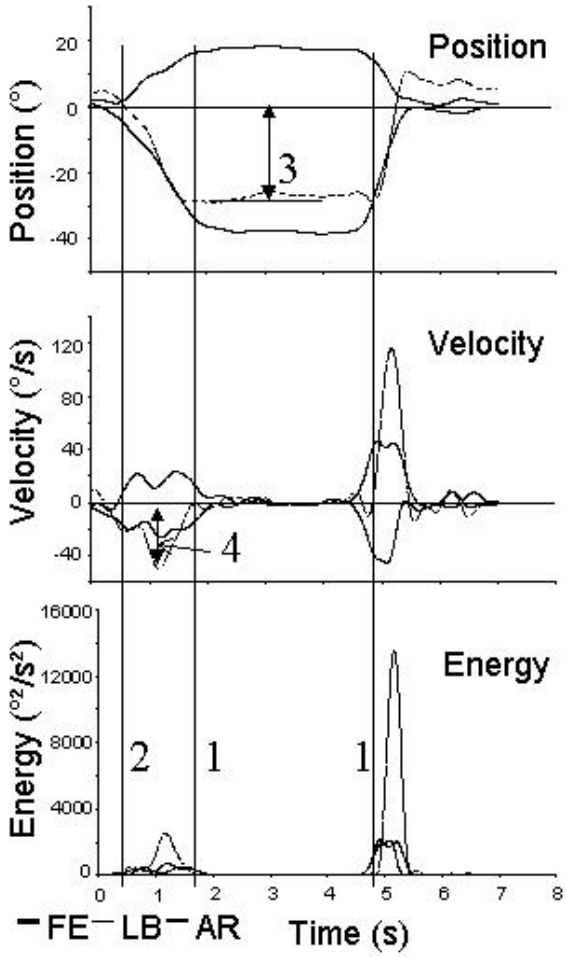

Figure 2: Lumbar kinematics parameters. 1 = onset and end of position maintenance, 2 = onset of motion, 3 = position in final posture, 4 = maximal velocity of installation phase.

A photograph was taken in first position (used as reference position) and in each final posture. These were used (Figure 3) to compute lower limb elevation (LLE), tragus or C7

displacement and shoulder inclination (SI). Reproducibility of the photographic technique was evaluated by repeating all measurements 10 times for one subject. Standard deviations did not exceed 0.9°. Dancer flexibility was represented by the LLE angle during DS (3 groups: < 120°, 120-130°, > 130°).

Due to deviation from normal distribution for several parameters, Krukal-Wallis and Wilcoxon matched pairs tests were used to evaluate the effect of gender, flexibility, pathology, side and type of motion on static and lumbar kinematics parameters. Spearman rank correlation coefficients were used to study the relation between postural parameters and lumbar kinematics. Finally Chi² independence tests (with Fischer's exact correction, if required) were used to study the links between flexibility and pathologies.

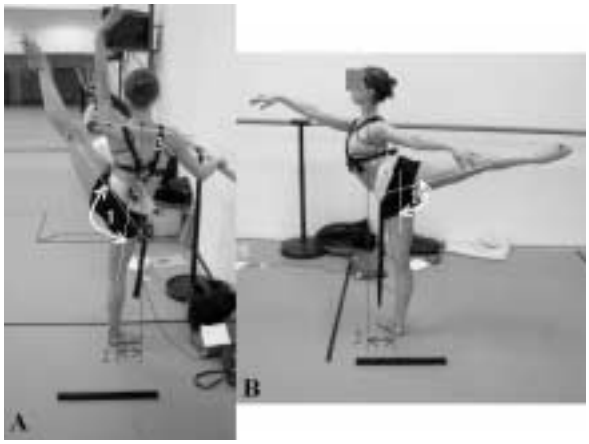

Figure 3: Photographic parameters for (A) DSB and (B) arabesque. 1 = LLE angle, 2 = C7 or tragus displacement, 3 = SI.

RESULTS AND DISCUSSION

Ballet experience was of 15 (SD 4) years and weekly practice of 33 (SD 11) hours. All dancers had suffered an injury or pain problem. Forty percent reported hip pain and 43% LBP. Average lumbar motion ranges and posture parameters are presented in table 1. Figure 4 shows examples of lumbar displacement curves during ballet movements.

Table 1: Average (SD) lumbar motion ranges and posture parameters during ballet movements.

	PM	DSB	DS	A
lumb. flexion (°)	30 (10)	16 (14)	12 (9)	-21 (10)
lumb. bending (°)	11 (6)	16 (5)	16 (6)	22 (7)
lumb. rotation (°)	-20 (5)	-17 (7)	-15 (7)	-11 (6)
LLE (°)	145 (21)	118 (20)	116 (20)	91 (9)
SI (°)	9 (6)	6 (5)	3 (7)	-
Tragus/C7 displ. (mm)	117 (60)	143 (52)	157 (36)	232 (42)

All movements were accompanied by homolateral lumbar bending and heterolateral axial rotation of the lumbar spine. PM, DSB and DB were accompanied by lumbar flexion and *arabesque* by extension. Lateral bending was significantly larger for right movements, except for *arabesque*.
Shoulder inclination did not exceed 10°, however, C7 displaced to the side of the supporting limb. There was a significant correlation between SI and C7 displacement for PM (R = 0.89) and DSB (R = 0.88), indicating that larger shoulder inclination was associated with larger C7 displacement. This correlation was weak but significant for DS (R = 0.49). Shoulder inclination and C7 displacement were to the opposite side of the elevated lower limb.

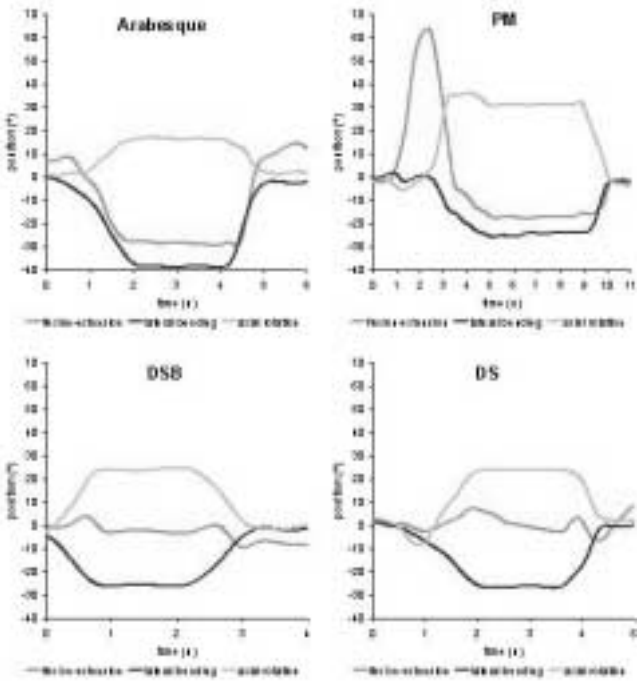

Figure 4: Lumbar displacement curves during ballet movements analysed.

Correlations between postural parameters and lumbar kinematics were in most instances weak and not significant. Dancers with intermediate hip flexibility index displayed significantly less lumbar lateral bending during all movements than dancers with larger or smaller flexibility (Figure 5). The same observation applied to lumbar lateral bending velocity, except during arabesque. During PM, DSB and DS, dancers with lowest flexibility index displayed a significantly larger lumbar oscillation frequency than the other groups ($p < 0.0001$, Kruskal Wallis Median test).

Flexibility was significantly linked to the presence of a history of low-back pain ($p = 0.003$), but not to the presence of hip pain ($p = 0.31$) or snapping hip syndrome ($p = 0.96$). Moreover, dancers with hip pain realized PM, DSB and DS with significantly higher lumbar lateral bending ($p=0.03$), and those with snapping hip syndrome or low-back pain displayed a significantly larger lumbar flexion associated with these movements ($p=0.04$).

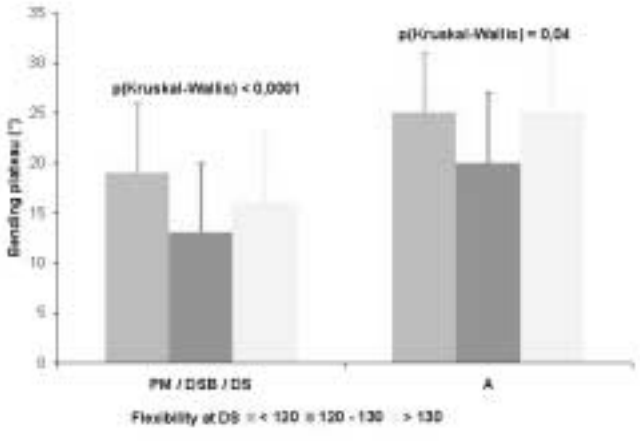

Figure 5: Lumbar lateral bending range in final posture as a function of flexibility.

SUMMARY

To our best knowledge, kinematical studies of ballet movements are rare (Bronner et al 2001, Spriggs et al 2001). This study showed the feasibility of the approach chosen and characterized the contribution of the lumbar spine of ballet movements. Specifically, all ballet motions tested were carried out with homolateral lumbar lateral bending and heterolateral rotation. The ranges of these two lumbar components ranged from 10 to 20°. The *arabesque* was accompanied by a 20° lumbar extension, whereas lumbar extension occurred during the *pied en main* (30°) and *développé à la seconde* (10 to 15°). Lower limb elevation was largest during *pied en main* (150°), followed by the *développé à la seconde* (120°) and the *arabesque* (90°).

REFERENCES

Baillon, J.M. (1983) *Acta Orthop. Belg.*, **49**, 112-116.

Bronner, S. et al (2001) *Proc of ISB2001*, 374.

Coplan, J.A. (2002) *J. Orthop. Sports Phys. Ther.*, **32**, 579-584.

Hamilton, L.H. et al (1989) *Am. J. Sports Med.*, **17**, 263-267.

Khan, K. et al (1995) *Sports Med.*, **19**, 341-357.

Luke A., Micheli L.J. (2000) *J. Dance Med. Sci.*, **4**, 6-15.

Micheli, L.J. (1983) *Clin. Sports Med.*, **2**, 473-484.

Quirk, R. (1983) *Clin. Sports Med.*, **2**, 507-514.

Sammarco G.J. (1983) *Clin. Sports Med.*, **2**, 485-498.

Sohl, P., Bowling, A. (1990) *Sports Med.*, **9**, 317-322.

Spriggs, J. et al (2001) *Proceedings of ISB2001*, 375.

TEITZ C. (2000) *J. Dance Med. Sci.*, **4**: 23-29.

AKNOWLEDGEMENTS

The authors express their gratitude to the artistic directors of the Koninklijk Ballet van Vlaanderen and Stedelijk Instituut voor Ballet (Antwerp, Be) for opening them the doors of their institutions for this study. We are also indebt to the ballet dancers who agreed to spend some of their precious time to take part in this study.