

THE ART ATHLETE: A SPORTS BIOMECHANICS PERSPECTIVE

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Overuse injuries are as much a problem for 'art athletes' (dancers and musicians and performing artists generally) as they are for those we more commonly term 'athletes'. Lower back injuries in male ballet dancers are certainly commonplace. 3D motion analysis in combination with 3D Static Strength Predicting analysis showed that compressive forces at L5/S1 were above the National Institute of Occupational Safety and Health 'Back Compression Design Limit' (~ 4,500N) and shear forces were high (~ 530 N) for male dancers performing two commonly used classical lifts. A research design for the use of an opto-reflective motion analysis (Vicon) to investigate shoulder joint loading in cellists and violinists will also be presented.

KEYWORDS: Dance, Music, Injury, Repetitive strain, Motion analysis

INTRODUCTION:

Many National Organising Committees now consider forms of dance a sport, so the line between what is traditionally defined as sport and the arts is gradually being blurred. While the general public acknowledges the athletic endeavour of our football, volleyball and basketball players amongst others, they are not so quick to give similar accolades for the physical training required by our professional dancers or musicians. However, the 'art athlete'; to achieve excellence in performance, train for long hours and their performance goals are also often hindered by injury, in much the same way as any 'sporting athlete'.

For example the majority of reported injuries by male ballet dancers are overuse in nature (Liederbach and Compagno, 2001) with a high incidence of lower back injuries (LBI)(Coplan, 2002; Macchi & Crossman, 1996). A LBI can lead to extended time where the dancer is unable to perform, or at worse premature retirement. The likelihood of a male dancer developing a LBI has been suggested to be higher than female ballerinas due to the lifting tasks they are required to perform in classical ballet choreography (Quirk, 1983; Gelabert, 1986). Similarly, the cellist (Fry, 1988) and violinist (Shan & Visenten, 2003; Visenten and Shan, 2004) suffer injuries primarily to the shoulder, that will often detract from their performance or totally preclude them from taking their place in the orchestra. Very limited data are available to indicate which variables, if any, would alter the likelihood of a male dancer experiencing a LBI during a classical ballet lift or from repeated lift efforts. Similarly little is known about the aetiology of shoulder injuries sustained by cellists or violinists, although incorrect posture and excessive muscle/joint overload, especially when sustained over a long period are thought to lay at the heart of the problem.

The aim of this research, the first 3D biomechanical analysis of classical ballet lifts, is to compare the L5/S1 peak anterior shear and corresponding compression forces in male dancers, performing full press (FP) and arabesque (AR) classical ballet lifts. Lumbar compression forces will be referenced to the National Institute of Occupational Safety and Health (NIOSH) normative data as an indicator of the likelihood of sustaining a LBI. A secondary aim is to 'set the scene' for the investigation of shoulder injuries in cellists and violinists using a sport biomechanics approach.

METHODS:

Eight male ballet dancers (mean age 22.6 ± 6.1 years) and five ballerinas (mean age 26.8 ± 10.6 years) were recruited from The West Australian Ballet Company, The West Australian Academy of Performing Arts and The Diana Waldron Ballet Academy. Prior to the collection of lifting data, 54 retro-reflective markers were placed on each male dancer's limbs, torso and head to meet the requirements of the UWA customised marker set and model. An additional 5 markers were placed on the male dancer's lumbar region to create a lumbar

segment, required for the calculation of shear and compression forces at L5/S1. Ballerinas were fitted with 6 markers on pelvic bony landmarks and two markers on each foot, such that the pelvis segment of the ballerina could be constructed in 3D and the point at which the ballerina left the ground during each lift could be identified. A twelve camera Vicon MX 3D motion analysis system (Oxford Metrics, Oxford, UK) and one AMTI force plate (1200 mm x1200 mm) (AMTI, Watertown, MA, USA) were used to collect 3D data during the lifting trials (Figure 1).

All male dancers completed five lifts of two lifting conditions:

Full Press (FP): lifting the ballerina from the waist in a standing posture, finishing in a pose with the ballerina laying supine on the male dancers hands with the trunk in hyperextension. In this lift the ballerina jumps vertically into the lift.

Arabesque (AR): lifting the ballerina in an arabesque position, one hand is placed on the torso and the other proximal to the knee of the extended leg. During this lift the ballerina maintains a static arabesque pose.

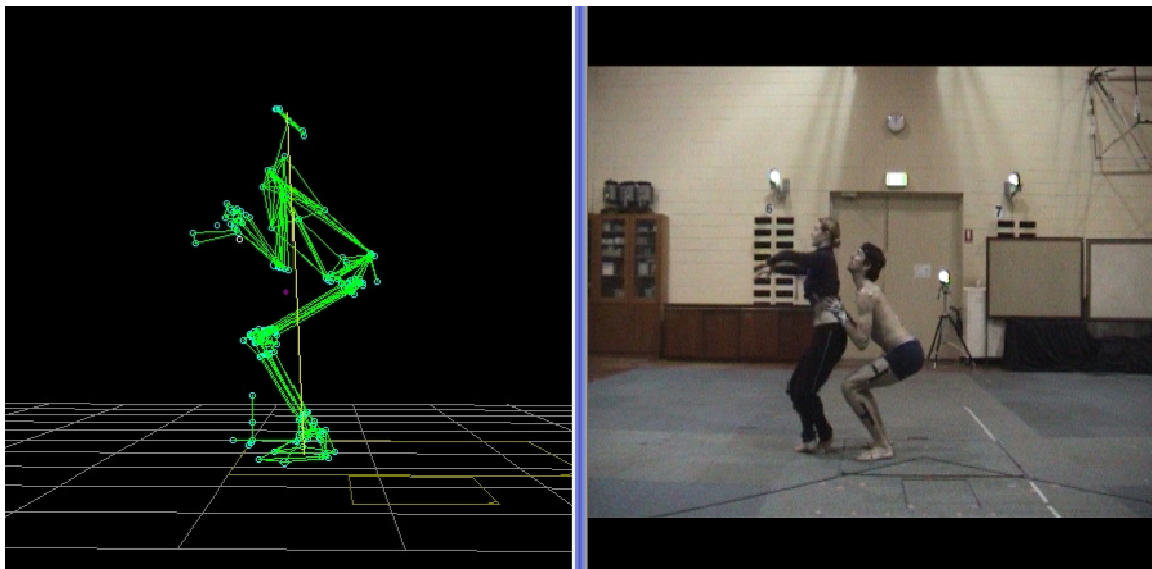


Figure 1: Sagittal plane view of a classical lift, with 3D reconstruction depicted and a standard image at the same point in time

Shear force was operationally defined as force acting from anterior to posterior through the lumbar segment. At the time of peak shear force, 2D multi-planar knee, hip, trunk, shoulder and elbow vector angles were recorded for input into the 3D Static Strength Prediction Package (3DSSPP) (University of Michigan, Centre for Ergonomics, 2006, Version 5.0.6). The 3DSSPP model comprises a series of inverse dynamic calculations utilising 2D kinematics, anthropometry and kinetic hand loads to calculate external moments. Hand loads were deemed to be equivalent to the weight of the ballerina. The customised 3D dynamic model showed that peak shear forces for all male dancers occurred at the commencement of the lift, just prior to the positive vertical displacement of the ballerina. Not surprisingly, this time point was also associated with peak GRF and peak trunk flexion. Visual inspection of the ballerina's mid-pelvis trajectory confirmed that her approximated centre of mass was not vertically displacing and therefore any vertical acceleration at the point of peak shear force was small. Therefore, the ballerinas were deemed to be not 'assisting' the male dancer by reducing the hand load at this point. In addition, a further assumption was that the ballerina's body weight was evenly distributed between the male dancer's hands and that no turning moment was generated about the hands during the lifting process.

All compression forces output from the 3DSSPP were referenced to NIOSH normative data as a predictor of potential injury to the lumbar spine. The NIOSH developed the compressive force limits, the Back Compression Design Limit (BCDL) and Back Compression Upper Limit

(BCUL), at the L5/S1 joint to be used as guidelines for lifting within an occupational setting. Any compression force lower than the BCDL of 3400N indicates a nominal risk to the lifter, whereas compression forces higher than the BCDL require administrative or engineering controls to reduce the potential risk of LBI. A compression force above the BCUL of 6400N suggests the task poses a serious risk of LBI to the lifter (Chaffin and Andersson, 1984).

Dependant t-tests were performed to ascertain whether the two lifting conditions were significantly different for the following independent variables determined from both the 3DSSPP model and the customised 3D dynamic model; 2D segment angles, trunk extension velocity and male dancer hand-to-feet distance.

RESULTS AND DISCUSSION:

The mean 3DSSPP compression forces in the FP condition were significantly greater ($4725.8\text{N} \pm 852.8\text{N}$) than in the AR lift ($4312 \pm 963.4\text{N}$), while similar peak shear forces were recorded across conditions ($\approx 530\text{N}$). Mean 3DSSPP compression forces at the point of peak shear for FP and AR ballet lifts fell within the NIOSH BCDL (3400 N) and BCUL (6400 N). Calculated lumbar forces of these magnitudes indicate a need for administrative controls in order to reduce the risk of LBI. When considering the fatigue related situations that Liederbach and Compagno (2001) reported to be associated with ballet injuries, reducing the total time and lift repetitions that are performed each day by male dancers may reduce fatigue and the potential of an overuse LBI. Comparatively, shear forces were slightly lower than the reported values of publicans lifting beer kegs (Jones et al., 2005) and compression forces were similar to those reported in paramedics manually transporting patients (Lavender et al., 2000). When one considers the L5/S1 low resistance to multi-directional forces (Fathallah et al., 1998), the forces found in this study indicate a genuine risk of LBI to male dancers during classical ballet lifts.

Compression forces were significantly higher in the more dynamic FP lift when compared with the AR lift. The timing of the vertical force generation between the male dancer and ballerina is crucial for a successful FP lift. The male dancer appears to eccentrically load the lower limb and back extensor musculature at the same time the ballerina is moving to peak knee flexion in preparation for the lift. However, the results of this study show that peak lumbar shear forces and high compression forces occur prior to the jump of the ballerina, such that the effectiveness of improving the ballerina's jump in reducing lumbar loading may be of limited value in reducing LBI in male dancers. This dynamic coordinated exertion may aid the male dancer once the ballerina has left the ground, but consequently may increase the multi-directional lumbar force at the point of peak shear.

Further, peak trunk extension velocity between the FP and AR conditions was not significantly different suggesting that the ballerina 'jumping into' the lift, as occurs in the FP lift does not significantly affect lifting velocity. Considering that a common assumption in the ballet community is that the FP lift is less demanding, and by extension, less dangerous to a male dancer due to the assistance he receives from the ballerina, this finding may have significant implications for training practices in the industry.

The male dancer's mean hand-to-feet distance in the FP condition (0.28 m) was significantly greater than in the AR (0.19 m) lift. This variable was emphasised by Chaffin and Andersson (1984) with reference to the NIOSH guidelines as a strong predictor of lumbar forces and the risk of injury.

CONCLUSION:

As scientists interested in movement associated primarily with sport it would appear that a similar research protocols are applicable to many activities typically classified as belonging to the 'arts'. In this paper we have presented approaches to LBI in classical ballet lifts. Shoulder injuries in cello playing is currently occurring with the Music School and research is currently being planned on assessing movement characteristics of violinists from a dynamical systems approach, in collaboration with the University of Massachusetts.

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