# Articles

# Examination of Weight Transfer Strategies During the Execution of *Grand Battement Devant* at the *Barre*, in the Center, and Traveling

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The purpose of this study was to examine grand *battement devant* at the *barre*, in the center, and traveling through space. The primary focus was to consider weight transfer in three conditions: from two feet to one foot for the *barre* and center conditions, and from one foot to the other foot in traveling. Forty female dancers volunteered (mean age 30.0 ± 13.0 yrs) and were placed in three groups: beginner ($n = 12$), intermediate ($n = 14$), and advanced ($n = 14$). Data were collected with a 7-camera Vicon motion capture system using a Plug-in Gait Full Body Marker set and with two Kistler force plates. Dancers executed five *grand battement devant* in each of three conditions in randomized order: at the *barre* in 1st position, in the center in 1st position, and traveling through space. Four variables were investigated: center of gravity of the full trunk, center of gravity of the pelvis, center of gravity of the upper trunk, and center of mass. Data were analyzed in three intervals—stance to *battement* initiation (STN to GBI), initiation to *battement* peak (GBI to GBP), and peak to end (GBP to END)—and in the x-axis and y-axis. The main effect condition was significant for all four variables in both x-axis and y-axis ($p<0.001$). There were no significant differences for training and no significant condition × training interactions. Condition was significant for all three intervals (STN to GBI, GBI to GBP, and GBP to END) for all four variables in both axes ($p<0.01$). Dance educators might consider the importance of allocating sufficient time in dance practice to each of the three conditions—*barre*, center, and traveling—to ensure development of a variety of motor strategies for weight transfer. *Med Probl Perform Art* 2012; 27(2):74–84.

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Dancers in classical ballet, and more recently in contemporary dance, have made use of the *barre* as a major component of dance training, and the *barre* has been the subject of dance research dating back to the late 1970s.[1,2] Many of the studies in the literature comparing work at the *barre* and in the center suggest that dancers work differently in these two conditions,[1,3–7] and other noted researchers in the field have theorized about the differences between muscle activation and motor strategies at the *barre* and in the center.[2,8,9] It has long been assumed that there is positive transfer of training from the *barre* to center work in dance training.[10] Looking to the motor control research, Cordo and Nashner[11] found that when the subject leaned on a bar and performed arm movements disturbing equilibrium, the lower extremity and trunk postural reflexes did not respond. It is currently unknown if there is enough similarity between the muscular and biomechanical aspects of movement at the barre and center to encourage positive transfer. If in fact there is dissimilarity and extensive time is spent at the barre, there may even be negative transfer, that is, *barre* work may be interfering with some aspects of dancing ability.

Other dance research has focused on the profiling of elite dancers, and comparisons between elite dancers and novice or nondancers.[1,12–24] There are mixed results demonstrating differences between elite and novice dancers, with certain factors clearly indicating differences such as variability[15] and anticipatory postural strategies,[19,20] while other factors do not differentiate between the two groups such as reaction time in certain balancing tasks.[21] If in fact there are aspects of dance practice that are similar across all levels of training, it might suggest that these elements of dance movement do not need attention in dance class for enhanced ability. One might even propose that these aspects cannot be affected by training, regardless of years of practice or training approaches.

The *grand battement* was the subject of one of the earliest biomechanics investigations in the dance literature.[25] Although Ryman and Ranney[2] collected data on the *grand battement devant* only in the unsupported condition, they discussed their observations of dancers at the barre, claiming that there is less weight shift to the supporting leg during the *battement* at the *barre* than in the center. Similarly, Laws[8] proposed that the *barre* allows for forward shift of the torso in arabesque and provides torso stabilization for movements such as *rond de jambe* that are not possible without the *barre*; he questions whether this work is transferrable to center practice. A recent investigation by Bronner and Ojofeitimi[13] did extensive descriptions for elite dancers executing *grand battement devant, à la seconde*, and *derrière*, and found large pelvic movements in all three planes to accommodate hip joint movement. However, there is no comparative data in the center, and therefore it is not possible to know if elite dancers perform these movements with similar strategies when unsupported.

In summary, the dance research to date suggests: (1) there are important differences between several aspects of movement execution with and without a barre, including weight shift strategies, muscle activation, joint torque, and dynamic alignment; (2) dancers rely on the barre in some aspects of movement organization regardless of level of training; and (3) the action of weight transfer in movement execution may be an area of particular concern, since this is such a crucial aspect of biomechanical and muscular organization in dance. To date, no dance research has compared barre and center work to dance movement traveling in space, and determined whether this third condition is significantly different from the other two.

If dance educators are to be optimally effective in preparing dancers for the performance of dance repertoire, it would be useful to understand what aspects of training are transferrable from *barre* to center and from center to traveling and in what ways elite dancers differ from novice dancers. Similarly, medical practitioners working in the field of dance injury rehabilitation could benefit from this knowledge and improve strategies for preparing dancers to return to full function. The purpose of this study was to examine *grand battement devant* in three conditions: at the *barre*, in the center, and traveling through space. The primary focus was to consider weight shift in the three conditions: from two feet to one foot for the *barre* and center conditions, and from one foot to the other foot in traveling. Additionally, the study explored whether or not there are significant differences between dancers of various training levels with regard to weight shift.

## METHODS

### Participants

Dancers were recruited for the study through announcements in university dance classes and postings in professional dance listservs and newsletters. Forty-three female dancers volunteered for the study. Inclusion criteria were enrollment in a university-level dance class or in a professional dance studio or training program and exposure to ballet and/or modern dance. Exclusion criteria were a history of confounding medical problems or a current injury impacting on execution of the dance task for the study. The study was approved by the Standing Advisory Committee for the Protection of Human Subjects at California State University, Northridge, and all subjects gave informed written consent.

One volunteer arrived with a recent injury and was excluded from the study. Data for two participants had to be eliminated from analysis due to lost data during collection. The remaining 40 subjects had a mean age of 30.0 ± 13.0 years, mean height 1.63 ± 0.06 meters, mean weight 59.0 ± 7.4 kg, and 13.9 ± 13.3 average years of training in ballet and/or modern dance. The three levels for the study were defined by two dance experts as follows: (1) beginning dancers ($n$ = 12) had <2 years of training; (2) intermediate dancers ($n$ = 14) had >2 years of training and no professional (paid) dance experience; (3) advanced dancers ($n$ = 14) had 10 or more years of training and professional (paid) dance experience. Dance experience included ballet, modern and contemporary dance, jazz, hip hop, break or street dance, musical theater, tap dance, and various world dance forms. Dancers from various professional dance companies were included.

### Instrumentation

Data were collected with a 7-camera Vicon MX Ultranet motion capture system (Oxford Metrics Ltd, Oxford, UK), with 35 spherical markers using a Plug-in Gait Full Body Marker set, sampled at 240 Hz. Markers were placed bilaterally at the acromio-clavicular joint, the lateral epicondyle of the elbow, the dorsum of the hand just below the head of the second metacarpal, anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), lateral mid-femur below the level of the hand, lateral epicondyle of the knee, lateral midcalf, lateral malleolus of the ankle, second metatarsal head on the midfoot side of the equinus break between the forefoot and midfoot, calcaneus at the same height as the toe marker, unilaterally at the jugular notch where the clavicles meet the sternum, xiphoid process of the sternum, spinous process of the seventh cervical vertebra, spinous process of the tenth thoracic vertebra, and the middle of the right scapula. Additionally the subject wore a headband around the skull just above the ears, with two anterior markers located approximately over the right and left temple and two posterior markers placed on the back of the head approximately in the horizontal plane with the front markers, and wristbands with markers on the thumb and pinkie sides as close to the wrist joint center as possible (see Figure 1).

Comparisons of the Vicon system to other motion analysis systems have shown it to be accurate and reliable.[26] The motion capture system was calibrated at the beginning of each day of data collection. Force plate data were collected with two Kistler force plates (9287A, 9287BA) (Kistler Instruments, Inc, Amherst, NY) at 960 Hz. Reconstruction, labeling and gap filling was done in Nexus 1.6.1.57351 and the filtering and kinematic scripts were completed in Visual 3D v4.75.36 (C-Motion Inc, Germantown, MD).

### Protocol

Dancers wore fitted mid-thigh bike shorts and sports bras and were given 15 minutes to perform a personal warm-up. Trials at the *barre* and in the center were executed in the dancer's

**FIGURE 1.** Participant with 35 spherical markers using a Plug-in Gait Full Body Marker set.

preferred first position (lower extremities externally rotated). All trials were executed with the right leg. It was decided to use 1st position at the *barre* and in the center since the right foot would pass the left foot in the traveling condition, and using 1st position for the stationary trials would be similar.

Dancers performed 5 trials at the *barre* in 1st with the left hand at the barre, 5 trials in the center in 1st, and 5 trials traveling, in randomized order, with 1 minute of rest between trials. For *barre* and center trials, dancers were instructed to hold the final stance position until told to rest. Traveling trials included two steps (right, left) prior to the battement, and two steps (right, left) after the battement. Steps were executed in *plié* to encourage traveling, and dancers were instructed to take the first step onto force plate 1 and the second step onto force plate 2, with the final two steps clearing the force plate area. While these instructions permitted some variance due to height and leg length, all dancers were encouraged to cover space. In essence, the traveling condition simulates the preparation for a *grand jeté*.

Trials were executed to a recording of the music called Dance of the Knights from the ballet *Romeo and Juliet* by Sergei Prokofiev at a tempo of 104 beats per minute. At the *barre*, the left hand was on the *barre*, and the right arm was in classical second position. For center and traveling trials, both arms were in classical second position.

### Definitions of Variables (Body Regions) and Events

Four variables were defined as follows: center of gravity of the full trunk (from a midline between the sternum and C7 markers to a midline between the hip joints), center of gravity of the pelvis, center of gravity of the upper trunk (from a midline between the sternum and C7 markers to a midline between ASIS and PSIS markers), and center of mass. Visual 3D automatically calculates center of gravity of the pelvis and center of mass.

Data for the x-axis represented lateral or frontal plane movement, and by convention, positive numbers were movement to the right, and negative numbers were movement to the left. Data for the y-axis represented sagittal plane movement, and by convention, positive numbers were movement forward, and negative numbers were movement backward. The data from the z-axis (the axis that is perpendicular to the x-axis and the y-axis) was not considered for analysis, but was used in identifying events. Four events were defined for evaluation: stance (STN), *grand battement* initiation (GBI), *grand battement* peak (GBP), and end (END).

For the *barre* and center conditions, the events were defined as follows:

- *Stance (STN)* is 120 samples or frames (0.5 seconds) prior to the GBI.
- *Grand Battement Initiation (GBI)* is the point in time when the velocity of the right heel marker starts moving in the forward (y-axis) direction. When the y-component of first derivative (velocity) of the right heel is greater than 0, it indicates that the right heel is moving in the forward direction.
- *Grand Battement Peak (GBP)* is the highest point in the z-axis for the right toe marker.
- *End (END)* is 120 samples or frames (0.5 seconds) after the point in time when the weight shifts from being entirely on the left foot back onto the right foot after the *grand battement*.

For the traveling condition, the events were defined as follows:

- *Stance (STN)* is the point in time when all of the weight is transferred onto the left foot prior to the *grand battement*, marked by toe off on the back force plate (force plate 1). At this point the right leg is behind the left leg but is not weight-bearing.
- *Grand Battement Initiation (GBI)* is the point in time when the right heel passes the left heel in the y-direction, as the right leg moves forward to initiate the *battement*.
- *Grand Battement Peak (GBP)* is the highest point in the z-axis for the right toe marker.
- *End (END)* is 120 samples or frames (0.5 seconds) after the point in time when the weight shifts entirely off the left foot onto the right foot after the *grand battement*, marked by toe off on the front force plate (force plate 2).

### Analysis

Differences in the distances between pairs of the four events were calculated (STN to GBI, GBI to GBP, and GBP to END), and these three distance measures were called intervals. Means and standard deviations (SD) for each subject and for all subjects combined for the four variables and for the three intervals were calculated. Table 1 shows the means and SDs for variables and intervals for all subjects combined in centimeters. Separate repeated measures ANOVAs (3:Condition × 3:Interval) were conducted for

TABLE 1. Mean Distance (in cm) of Weight Transfer for COG Full Trunk, COG Pelvis, COG Upper Trunk, and COM for Three Intervals*

| | Stance to Initiation | | Initiation to Peak | | Peak to End | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| **x-axis (lateral movement)** | | | | | | |
| Full Trunk | | | | | | |
| Barre | −2.21 | 1.13 | −2.80 | 1.62 | 3.75 | 1.90 |
| Center | −2.71 | 0.99 | −3.32 | 1.84 | 6.01 | 2.26 |
| Traveling | −1.29 | 0.99 | 0.75 | 1.20 | 1.39 | 2.05 |
| Pelvis | | | | | | |
| Barre | −2.08 | 1.01 | −2.48 | 1.89 | 3.50 | 2.13 |
| Center | −2.46 | 1.05 | −3.02 | 2.14 | 5.58 | 2.37 |
| Traveling | −1.16 | 1.29 | 0.60 | 1.67 | 1.24 | 2.28 |
| Upper Trunk | | | | | | |
| Barre | −2.19 | 1.15 | −3.74 | 1.75 | 4.61 | 2.06 |
| Center | −2.88 | 1.07 | −4.42 | 2.03 | 7.21 | 2.47 |
| Traveling | −2.29 | 0.96 | −0.14 | 1.27 | 2.01 | 2.31 |
| Center of Mass | | | | | | |
| Barre | −1.96 | 0.98 | −2.77 | 1.38 | 3.62 | 1.75 |
| Center | −2.50 | 0.088 | −3.28 | 1.74 | 5.76 | 2.06 |
| Traveling | −1.18 | 0.99 | 0.48 | 1.07 | 1.03 | 2.10 |
| **y-axis (sagittal movement)** | | | | | | |
| Full Trunk | | | | | | |
| Barre | 0.99 | 1.35 | −2.93 | 2.04 | 4.52 | 2.19 |
| Center | −0.49 | 1.74 | −1.54 | 1.71 | 4.83 | 1.64 |
| Traveling | 12.20 | 11.52 | 22.15 | 4.83 | 41.75 | 32.45 |
| Pelvis | | | | | | |
| Barre | −0.34 | 1.70 | 0.97 | 3.33 | 0.11 | 3.36 |
| Center | 0.19 | 2.18 | 1.73 | 2.97 | 0.82 | 2.87 |
| Traveling | 13.45 | 10.95 | 22.09 | 4.90 | 35.31 | 31.30 |
| Upper Trunk | | | | | | |
| Barre | −1.03 | 1.52 | −5.52 | 1.78 | 7.22 | 1.93 |
| Center | −0.76 | 1.66 | −3.72 | 1.88 | 7.27 | 1.86 |
| Traveling | 11.22 | 11.62 | 20.83 | 4.60 | 44.56 | 32.89 |
| Center of Mass | | | | | | |
| Barre | −0.49 | 1.32 | 0.78 | 1.72 | 0.31 | 2.02 |
| Center | 0.23 | 1.93 | 1.92 | 1.39 | 0.45 | 1.39 |
| Traveling | 14.57 | 11.39 | 22.62 | 4.31 | 36.37 | 34.29 |

*Three intervals are Stance to Initiation, Initiation to Peak, Peak to End. In the x-axis, positive numbers are weight shift to the right, negative numbers are weight shift to the left. In the y-axis, positive numbers are weight shift forward, negative numbers are weight backward.

each variable in each axis, with training level as a between-subjects factor. Where significant main effects were observed, a Bonferroni procedure was conducted to determine where significant differences occurred. Analysis was set at 0.05 alpha level. Bonferroni adjusts for Type 1 error, so no further adjustments to the alpha level were necessary. All reported *p* values are the adjusted *p* values based on the Bonferroni procedure.

## RESULTS

The main effect condition was significant for all four variables (COG full trunk, COG pelvis, COG upper trunk, and center of mass) in both the x-axis and the y-axis at $\alpha = 0.05$. There were no significant differences for training and no significant condition × training interactions. Further, condition was significant for all three intervals (STN to GBI, GBI to GBP, and GBP to END) for all four variables in both axes at $\alpha = 0.05$, using the Greenhouse-Geisser adjustment. The *p* values for the four variables (full trunk, pelvis, upper trunk, and center of mass) for all three intervals (Stance to Initiation, Initiation to Peak, and Peak to End) in both x-axis and y-axis are represented in Table 2.

Because condition for each interval was significant for all four variables in both axes, as reported in Table 2, a Bonferroni procedure was conducted to compare *barre* to center, *barre* to traveling, and center to traveling at each interval and in each axis. The *p* values of condition pairwise comparisons for the four variables (full trunk, pelvis, upper trunk, and center of mass) for all three intervals (Stance to Initiation, Initiation to Peak, and Peak to End) in both x-axis and y-axis are represented in Table 3.

TABLE 2. Significance levels for the COG Full Trunk, COG Pelvis, COG Upper Trunk, and COM, for All Three Intervals in Both Axes at $\alpha$ = 0.05

| Body region variables | Axis | Interval | *df* values Numerator | *df* values Denominator | *F* value | *p* value |
|---|---|---|---|---|---|---|
| Full Trunk | x-axis | STN to GBI | 1.7 | 64.7 | 21.527 | 0.000 |
| | x-axis | GBI to GBP | 1.8 | 65.2 | 153.973 | 0.000 |
| | x-axis | GBP to END | 1.6 | 59.5 | 76.539 | 0.000 |
| | y-axis | STN to GBI | 1.0 | 37.6 | 48.226 | 0.000 |
| | y-axis | GBI to GBP | 1.1 | 42.3 | 1310.464 | 0.000 |
| | y-axis | GBP to END | 1.0 | 37.1 | 50.084 | 0.000 |
| Pelvis | x-axis | STN to GBI | 1.7 | 64.0 | 16.120 | 0.000 |
| | x-axis | GBI to GBP | 1.7 | 61.7 | 106.817 | 0.000 |
| | x-axis | GBP to END | 1.5 | 54.5 | 65.445 | 0.000 |
| | y-axis | STN to GBI | 1.0 | 38.0 | 58.763 | 0.000 |
| | y-axis | GBI to GBP | 1.1 | 42.2 | 797.989 | 0.000 |
| | y-axis | GBP to END | 1.0 | 37.1 | 47.323 | 0.000 |
| Upper Trunk | x-axis | STN to GBI | 1.9 | 70.0 | 5.427 | 0.007 |
| | x-axis | GBI to GBP | 1.8 | 66.8 | 150.705 | 0.000 |
| | x-axis | GBP to END | 1.6 | 57.9 | 80.973 | 0.000 |
| | y-axis | STN to GBI | 1.0 | 37.6 | 41.053 | 0.000 |
| | y-axis | GBI to GBP | 1.2 | 44.2 | 1298.643 | 0.000 |
| | y-axis | GBP to END | 1.0 | 37.1 | 49.686 | 0.000 |
| Center of Mass | x-axis | STN to GBI | 1.8 | 65.0 | 21.678 | 0.000 |
| | x-axis | GBI to GBP | 1.7 | 63.6 | 159.080 | 0.000 |
| | x-axis | GBP to END | 1.5 | 55.0 | 78.238 | 0.000 |
| | y-axis | STN to GBI | 1.0 | 37.7 | 62.380 | 0.000 |
| | y-axis | GBI to GBP | 1.1 | 42.0 | 1062.695 | 0.000 |
| | y-axis | GBP to END | 1.0 | 37.1 | 43.515 | 0.000 |

### Stance to Initiation, x-axis

In the x-axis, Stance to Initiation demonstrated significant differences for all 3 conditions (*barre*, center and traveling) for COG of the full trunk. As the dancers began to initiate the *grand battement*, they shifted the full trunk 2.2 cm to the left at the *barre*, 2.7 cm to the left in the center, and only 1.2 cm to the left while traveling. For the COG of the pelvis in this first phase, *barre* and center were not significantly different ($p$ = 0.149), but traveling was significantly different from the other two conditions. The pelvis shifted 2.1 cm to the left at the barre, 2.5 cm to the left in the center, and only 1.2 cm to the left while traveling. The COG of the upper trunk shift was similar between *barre* and traveling ($p$ = 1.00), but center was significantly different from both *barre* and from traveling. The upper trunk shifted 2.2 cm to the left in this movement phase at the barre, 2.9 cm in the center, and 2.3 cm traveling. Finally, as with the full trunk, the COM of the full body demonstrated significant differences for all three conditions, shifting to the left 2.0 cm at the *barre*, 2.5 cm in the center, and 1.2 cm while traveling. Figure 2 graphically displays the mean distances from Stance to Initiation in the x-axis, broken down by body region and condition.

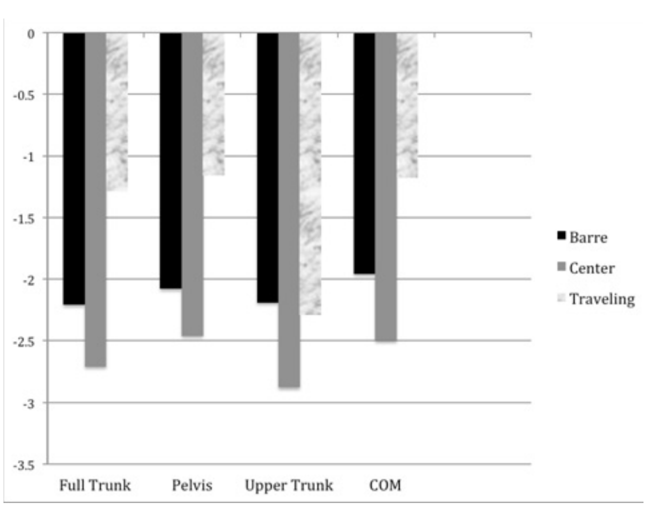


**FIGURE 2.** Distance from Stance to Initiation in the x-axis in cm: COG full trunk, COG pelvis, COG upper trunk, COM.

### Initiation to Peak, x-axis

In this second phase, Initiation to Peak, traveling was significantly different from *barre* and center for all variables. The full trunk shifted 2.8 cm to the left at the *barre*, 3.3 cm left in the center, and 0.8 cm to the right for the traveling condition. For the full trunk, *barre* was not significantly different from center in this phase, but there is a trend towards significance ($p$ = 0.06). For both the pelvis and the upper trunk, all three conditions were significantly different. The shift of the pelvis was 2.5 cm to the left at the *barre*, 3.0 cm to the left in the center, and 0.6 cm to the right while traveling. For the upper trunk, the shift was 3.7 cm to the left at

TABLE 3. Pairwise Comparisons for COG Full Trunk, COG Pelvis, COG Upper Trunk, and COM for All Three Intervals

| | | STN to GBI | GBI to GBP | GBP to END |
|---|---|---|---|---|
| x-axis | | | | |
| Full Trunk | Barre to Center | 0.028 | 0.060* | 0.000 |
| | Barre to Traveling | 0.002 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |
| Pelvis | Barre to Center | 0.149* | 0.038 | 0.000 |
| | Barre to Traveling | 0.004 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |
| Upper Trunk | Barre to Center | 0.003 | 0.020 | 0.000 |
| | Barre to Traveling | 1.000* | 0.000 | 0.000 |
| | Center to Traveling | 0.036 | 0.000 | 0.000 |
| COM | Barre to Center | 0.006 | 0.050 | 0.000 |
| | Barre to Traveling | 0.005 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |
| y-axis | | | | |
| Full Trunk | Barre to Center | 0.034 | 0.000 | 0.505* |
| | Barre to Traveling | 0.000 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |
| Pelvis | Barre to Center | 0.086* | 0.005 | 0.009 |
| | Barre to Traveling | 0.000 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |
| Upper Trunk | Barre to Center | 0.485* | 0.000 | 1.00* |
| | Barre to Traveling | 0.000 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |
| COM | Barre to Center | 0.006 | 0.000 | 1.00* |
| | Barre to Traveling | 0.000 | 0.000 | 0.000 |
| | Center to Traveling | 0.000 | 0.000 | 0.000 |

All comparisons are significant except those noted (* = NS).

the *barre*, 4.4 cm to the left in the center, and 0.1 cm to the left traveling.

For the COM, *barre* and center were not significantly different, but as with the full trunk there is a trend towards significance ($p$ = 0.05). The shift was 2.8 cm to the left at the *barre*, 3.3 cm to the left in the center, and 0.5 cm to the right for traveling. Note that the upper trunk was the only variable that demonstrated a shift to the left in the traveling condition during this phase. The other three body regions shifted to the right in this phase. Figure 3 graphically displays the mean distances from Initiation to Peak in the x-axis, broken down by body region and condition.

### Peak to End, x-axis

For Peak to End, all variables again demonstrated significant differences between all conditions for all variables. For full trunk, the shift was 3.7 cm to the right at the barre, 6.0 cm to the right in the center, and 1.4 cm to the right while traveling. For the pelvis, the shift was 3.5 cm to the right at the barre, 5.6 cm to the right in the center, and 1.2 cm to the right while traveling. For the upper trunk, the shift was 4.6 cm to the right at the barre, 7.2 cm to the right in the center, and 2.0 cm to the right while traveling. And for the COM, the shift was 3.6 cm to the right at the *barre*, 5.8 cm to the right in the center, and 1.0 cm to the right while traveling.

Figure 4 graphically displays the mean distances from peak to end in the x-axis, broken down by body region and condition. It can be observed that the upper trunk does the largest amount of lateral movement in this phase for all three conditions.

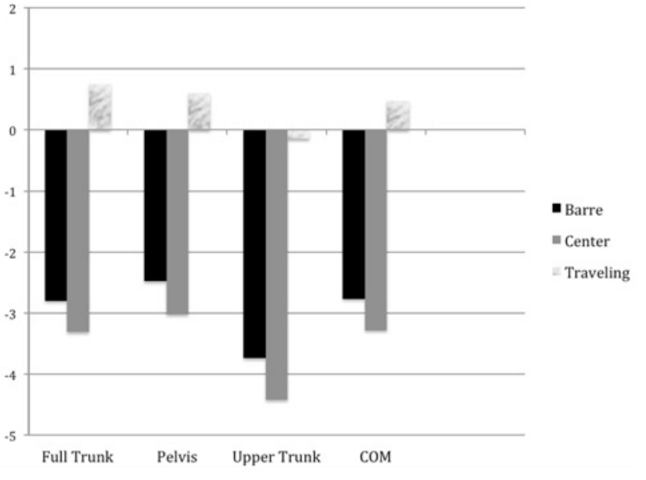


**FIGURE 3.** Distance from Initiation to GB Peak in the x-axis in cm: COG full trunk, COG pelvis, COG upper trunk, COM.

**Stance to Initiation, y-axis**

Similar to the x-axis, most variables in the y-axis demonstrated significant difference for all conditions, in all three movement phases, with several shifts occurring in the backward direction. The exception to this backward shift was for all body regions of the traveling condition, in which all shifts were forward, and for pelvis and COM for the center condition. During Stance to Initiation in the y-axis, for the full trunk, all three conditions differed significantly. The shift was 1.0 cm backward at the *barre*, 0.5 cm backward in the center, and 12.2 cm forward in the traveling condition. For the pelvis, *barre* and center were not significantly different ($p$ = 0.086), but traveling differed significantly from the other two conditions. The shift for the pelvis was 0.3 cm backward at the *barre*, 0.2 cm forward in the center, and 13.4 cm forward in the traveling condition. For the upper trunk, again *barre* and center were not significantly different ($p$ = 0.485), but traveling was significantly different from the other three conditions. The shift for upper trunk was 1.0 cm backward at the *barre*, 0.8 cm backward in the center, and 11.2 cm forward in the traveling condition. Finally, as with the full trunk, the COM of the full body demonstrated significant differences for all three conditions; the shift was 0.5 cm backward at the *barre*, 0.2 cm forward in the center, and 14.6 cm forward in the traveling condition. Figure 5 graphically displays the mean distances from stance to initiation in the y-axis, broken down by body region and condition.

**Initiation to Peak, y-axis**

For Initiation to Peak, all variables demonstrated significant differences between all conditions. For the full trunk, the shift was 2.9 cm backward at the *barre*, 1.5 cm backward in the center, and 22.1 cm forward in the traveling condition. For the pelvis, the shift was 1.0 cm forward at the *barre*, 1.7 cm forward in the center, and 22.0 cm forward in the traveling condition. For the upper trunk, the shift was 5.5 cm backward at the *barre*, 3.7 cm backward in the center, and 20.8 cm forward in the traveling condition. And for the COM, the shift was 0.8 cm forward at the *barre*, 1.9 cm forward in the center, and 22.6 cm forward in the traveling condition. Figure 6 graphically displays the mean distances from initiation to peak in the y-axis, broken down by body region and condition.

**Peak to End, y-axis**

In the y-axis, *barre* and center most closely resembled each other in this last movement phase, with the pelvis demonstrating the only significant difference between these two conditions. For the full trunk $p$ = 0.505, for the upper trunk $p$ = 1.00, and for the COM $p$ = 1.00. However, traveling was significantly different from the other 2 conditions for all four body regions. All weight shift was forward in this last phase. For full trunk, the shift was 4.5 cm at the *barre*, 4.8 cm in the center, and 41.7 cm in the traveling condition. For the pelvis, the shift was 0.1 cm at the barre, 0.8 cm in the center, and 35.3 cm in the traveling condition. For the upper trunk, the shift was 7.2 cm at the *barre*, 7.3 cm in the center, and 44.6 cm in the traveling condition. And for the COM, the shift was 0.3 cm at the *barre*, 0.5 cm in the center, and 36.4 cm in the traveling condition. Figure 7 graphically displays the mean distances from peak to end in the y-axis, broken down by body region and condition.

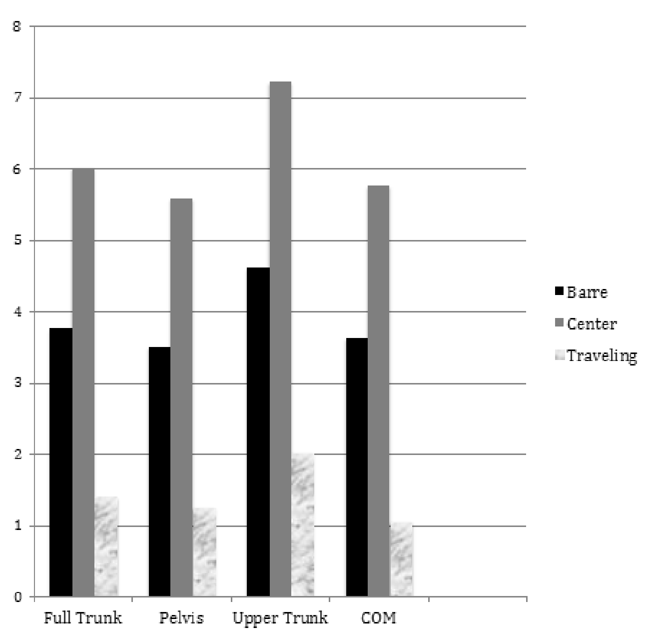


**FIGURE 4.** Distance from GB Peak to End in the x-axis in cm: COG full trunk, COG pelvis, COG upper trunk, COM.

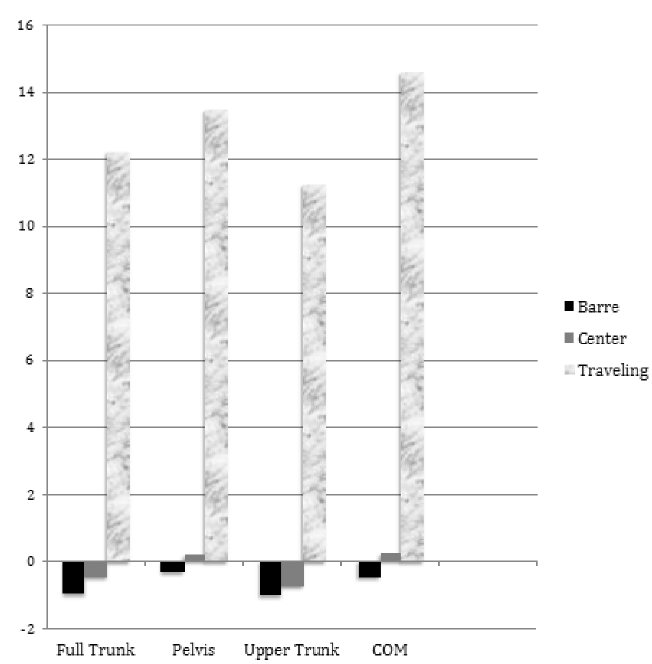


**FIGURE 5.** Distance from Stance to Initiation in the y-axis in cm: COG full trunk, COG pelvis, COG upper trunk, COM.

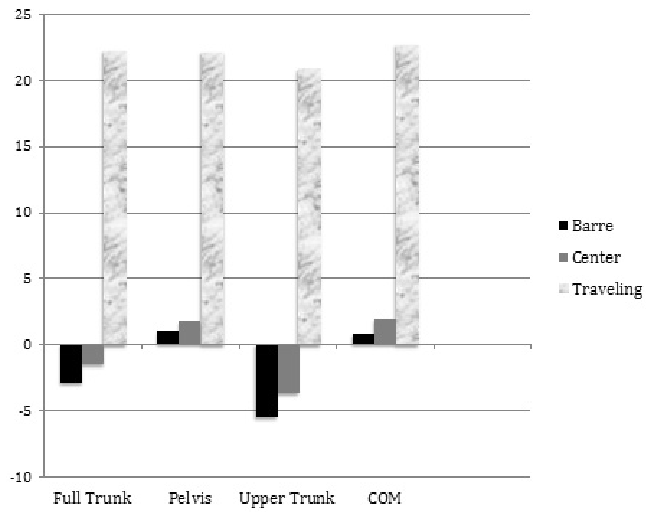


**FIGURE 6.** Distance from Initiation to GB Peak in the y-axis in cm: COG full trunk, COG pelvis, COG upper trunk, COM.

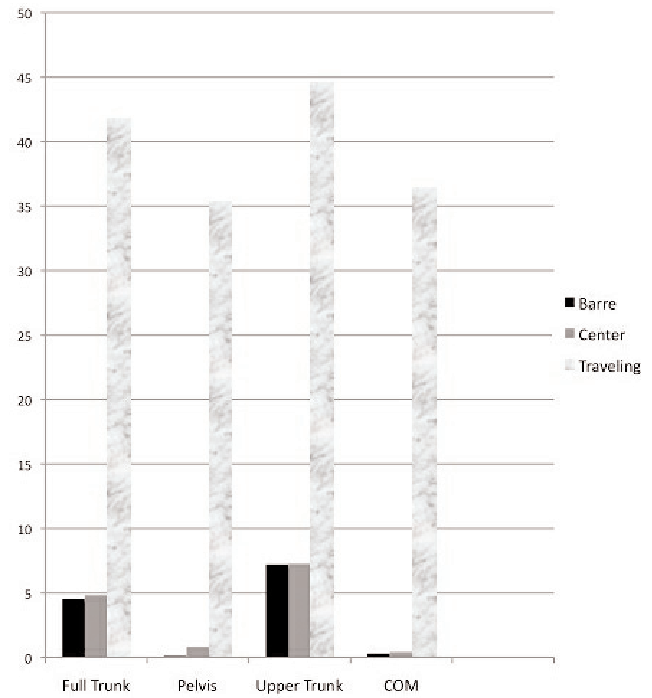


**FIGURE 7.** Distance from GB Peak to End in the y-axis in cm: COG full trunk, COG pelvis, COG upper trunk, COM.

## DISCUSSION

It is interesting to note that there were no significant differences due to level of training in the results of this study. It is likely that dancers with different levels of training vary in the aesthetics of movement execution, and this has been noted in other research.[17,19,20,24] For example, Mouchnino[20] found that the advanced dancers used a translation strategy to shift the pelvis onto the supporting leg from stance on two feet, while the novices used an inclination strategy. In this study, the research question involved the amount of transfer executed, looking at various body segments, and for this question, no differences in training levels were exhibited. Further inquiry into the joint angles might uncover differences in the 3 groups of dancers.

Overall, it can be stated that although dancers are often instructed to maintain the full trunk as a unit during weight transfer, it was not uncommon in this study for the dancers to use different motor strategies for the upper trunk and the pelvis. Further, in most intervals, there are clear differences in amount and direction of weight transfer in the three conditions, *barre*, center, and traveling.

### Stance to Initiation, x-axis

It can be seen that the shift towards the supporting foot was greater in the center than at the *barre* for all four body regions (reaching statistical significance for all but the pelvis) in the Stance to Initiation phase. At the *barre*, each region shifted a similar amount, from 2.0 cm to 2.2 cm, whereas in the center, the range of values was from 2.5 to 2.9 cm. This result supports previous research in 5th position work, which demonstrated more sagittal shift, or movement towards the supporting foot, in the center than at the *barre*.[2] The traveling condition had the smallest values in shift to the supporting foot, with full trunk, pelvis, and COM at 1.2 cm, but upper trunk at 2.3 cm, which is why it is not significantly different from the *barre* in this phase. It seems that the momentum of traveling forward reduces overall lateral shift onto the supporting foot during the stance to initiation phase, but dancers use a strategy of moving the upper trunk in that direction to accommodate the movement.

### Initiation to Peak, x-axis

There is considerable similarity in values between full trunk, pelvis, and COM in the Initiation to Peak phase in the x-axis. It is for the upper trunk that dancers use a very different strategy during this phase of the movement. The shifts at the *barre* and center are greatest for the upper trunk, and it is only for this variable that the shift in the traveling condition is to the left.

It is also noteworthy to observe how different the strategy is for the traveling condition from Stance to Peak, relative to what is occurring at *barre* and center. During the Stance to Initiation phase, while traveling, the weight shifted to the left for all variables, but as the leg moved from Initiation to Peak, the weight started to shift back to the right (except for the upper trunk) in preparation for shifting the weight onto the gesture leg after the *battement*. In other words, even before the gesture leg had reached peak, the weight was already starting its shift towards the leg that would become the new support. At the *barre* and center, the weight continues its transfer towards the supporting leg throughout both of these first two phases.

**Peak to End, x-axis**

If the values for stance to initiation and initiation to peak are added and compared to Peak to End, there is a pattern that can be observed across all variables when examining *barre* and center. At the *barre*, the shift to the left in the first half of the movement was 5.0 cm for the full trunk, but the return from peak to end was only 3.7 cm to the right. For the pelvis, the shift was 4.6 cm to the left, and the return was 3.5 cm to the right. For the upper trunk, the shift was 5.9 cm to the left, and the return was 4.6 cm to the right. Finally, for the COM, the shift was 4.8 cm to the left, and the return was 3.6 cm to the right. In each case, the dancer did not return to the starting position, that is, after the *battement* was completed, the center of gravity of the various body regions remained further towards the *barre* than prior to the battement.

However, for the center condition, the pattern was quite different. For the full trunk, the shift in the first half of the movement was 6.0 cm to the left, and the return was 6.0 cm to the right. For pelvis, the shift was 5.5 cm to the left, and the return was 5.6 cm to the right. For the upper trunk, the shift was 7.3 cm to the left and the return was 7.2 cm to the right. And for the COM, the shift was 5.8 cm to the left and the return was 5.8 cm to the right. In each instance, the dancer returned to the starting (stance) position after the *battement*. It would seem counter-productive to practice this movement repeatedly at the *barre* and train the body to fail to return to a place with the weight centered on both feet if it is to have application to unsupported movement.

It is of interest to note, in general, how small the values were in the x-axis for all conditions and intervals for the traveling condition. While dancers spend considerable time learning how to shift onto the supporting leg, once the body began traveling in the forward direction, very little shift to the supporting leg, i.e., the base of support, occurred. The act of moving forward appears to entail little time spent in balance on either foot, and if the body were to stop moving at any point in the movement sequence, it would fall sideways as well as forward.

Finally, the upper trunk displayed the largest movement in all three phases, for all variables. Further, during the traveling condition, the upper trunk and pelvis moved in opposite directions in the Initiation to Peak phase. Despite instructions to dancers to maintain these two body regions as a unified segment, as the leg is rising in *grand battement devant*, there is clearly a difference in upper trunk and pelvic motion during this movement.

**Stance to Initiation, y-axis**

Although the values are small in the Stance to Initiation phase in the y-axis, it is interesting to note that in the center condition, the full trunk and upper trunk moved backward in this first phase, while the pelvis and COM shifted forward. At the *barre*, however, all four variables indicated movement backward. It may be that in the unsupported condition, there is a counterbalance occurring in the upper trunk and pelvis that is not needed at the *barre*.

**Initiation to Peak, y-axis**

In the Initiation to Peak phase, for the full trunk and the upper trunk, *barre* and center were significantly different from each other even though the shift was backward for both. The pelvis and COM moved forward for both *barre* and center, which were also significantly different. Hence, it is the quantity and not the direction of shift that made barre and center differ significantly for all body regions in this movement phase. Further, the full trunk and upper trunk shifted more at the *barre* than in the center, but the pelvis and COM shifted less at the *barre*. Therefore, both quantity of shift and strategy and direction for the various regions of the body differentiate barre and center in this phase of the movement.

**Peak to End, y-axis**

From Peak to End, the pelvis and COM make little shift forward in either the *barre* or center condition, compared to the movement of the full trunk and upper trunk. Although alignment was not a focus of this study, it is possible that the trunk is leaning back at the initiation of the battement and moves forward as the body follows through from Peak to End to accomplish the weight transfer onto the new supporting foot. Additional study would be needed to verify this strategy.

Again, it is of interest to compare the shift in the first half of the movement (Stance to Peak) to the return (Peak to End) for *barre* and center. At the *barre*, for the full trunk the shift backward in the first half of the movement was 3.9 cm, but the return from peak to end was 4.5 cm forward. For the pelvis, the shift was 0.7 cm forward in the first half, and the return was 0.1 cm further forward. For the upper trunk, the shift was 6.5 cm backward, and the return was 7.2 cm forward. Finally, for the COM, the shift was 0.3 cm forward, and the return was 0.3 cm further forward. In each case, the dancer ended slightly further forward than they began. The differences are 0.6, 0.8, 0.7, and 0.6.

For the center condition, the pattern is similar in that the dancers ended further forward, but the quantity is larger. For the full trunk, the shift in the first half of the movement was 2.0 cm backward, and the return was 4.8 cm forward. For pelvis, the shift was 1.9 cm forward, and the return was 0.8 cm further forward. For the upper trunk, the shift was 4.5 cm backward and the return was 7.3 cm forward. And for the COM, the shift was 2.1 cm forward and the return was 0.5 cm further forward. For this condition, the differences are 2.8, 2.7, 2.8, and 2.6.

What is striking is how similar the differences from start to finish were for the four variables in each condition. For the *barre*, the range is 0.6 to 0.8 cm, and for the center condition, the range is 2.6 to 2.8 cm. Despite differences observed during phases of the movement for these variables, overall, each body region (full trunk, pelvis, upper trunk and the COM) ends further forward from where it began and at approximately the same distance per condition.

For the traveling condition, as might be expected, large changes are occurring in the forward direction throughout the movement. It is worth noting that the distance traveled from Stance (when the weight first shifted onto the left foot in preparation for the *battement*) to Initiation was just over half the distance covered from Initiation (when the right heel passes the left heel as it begins to leave the floor for the *battement*) to Peak. It is clear that the right leg is traveling with great force in the *z*-axis, and yet the momentum to travel forward continues to build. This movement, the traveling *battement*, is preparation for *grand jeté*, and the strategies learned at the *barre* and in the center are not similar to the movement execution in traveling.

### Relevance

It is crucial that dancers develop appropriate motor strategies for weight transfer as part of their dance training to ensure coordinated movement and potentially to reduce injury incidence through loss of balance and control. It is suggested by this study and previous research that dance classes devoting an inordinate amount of time to barre work may not be developing appropriate weight transfer strategies for unsupported and traveling movement. It is recommended that dance training and injury rehabilitation consider the importance of allocating sufficient time to each of the three conditions, *barre*, center, and traveling, to ensure development of varied and appropriate motor strategies for weight transfer in dance practice.

## CONCLUSION

The purpose of this study was to examine *grand battement devant* in three conditions: at the *barre*, in the center, and traveling through space. The primary focus was to consider weight transfer in the three conditions, from two feet to one foot for the *barre* and center conditions, and from one foot to the other foot in traveling. Additionally, the study investigated differences in weight transfer strategies between three levels of dancers—beginning, intermediate, and advanced. This is the first known study in the literature to consider dance movement traveling through space and to compare it to *barre* and center practice.

As with other studies in the literature comparing dance movements at the *barre* and in the center, results demonstrated significance for the main effect of condition, and for almost all intervals for all conditions. However, there were no significant effects for training level, or for condition by training interactions. In general, for lateral movement, dancers shift further to the supporting leg in the center than at the barre, for all variables considered, and shift the least in the traveling condition. For sagittal movement, no overall pattern between center and *barre* can be stated, as it varies from interval to interval, but there are differences between the three conditions.

It is clear from this study that weight transfer strategies differ between *barre*, center, and traveling, and each condition requires sufficient attention during training to develop the appropriate motor strategies. Educators are encouraged to examine class structure to ensure adequate time allocated to all aspects and conditions of weight transfer.

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