BIOMECHANICAL ANALYSIS OF HIGH-LOW IMPACT AEROBIC DANCE AND STEP AEROBICS

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The purpose of this study was to compare the kinematics and kinetics both in high-low impact aerobic dance and step aerobics. Six female subjects performed front knee lift movements under high-low impact aerobics and two-step heights (10, 20 cm) in step aerobics. One Peak high-speed camera (120 Hz) and one Kistler force plate (600 Hz) were synchronized to collect the data. An ANOVA for repeated measures was used to identify differences for each dependent variable. The result indicated that it is important to flex at the knee and ankle joints in order to absorb and reduce the shock in the landing phase. When compared to the low impact front knee lift, high impact front knee lift and two-step heights of step aerobics had significant shorter time to first peak impact force and higher values for first peak impact force, passive impact impulse, and total work.

KEY WORDS: aerobic dance, step aerobics, ground reaction force, work.

INTRODUCTION: Aerobic dance and step aerobics have become very popular in the last decade, there are many forms of aerobic dance -- running, hopping, skipping and jumping movements, for example. Exercise frequency, shoe type, floor surface and technique will all cause injury (Richie, Kelso, & Bellucci, 1985). Garrick, Gillien, and Whiteside (1986) recruited 60 instructors and 351 students and found that an injury rate of 75% for instructors and 44.1% for students. The most common place of injury was leg/calf/Achilles for instructors and students. Rothenberger, Chang, and Cable (1988) surveyed 726 aerobic dancers by questionnaire and found that 49% of them reported at least one injury related to aerobic dance. Most of the injuries were to the shin (24.5%), lower back (12.9%), and ankle (12.2%). Mutoh, Sawai, Takanashi, and Skurko (1988) reviewed 161 instructors and 800 aerobic students and found an injury rate of 72.4% for instructors and 22.8% for students. The lower leg and foot were the most common injury areas for instructors and students, respectively. Several other surveys have also indicated that the lower extremity is the most common site of injury in aerobic dance (Francis, Francis, & Welshons-Smith, 1985; Richie *et al.*, 1985; Vetter, Helfet, Sear, & Matthews, 1985), and that incidence of injury appears to increase with exercise intensity, duration and frequency (Francis *et al.*, 1985). This relatively high rate of injury has led some instructors to shift from high impact aerobics to low impact aerobics, because while high impact aerobics require both feet to be off the ground at the same time, low impact aerobics is performed with one foot on the ground at all times. Only a few studies have specifically quantified the ground reaction forces in high-low impact aerobic dance. Korzick (1987) showed that four kinds of common high impact aerobic dance movements produced vertical ground reaction forces that are 2-3.5 times one's body weight (BW). Ricard and Veatch (1990) compared the ground reaction force variables in low impact and high impact aerobic dance movements (front knee lift), discovering that peak impact force was significantly lower in low impact (0.98 BW) versus high impact (1.98 BW) aerobics. A significantly lower landing rate (14.38 BW/s) than in high impact movements was also found in the low impact (42.55 BW/s). Ricard and Veatch (1994) compared the vertical ground reaction force variables in five jumping heights (0, 2, 4, 6, and 8 cm) of aerobic dance and five running speeds (2.4, 2.8, 3.2, 3.6, and 4.0 m/s). The first peak impact forces resulting from airborne aerobic dance (1.96-2.62 BW) were greater than the first peak impact forces in running (1.30-2.01 BW). When compared to aerobic dance, running had a shorter time to peak impact force and higher values for landing rate, high-frequency impulse, and 50-ms impulse. All of the previous studies have focused on ground reaction forces generated during high-low impact aerobic dance, while there is a lack of information about the change of the body position associated with either high-low impact aerobic dance or step aerobics. That is the reason why, the purpose of this study was to compare the kinematics and kinetics both in high-low impact aerobic dance and step aerobics.

METHODS: Six female subjects, experienced in aerobic dance, volunteered for this study. They were skilled in both high-low impact aerobic dance and step aerobics and had engaged in aerobic dance classes at least four hours per week for a mean of 2.6±0.42 yr. The mean values for age, height, and mass of the group were 24.8±2.2 yr, 162±2.16 cm, and 53.7±3.9 kg, respectively. The aerobic dance movement selected for analysis was shown in Figure 1. The International Dance Exercise Association (IDEA) defined this movement as the Front Knee Lift (FKL). As shown in Figure 1, the only difference between low impact front knee lift (LFKL) and high impact front knee lift (HFKL) is that the HFKL consists of an airborne phase (3). The movement selected for step aerobics was HFKL.

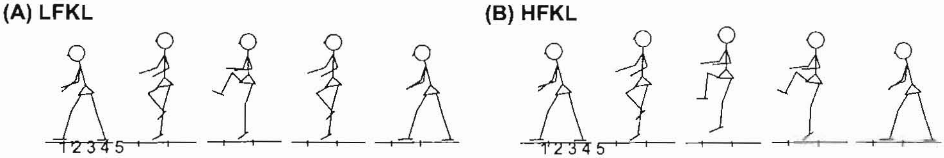

Figure 1. Front knee lift aerobic dance exercise. (A) Low impact front knee lift (LFKL). (B) High impact front knee lift (HFKL). Note: From Ricard & Veatch, 1994.

One Peak high-speed camera was operated at 120 Hz and set up to record the participants in the sagittal plane, and one Kistler force platform (600 Hz) was synchronized to collect the ground reaction forces. The subjects were given as much practice as they needed and they were asked to land consistently in the area of the force platform with the right foot. Each subject performed five trials at each condition of LFKL and three kinds of HFKL (flat, 10 cm-step, and 20 cm-step). Each kind of FKL movements was monitored by visual inspection and metronome (120 beats/minute). The force data for each trial was recorded, but only the third trial's data (the motion was more stable) was collected for analysis. All subjects wore the shoes that they customarily used in aerobic dance class. A typical vertical force curve for the HFKL consisted of three phases: propulsion, flight, and landing (Figure 2). From each force curve, including LFKL and the three types of HFKL, the following dependent variables were calculated: first peak impact force, time to first peak impact force, passive impact impulse, and first peak impact impulse in the landing phase. The passive impact impulse was the area under the vertical force curve during the first 50 ms of the loading phase. The first peak impact impulse was the area under the vertical force curve from the beginning of loading to the first peak impact force. Five body landmarks were placed on the shoulder, hip, knee, ankle, and toe, and another reference point was placed on the force platform. All of the landmarks were digitized and framed by Peak Motus 7.0 System. Values for segment mass and positions of CM were obtained from anthropometrical tables (Dempster, 1955). Using an inverse dynamics process to calculate net joint reaction forces and net muscle joint moments (M), the net muscle joint powers (P) were calculated as $P_i=M_i\times$, (i=hip, knee and ankle). The net muscle joint works (W) were calculated by the formula $W_i= P_i \times dt$, while total work (TW) was calculated by summing the work of individual joints: $TW= W_i$. All kinetic parameters were normalized for the subject's body weight. An ANOVA for repeated measures was used to identify differences for each dependent variable. A statistical significant level was set at $P<0.05$ for all comparisons.

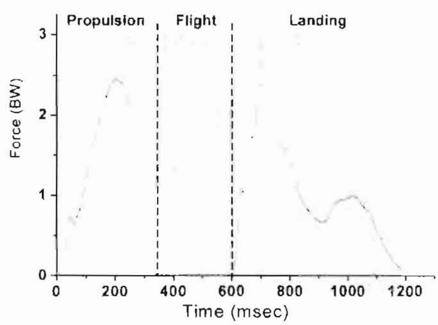

Figure 2. Typical high impact front knee force-time curve.

RESULTS AND DISCUSSION: Jumping height was calculated using the flight time of each jump. This method of calculation assumes that the subject's body position was the same at takeoff and landing. As shown in Table 1, no significant difference was found among HFKL, 10 cm and 20 cm step aerobics for jumping height. The peak impact force in the propulsion phase occurred when the whole sole of the foot hit the ground. At this moment, the hip, knee, and ankle joint angles in HFKL and step aerobics were lower than in LFKL. This is because HFKL and step aerobics required more elastic energy to jump so that the angle of the lower extremity was more flexible. Due to step aerobics required to move the foot on the step, the hip angle in step aerobics was the fact that lower than in HFKL. The first peak impact force in the landing phase also occurred when the whole sole of the foot hit the ground. At that moment, in order to absorb the energy associated with the impact, the knee and ankle joint angles in HFKL and step aerobics were significantly lower than that in LFKL. However, no significant difference was found in LFKL, HFKL and step aerobics for the hip angle. This result indicated that it is important to flex at the knee and ankle joints in order to absorb and reduce the shock in the landing phase.

Table 1. Comparison with jumping height and the joint angle at different moments.

	LFKL	HFKL	10 cm-Step	20 cm-Step
Jumping height (cm)	0	9.17±1.77	8.77±1.25	7.68±1.27
At peak impact force moment in the propulsion phase				
Hip joint (degree)	148.67±7.42*	136.05±7.08[ab]	126.74±6.67[a]	125.43±4.99[b]
Knee joint (degree)	141.86±5.25*	116.90±2.89	117.92±4.98	119.21±3.53
Ankle joint (degree)	120.61±2.53*	105.90±4.02[b]	109.48±5.23	112.46±6.38[b]
At first peak impact force moment in the landing phase				
Hip joint (degree)	145.91±9.89	144.95±3.87	144.58±4.74	142.77±5.69
Knee joint (degree)	149.39±8.04*	132.80±3.42	130.05±4.56	131.54±5.27
Ankle joint (degree)	119.71±2.92*	111.54±3.32	110.39±3.56	112.92±2.37

n=6; Mean±SD; $p<0.05$. * LFKL was significantly greater than all the others.
[a] Significant differences between HFKL and 10 cm-step. [b] Significant differences between HFKL and 20 cm-step.

The vertical force-time curve for LFKL only consisted of propulsion and landing phases but the curve for two-step heights of step aerobics was similar to that in HFKL. As shown in Table 2, the first peak impact force in the landing phase was significantly greater in HFKL (2.78 BW), 10 cm-step (2.50 BW) and 20 cm-step (2.35 BW) than that in LFKL (1.09 BW). Moreover, HFKL was also significantly greater than 20 cm-step. In contrast with Table 1, the first peak impact force increased with jumping height. The range of first peak impact forces both in LFKL and HFKL was approximately that of previous studies (Ricard & Veatch, 1990,1994). The time in the first peak impact force was longer in LFKL (181.50 ms) than in HFKL (102.77 ms), 10cm-step (106.47 ms) and 20cm-step (104.48 ms), which was different from Ricard and Veatch (1990). This difference could be from the metronome (Ricard and Veatch only used visual inspection). Nigg (1985) defined the forces that reach a peak in less than 50 ms as passive forces, which have been associated with injuries to both soft tissue and bone. Since these forces are applied at a rate that is faster than the reaction time of the neuromuscular system (50-70 ms), the muscles are unable to absorb the shock. According to the result, we found that all of the time for the first peak impact force was longer than 50 ms, such that the muscles are able to absorb the shock by flexing at the lower extremity. Besides, the passive impact impulses for HFKL, 10 cm-step and 20 cm-step were shown to be significantly greater than for the LFKL, as the passive impact impulse for HFKL was almost 2 times greater than that for the LFKL, 0.0392 BW•s and 0.0207 BW•s, respectively. No significant difference was found in LFKL, HFKL and step aerobics for first peak impact impulse. A full, whole cycle of each FKL movement consists of five phases: stance (preparation), push off (propulsion), toe-up (low impact) or lift-off (high impact), landing, and stance (Figure 1). Total work was calculated as a whole cycle of each FKL movement. In the present study, the total work for HFKL, 10 cm-step and 20 cm-step, was approximately 3.7 times significantly greater than for the LFKL, it is shown that HFKL aerobic dance and step aerobics could use more energy than LFKL aerobic dance. In this study, the percentage of total work was the individual joint contributions relative to the total performance output for each movement. During LFKL aerobic dance, the average relative contributions of the hip joint (approximately 52%) was the maximum contribution of the lower limbs, while during HFKL aerobic dance, the ankle joint (approximately 45%) became the maximum contribution of the lower limbs. Following an increase in step height, the average relative contributions of the hip joint were also increased from 23% (HFKL), 31% (10 cm-step), to 36% (20 cm-step). Because of this, was no significant difference among HFKL and two-step heights of step aerobics for total work so the change of the individual joint contributions meaning that the training position among HFKL and two-step heights of step aerobics was different.

Table 2. Comparison with first peak impact force, impulse variables, total work, and the percentage of total work.

	LFKL	HFKL	10 cm-Step	20 cm-Step
In the landing phase				
First peak impact force (BW)	1.09±0.14*	2.78±0.29*[b]	2.50±0.23*	2.35±0.46*[b]
First peak impact force time (ms)	181.50±14.07*	102.77±11.81*	106.47±7.43*	104.48±13.29*
Passive impact impulse (BW•s)	0.0207±0.008*	0.0392±0.006*	0.0330±0.005*	0.0293±0.006*
First peak impact impulse (BW•s)	0.1139±0.011	0.1366±0.014	0.1337±0.009	0.1273±0.017
Total work (J/kg)	1.58±0.27*	5.96±0.70*	6.08±1.08*	6.12±0.84*
The percentage of total work				
Hip joint (%)	51.99±5.14*	23.41±3.72*[ab]	30.64±5.47*[ac]	36.12±4.90*[bc]
Knee joint (%)	27.40±5.04	31.48±7.40	29.22±8.04	30.59±6.27
Ankle joint (%)	20.61±2.14*	45.11±6.77*[b]	40.14±5.72*[c]	33.29±4.22*[bc]

n=6; Mean±SD; $p<0.05$. * Significant differences between LFKL and all the others.
[a] Significant differences between HFKL and 10 cm-step. [b] Significant differences between HFKL and 20 cm-step.
[c] Significant differences between 10 cm-step and 20 cm-step.

CONCLUSION: The results of this study provide relevant and objective information to the instructors and aerobic dance students, it suggested that it is important to flex the knee and ankle joints to absorb and reduce the shock in the landing phase. HFKL and step aerobics had significant shorter time for the first peak impact force and higher values for the first peak impact force, passive impact impulse, and total work, so the instructors required designing the movements alternate high and low impact aerobics in aerobic dance class.

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