Korean Journal of Sport Biomechanics
Vol. 21, No. 1, March 2011, 025-029

ISSN 1226-2226(Print), ISSN 2093-9752(Online)
DOI: 10.5103/KJSB.2011.21.1.025
http://www.kssb.or.kr

Quantitative and Qualitative Differences according to the Shoe Type for the Grand Jete Landing in Ballet

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Received 30 September 2010; Received in revised form 8 December 2010; Accepted 7 March 2011

ABSTRACT

The purpose of this study was to analyze quantitative and qualitative differences according to shoe type for the grand jete landing in ballet. The subjects for this study were 9 female ballet majors with an average of 12 years of experience. Subjects jumped, performing a front split, and landed on 1 foot, a movement called the grand jete. Analysis was performed on the students' landing. Independent variables were 3 shoe types: split sole, traditional out sole, and 5-toed forefoot shoes, with bare feet as a control group. Dependent variables were vertical passive ground reaction force and qualitative elements. Passive ground reaction force variables(maximum passive peak value, number of passive peaks, passive force-time integral, and center of pressure) were measured by the Kistler 9281B Force Platform. Qualitative elements were comfort, cushioning, pain, and fit. Statistical analysis included both 1-way ANOVA and Tukey's test for follow-up. Finalized data demonstrated that the 5-toed forefoot shoe allows the forefoot to expand and the toes to individually press down upon landing, increasing foot contact with the surface. Five-toed forefoot shoes minimize passive peaks and pain, while increasing comfort, cushioning, and fit.

Most ballet movements are composed of jumping, balancing, landing, and spinning. Wearing 5-toed forefoot shoes allows for a natural range of movement in each toe, to improve both technique and balance. Pain and injuries from ballet can be minimized by wearing the correct shoe type. According to this analysis, it is possible to customized ballet shoes to increase the efficiency of techniques and movements.

Keywords : Ground Reaction Force, Qualitative Elements, Grand Jete, 5-Toed Forefoot Shoes

Ⅰ. Purpose

Ballet movements such as the turn out, toe dancing, jumping, and pirouettes cause injury by forcing the human body to move outside of its normal range of motion(Contompaisis, 1984; Quirk. 1988; Ryan & Stephens, 1987; Thomasen, 1982; Washington, 1978; Choi, 1997).

There are five jumps in ballet according to foot position when jumping and landing. A jump and landing with both feet is chamgement de pieds, a two foot jump and one foot landing is the sissonnes, assembles, a one footed jump and two foot landing is the assembles. A one footed jump and one foot landing with the opposite foot is the jete´. A single foot jump and landing with the same foot is known as the temps leves, or fouettes sautes(Lawson, 1979).

The grand jete´ is one of the most powerful movements in ballet. It is the longest(in both duration and distance) and highest jump in ballet. During the jump, performers must maintain a full front split while airborne. These types of movement result in high impact forces on the body. For a vertical jump, impact force peaks at 3.5 to 7.1 times the performer's bodyweight during landing(Cavanah & Lafortune, 1980). These high impact forces travel throughout the body, from the point of impact to the

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extremities. The amount of impact force depends on knee angle, landing type, jump height(Lee, 1994), and the relationship between the foot and landing surface(Yi, 1999).

Foot flexibility and complex foot movement facilitate foot function and foot strength, enhancing ballet performance creating fluid, graceful movements. The array of tarsal bones is important because misalignment of these bones leads to knee and ankle injury and negatively effects both jumping and landing(Seo, 1992).

Tarsal misalignment can result in sprains in the metatarsal phalanges, the arch of foot, or the ankle.

During performance and practice ballet dancers typically wear shoes that constrict the toes, causing the toes to impact against one another. This leads to foot muscle degeneration, misalignment, foot deformities, pain, and injury. Five-toed shoes force misaligned feet into a proper alignment, activating abductor muscles and helping to dissipate pressure evenly, strengthening foot muscles and eventually correcting foot deformity(Yi, 2009).

Because the five-toed shoes allow the toes to spread naturally(Yi, 2009), users benefit from a larger base of support than with normal ballet shoes.

Most ballet movements combine elements of turning, jumping, balancing, and or landing. Five-toed shoes' broader base of support can provide greater stability for all of these movements. The purpose of this study was to analyze vertical ground reaction force and qualitative variables according to ballet shoe type. These results can be used to develop ballet foot ware in order to both to alleviate chronic pain or injury and also to improve performance for ballet dancers.

Ⅱ. Methods

1. Subjects

The subjects for this study were nine female ballet majors in Seoul with an average of twelve years of experience.

Table 1. General characteristics of the subjects (n=9)

Items	Age(yrs)	Height(cm)	Weight(kg)	Career(yrs)
Average	21.8	165.9	48.3	10.8
standard deviation	2.09	6.43	5.76	2.61

2. Equipment

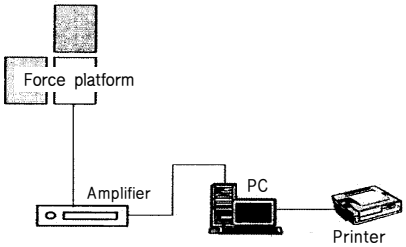

Figure 1. Equipment placement

(a) (b) (c) (d)

Figure 2. Experimental Condition
(a) Split Sole
(b) Traditional out sole
(c) Five-toed forefoot shoes
(d) Bare feet

Figure 3. Experimental movement : grand jete´

3. Procedure

Subjects jumped, performing a front split to create a movement called the grand jete´. Analysis was performed on the students' one footed grand jete´ landing.

4. Variables

Independent variables were four shoe types: split sole, traditional out sole, five-toed forefoot shoes, and bare feet.

Dependent variables were passive ground reaction force and qualitative elements. Passive ground reaction force variables(maximum passive peak value, number of passive peaks, passive force-time-integral, and center of pressure) were measured by the Kistler 9281B Force Platform. Qualitative elements were comfort, cushioning, pain, and fit.

5. Statistics

Statistical analysis was performed through a combination of both One-way ANOVA, and Tukey for follow-up.

Ⅲ. Results

1. The Maximum Passive Impact Peak Value

There were no statistically significant differences according to shoe type for maximum impact peak value.

However, the traditional out soles showed the highest level of maximum impact value(3.95BW%), while five-toed forefoot shoes showed the lowest(2.83BW%).

Table 2. The maximum passive impact peak value

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	3.491	0.586	2.180	4.130			
traditional out sole	3.946	1.030	3.019	6.535			
bare feet	3.234	0.948	2.242	5.503	2.747	.059	2-4
five-toed forefoot shoes	2.833	0.744	2.000	4.181			
total	3.376	0.906	2.000	6.535			

** split sole: 1, traditional out sole: 2,
bare feet: 3, five-toed forefoot shoes: 4

2. Number of Passive Peaks

There was a statistically significant difference between the number of passive peaks according to shoe type. The highest number of passive peaks were for traditional out soles(7.22n) and the lowest were for five-toed forefoot shoes(3.67n) (F=12.947, p<.00). Split soles and traditional out soles were not significantly different. Both sole types showed a high number of passive peaks. Split soles had significantly higher number of passive peaks than both bare feet and five-toed forefoot shoes(p<.01). Statistical differences between bare feet and five-toed forefoot shoes were not found. However, five-toed forefoot shoes(3.67n) had a lower number of passive peaks than bare feet(4.33n).

Table 3. Number of Passive Peaks

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	6.78	1.093	5	8			
traditional out sole	7.22	1.986	5	10			1-3
bare feet	4.33	1.225	3	6	12.947	.000***	1-4
five-toed forefoot shoes	3.67	1.414	2	7			2-3 2-4
total	5.50	2.090	2	10			

*** p<.001, ** split sole: 1, traditional out sole: 2,
bare feet: 3, five-toed forefoot shoes: 4

3. Passive Force-Time-Integral

Statistically the passive force-time-integral was highest in the traditional out soles(0.55%BW), while the five-toed forefoot shoes was the lowest(0.40%BW)(F=4.378, p<.011). Split soles(p<.05) and the traditional out soles(p<.05) were higher than five-toed forefoot shoes, statistically.

Table 4. Passive Force-Time-Integral

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	0.535	0.071	0.439	0.633			
traditional out sole	0.547	0.105	0.402	0.680			
bare feet	0.494	0.101	0.336	0.642	4.378	.011*	1-4 2-4
five-toed forefoot shoes	0.400	0.102	0.248	0.536			
total	0.494	0.109	0.248	0.680			

* p<.05, ** split sole: 1, traditional out sole: 2,
bare feet: 3, five-toed forefoot shoes: 4

4. COP(center of pressure) range

There was no statistically significant different for COP range according to shoe type. However, traditional out soles(8.54 BW%)was measured to be highest while five-toed forefoot shoes being the lowest(1.96BW%).

Table 5. COP(center of pressure) range

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	6.077	8.590	0.150	25.248			
traditional out sole	8.545	7.013	0.555	18.915			
bare feet	8.892	7.358	0.341	24.706	2.019	.131	•
five-toed forefoot shoes	1.958	2.239	0.146	6.783			
total	6.368	7.036	0.146	25.248			

** split sole: 1, traditional out sole: 2,
bare feet: 3, five-toed forefoot shoes: 4

5. Shoe Sensitivity for Different Ballet Shoes

1) Comfort

The comfort level for different ballet shoes was significantly different. The comfort level was highest in bare feet and five-toed forefoot shoes(4.67P) and lowest in the traditional out soles(1.56P)

Table 6. Comfort

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	2.333	0.707	1	3			
traditional out sole	1.556	0.527	1	2			1-2
bare feet	5.000	0.000	5	5	81.739	.000***	1-3 1-4
five-toed forefoot shoes	4.667	0.707	3	5			2-4 3-2
total	3.389	1.591	1	5			

***p<.001, **split sole: 1, traditional out sole: 2, bare feet: 3, five-toed forefoot shoes: 4

(F=81.739, p<.00). There was also a statistical difference between the comfort levels of the split soles(p<.031) and traditional out soles(p<.031), with the split soles(2.33P) being higher than the traditional out soles(1.56P). There was a significant difference between the comfort levels the split soles(p<.00) and both bare feet(p<.00) and five-toed forefoot shoes(p<.00). Bare feet(5.00P) and five-toed forefoot shoes(4.67P) were significantly higher(p<.00).

2) Cushioning

Cushioning level for different ballet shoes was significantly different. The cushioning level was highest for five-toed forefoot shoes(4.78P) and lowest for the traditional out soles(1.22P) (F=182.899, p<.00). Split soles(3.33P) was higher than traditional out soles(1.22P), and bare feet(1.00P)(p<.00). The cushioning level for split soles, bare feet and five-toed forefoot shoes was significantly different. Five-toed forefoot shoes(4.78P) was the highest(p<.00).

Table 7. Cushioning

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	3.333	0.500	3	4			
traditional out sole	1.222	0.441	1	2			1-2
bare feet	1.000	0.000	1	1	182.899	.000***	1-3 1-4
five-toed forefoot shoes	4.778	0.441	4	5			2-4 3-4
total	2.583	1.628	1	5			

***p<.001, **split sole: 1, traditional out sole: 2, bare feet: 3, five-toed forefoot shoes: 4

3) Pain

Pain level for different ballet shoes was significantly different. Pain level was highest in traditional out soles, bare feet(4.00P) and lowest in Five-toed forefoot shoes(1.44P)(F=53.635, p<.00). Pain level for the traditional out soles(4.00P) was higher than split out soles(1.67P)(p<.00). Pain level for difference between bare feet and Five-toed forefoot shoes was significantly different. Bare feet (4.22P) was higher than Five-toed forefoot shoes(1.44 P)(p<.00).

Table 8. Pain

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	1.667	0.500	1.000	2.000			
traditional out sole	4.000	0.707	3.000	5.000			1-2
bare feet	4.222	0.667	3.000	5.000	53.635	.000***	1-3 2-4
five-toed forefoot shoes	1.444	0.527	1.000	2.000			3-4
total	2.833	1.424	1.000	5.000			

***p<.001, **split sole: 1, traditional out sole: 2, bare feet: 3, five-toed forefoot shoes: 4

4) Fit

Fit was statistically different for all shoe types. Bare feet and five-toed forefoot shoes had the best ratings for fit (4.67P)(p<.00) and traditional out soles was the lowest at 1.11point.(F=182.545, p<.00). Split soles(3.67P) was higher than traditional out soles(1.11P)(p<.00).

Table 9. Fit

	Avg	Std Dev	Min	Max	F	*p*	Tukey HSD
split sole	3.667	0.500	3.000	4.000			
traditiona lout sole	1.111	0.333	1.000	2.000			1-2 1-3
bare feet	5.000	0.000	5.000	5.000	182.545	.000***	1-4 2-3
five-toed forefoot shoes	4.667	0.500	4.000	5.000			2-4 3-4
total	3.611	1.591	1.000	5.000			

***p<.001, **split sole: 1, traditional out sole: 2, bare feet: 3, five-toed forefoot shoes: 4

Ⅳ. Conclusions

1. The maximum passive peak value was not significantly different for different shoe types. However, the five-toed forefoot shoes had the highest value.

2. The number of passive peaks was statistically different according to shoe types. Five-toed forefoot shoes had the lowest number of the passive peaks, demonstrating an improved ability to control or absorb impact during landings.
3. The force-time-integral was statistically different according to shoe types. Five-toed forefoot shoes had the lowest force-time-integral.
4. COP(center of pressure) range was not significantly different according to shoe types. However, five-toed forefoot shoes had the lowest value.
5. Qualitative values for different ballet shoes were statistically different according to shoe types. The traditional outsoles rated lowest for comfort, cushioning, and fit, while the five-toed forefoot shoes showed had the highest ratings.

The analyzed data demonstrates that five-toed forefoot shoe is loose enough to allow the forefoot to expand and let the toes press down upon landing. This analysis shows that wearing five-toed forefoot shoes minimizes passive peaks and pain, while increasing comfort, cushioning, fit. This result shows that five-toed forefoot shoes seem to allow each toe to be used when landing, increasing foot contact with surfaces.

Most ballet movements are composed of jumping, balance, landing and spinning. By wearing five-toed forefoot shoes allow for a natural range of movement to improve techniques and balance.

Pain and injuries from practicing ballet for a long period of time can be minimized by wearing correct shoe types. According to this analysis, it is possible to develop customized shoes to increase efficiency and techniques of movement.

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