Anthropometric Factors Affecting Vertical Jump Height in Ballet Dancers

Matthew Wyon, Ph.D.,Nicolas Allen, M.Sc., Manuela Angioi, M.Sc., Alan Nevill, Ph.D., and Emily Twitchett, B.Sc.(HONS)

Proofs to: m.wyon@wlv.ac.uk

Abstract

Jumping plays an integral part of ballet performance and this study examines some of the ballet dancer's characteristics that influence jump height. Forty-nine dancers (M = 21; F = 28) completed a series of tests that included two footed vertical jump height, single leg vertical jump height and anthropometric measurements. Supplemental training history and company position were also recorded. Statistical analysis (ANCOVA and MANOVA) indicated males had a greater vertical jump height than females ($p < 0.01$) and soloist and first artists had significantly greater vertical jump height than principals and artists for both male and females ($p < 0.05$). Anthropometric data indicated males having significantly larger leg girths than females. Males and females had no significant bilateral differences in girth measurements though male artists had significantly smaller thighs and calves than the other seniority levels ($p < 0.05$). Supplemental training did not influence jump height in this study's population though males carried out significantly more weight training ($p < 0.01$) and females more aerobic training ($p < 0.05$). When jump height was analyzed in relation to cross-sectional area of the calf and thigh, there was no gender difference ($p > 0.05$). These results corroborate to previous research and also provide greater insight on how anthropometric and choreographic factors potentially influence vertical jump height in ballet dancers. The ineffective influence of supplemental training on vertical jump height needs greater examination. How other training regimens could influence jump height in dancers needs to be examined.

Within the dance world most dancers, particularly male classical ballet dancers, are required to achieve performance feats such as exciting and dramatic elevation (e.g., jumps).[1] It is proposed that jump height can be affected by various factors, such as muscle mass,[2-5] flexibility, isometric muscle strength, age, height, weight,[6] and level of expertise.[7] However, although classical ballet traditionally requires the male dancers to perform explosive and high elevation, there has been very little published on the effect of gender on jump height, in dance. This difference in performance has been documented in sport.[3,8,9]

Harley and colleagues[6] showed that even though dancers had greater quadriceps muscle strength compared to physically active control subjects, they did not jump significantly higher. Another study highlighted that jump height may be related to level of expertise, or amount of training.[7] This suggests that dance training may eventually lead to an increase in jump height.

Golomer and Fery[10] suggest that ballet training is symmetrical, in that both sides of the body are trained equally. However, if dancers jump, leading with their "preferred" leg, this may develop bilateral differences. How often this occurs during performance, depends on the choreography of the specific piece being performed.

Golomer and Fery,[10] in their study on female ballet dancers, found that although the dancers preferred to take off from their left leg, therefore leading with the right (as in an assemblé or jeté), that there was no significant difference in jump height between left and right legs.

Athletes, particularly those specialising in jumping (e.g., high jump or long jump), train muscle strength and power specifically to achieve higher jumps for much longer.[11] It seems, however, that dancers undertake very little supplementary training to increase jump height.[1,12] Examples of such training include

Matthew Wyon, Ph.D., Manuela Angioi, M.Sc., Alan Nevill, Ph.D., and Emily Twitchett, B.Sc.(HONS), are from the School of Sport, Performing Arts and Leisure, University of Wolverhampton, United Kingdom. Nicolas Allen, M.Sc., is from the Jerwood Centre for Dance Injuries, Birmingham Royal Ballet, United Kingdom.

Correspondence: Matthew Wyon, Ph.D., School of Sport, Performing Arts and Leisure, University of Wolverhampton, Gorway Road, Walsall, United Kingdom

Table 1 Participant's descriptive data

	Principal		Soloist		First artist		Artist	
	M	F	M	F	M	F	M	F
	n = 5	n = 4	n = 4	n = 7	n = 4	n = 2	n = 8	n = 15
Time with Company (yrs)	8.2 ± 6.05	10.1 ± 6.14	5.0 ± 4.08	6.6 ± 2.57	5.3 ± 0.95	3.5 ± 3.54	2.3 ± 1.19	2.3 ± 1.33
Years dancing (yrs)	28.6 ± 5.22	31.7 ± 4.78	25 ± 3.65	26.1 ± 2.54	25.8 ± 2.5	23.0 ± 0.01	21.3 ± 2.25	20.9 ± 2.28
Height (m)	1.81 ± 0.05	1.62 ± 0.03	1.79 ± 0.05	1.66 ± 0.04	1.79 ± 0.03	1.67 ± 0.02	1.82 ± 0.02	1.66 ± 0.03
Weight (kg)	71.5 ± 6.26	51.1 ± 5.02	69.9 ± 5.7	52.4 ± 3.4	70.8 ± 5.87	46.9 ± 3.61	67.3 ± 5.37	50.6 ± 4.86
BMI	21.8 ± 1.11	19.3 ± 2.11	21.9 ± 0.86	18.9 ± 0.58	22.1 ± 1.13	16.8 ± 0.89	20.2 ± 1.47	18.3 ± 1.33
SKF* (mm)	35.9 ± 7.62	56.2 ± 16.68	37.6 ± 2.51	54.2 ± 8.73	33.7 ± 1.55	43.9 ± 8.34	30.3 ± 5.22	50.2 ± 6.91

*4 site – bicep, tricep, suprailiac and subscapular, **denotes significant difference ($p < 0.05$)

Table 2 Descriptive data for gender and dancer level

	Principal		Soloist		First Artist		Artist	
	M	F	M	F	M	F	M	F
	n = 5	n = 4	n = 4	n = 7	n = 4	n = 2	n = 8	n = 15
VO_2peak (ml.kg.$^{-1}$min^{-1})	49.84 ± 4.03	47.04 ± 1.65	49.14 ± 4.15	40.51 ± 6.71	46.39 ± 4.97	39.04 ± 4.72	49.79 ± 3.59	44.57 ± 4.18
VT* (%)	63.12 ± 17.84	62.1 ± 5.51	83.9 ± 4.84	73.09 ± 15.92	77.22 ± 1.10	64.35 ± 21.99	67.9 ± 5.78	76.0 ± 7.06
VJ Height (cm)	50.5 ± 3.79	33.0 ± 1.41	55.3 ± 4.99	39.2 ± 5.74	56.0 ± 9.76	39.0 ± 2.82	50.8 ± 7.94	37.3 ± 5.63
Left Hop	32.2 ± 6.94	22.0 ± 3.42	34.0 ± 4.97	28.7 ± 4.97	38.3 ± 5.56	26.5 ± 3.54	33.4 ± 2.76	26.4 ± 3.58
Right Hop	35.0 ± 4.24	21.0 ± 2.31	35.0 ± 5.35	29.2 ± 6.24	36.5 ± 5.26	26.5 ± 2.12	32.7 ± 3.98	24.4 ± 7.31
Left Thigh (cm)	55.5 ± 3.37	49.3 ± 2.89	55.7 ± 2.76	50.1 ± 2.21	54.2 ± 0.723	46.2 ± 2.82	50.4 ± 1.92	48.6 ± 3.38
Right Thigh (cm)	55.0 ± 3.40	49.3 ± 3.19	54.9 ± 2.32	49.8 ± 2.63	53.6 ± 1.34	45.6 ± 2.55	50.9 ± 1.77	49.3 ± 3.68
Left Calf (cm)	37.6 ± 1.93	34.8 ± 2.59	39.8 ± 1.51	35.5 ± 0.62	39.5 ± 2.41	33.0 ± 1.41	36.6 ± 1.65	34.5 ± 1.77
Right Calf (cm)	37.8 ± 1.76	34.4 ± 2.88	39.9 ± 1.91	35.5 ± 1.17	39.5 ± 1.93	33.2 ± 1.77	37.1 ± 1.08	34.5 ± 1.71
Leg Length (cm)	84.9 ± 4.04	79.1 ± 2.85	84.4 ± 3.25	80.5 ± 2.48	84.6 ± 1.25	79.3 ± 1.06	85.8 ± 2.05	79.2 ± 3.10

* expressed as a percentage of VO2 peak

Table 3 Supplemental Training Data for Gender and Level.

	Principal		Soloist		First Artist		Artist	
	M	F	M	F	M	F	M	F
Hours Trained per week	n = 5	n = 4	n = 4	n = 7	n = 4	n = 2	n = 8	n = 15
Total	3.7 ± 3.11	7.3 ± 4.64	2.3 ± 3.86	3.9 ± 2.54	5.1 ± 4.01	1.0 ± 1.41	3.5 ± 3.82	4.8 ± 4.42
Cardiovascular	1.2 ± 0.45	1.8 ± 0.50	1.0 ± 0.15	1.9 ± 0.38	1.3 ± 0.5	1.0 ± 0.01	1.1 ± 0.35	1.5 ± 0.51
Weights	1.6 ± 0.55	1.0 ± 0.0	1.0 ± 0.21	1.0 ± 0.0	1.0 ± 0.1	1.0 ± 0.0	1.4 ± 0.52	1.1 ± 0.26
Pilates	1.0 ± 0.0	1.8 ± 0.50	1.5 ± 0.58	1.0 ± 0.0	1.8 ± 0.50	1.5 ± 0.71	1.4 ± 0.52	1.4 ± 0.51

Author: table 1 footnote has two asterisks (**), but there are none in the table. Please insert where appropriate whole body vibration (WBV) training,[13,14] resistance training,[5] and plyometrics.[15]

It was hypothesized that jump height in dancers is predicted by gender, company rank (principal, soloist, first artist and artist), level of expertise, anthropometric indices, lower extremity differences and amount and type of supplemental training.

Method

As part of the company's pre-season screening all dancers were required to participate in a series of fitness tests. These included VO_2 peak, power, flexibility and anthropometric tests as well as a record of any supplemental training that each individual carried out. Forty-nine dancers (M = 21; F = 28) completed the fitness battery (Table 1), with 11 dancers being excluded due to injury status. Retrospective ethical approval from the University of Wolverhampton was gained, though all participants signed an informed consent prior to commencing the tests as part of the screening process. A questionnaire about previous medical history was not used as the company has full-time medical support and participation in the fitness tests was pre-determined by the company's clinical specialist.

Vertical Jump Test

A vertical jump test, using a Just Jump mat (Proboctics, Huntsville, AL USA),[16] was used to measure power. The mat measures air time and calculates jump height from these data. The tests were vertical jump (both legs), left and right leg hops with no countermovement arm action, hands remained at the dancers' sides. It was decided to examine left and right leg differences rather than preferred legs after consultation with dancers who reported that choreography often determined take off leg rather than themselves. To make the test more dance specific, the dancers started each jump with a plié in first position or turned out for the hops. The highest jump (in centimeters) of three attempts was recorded for each test.

Anthropometric

A series of anthropometric tests were carried out on each participant these included skinfolds, girth measurements, lower limb length, height and weight. The skinfolds were taken at six sites; bicep, triceps, subscapular, suprailiac, thigh and calf; the British Association of Sport and Exercise Science (BASES) guidelines[17] were followed. The mean value for each site taken and the total of all skinfolds was recorded. Girth measurements were taken at the mid-point of the thigh and widest part of the calf; and the leg lengths between the greater trochanter and lateral malleolus. Lower limb girth and skinfold measurements were taken to calculate a normalized girth variable using the formula in Figure 1.

Statistical Analysis

MANOVA was used to see if there were any trends in the data dependent on company position (principal, soloist, first artist and artist) and gender (post hoc analysis – Tukey) and regression ANCOVA was used to assess the effect of the measured anthropometric and training variables on jump performance. Alpha level was set at the $p < 0.05$ level.

Results

Vertical Jump Height

Gender differences were seen for jump height ($F_{1\ 30} = 1426.85$; $p < 0.01$). Differences were shown between dancer levels for jump height ($F_{3\ 38} = 114.17$; $p < 0.05$). Soloists and first artists had significantly greater jump heights compared to principals and artists ($p < 0.05$). Within gender there were no bilateral differences in jump height off the right or left legs ($p > 0.05$).

Anthropometric

Male dancers had significantly greater girth and leg length measurements than their female counter parts (girths $F_{1\ 47} = 23.215$; $p < 0.01$; leg length $F_{1\ 47} = 49.279$; $p < 0.01$). There were no significant differences in the female girth measurements between dancer company positions or between left and right legs. Within the male dancers there were no bilateral girth differences but between company position the artists had significantly smaller thigh girths than the other positions ($p < 0.05$) and the artists and principals had significantly smaller calf girths than first artists and soloists.

$$g \div \pi = d$$

$$(d - [s + s])^2 \times \frac{\pi}{4} = c$$

Figure 1 Equation to calculate normalized girth measurements; g = girth measurement; d = diameter; s = skinfold; c = cross-sectional area.

Training

Neither the hours trained nor the type of training had a significant influence on vertical jump height ($p > 0.05$). Data on supplemental training indicated no differences in hours trained per week between the dancer levels though the males did significantly more weight training ($F_{1\ 48} = 6.714$; $p < 0.01$) and the females more aerobic training ($F_{1\ 48} = 13.143$; $p < 0.05$).

Thigh ($F_{1\ 38} = 11.03$; $p < 0.01$) and calf ($F_{1\ 38} = 9.29$; $p < 0.01$) circumference were significant predictors of jump height. When jump height was analyzed with respect to the normalized limb girth variable, no gender differences were seen ($p > 0.05$).

Discussion

Jumping is an integral part of the majority of ballets and too often dancers state that they are "just not jumpers." This study has reinforced some obvious trends within dance with regards jumping, as well as highlighting interesting areas that require further examination. Male ballet dancers are renown for their jumping ability. While males jumped higher than females in this study, this appears to be due to larger thigh and calf girth. When jump height was examined in relationship to girth, no gender differences were seen. These results correspond to the research by Golomer and associates[2] and Harley and coworkers,[6] which both found that jump height is linked to muscle mass.

Earlier work by Golomer and Fery[10] suggested that ballet training is symmetrical and this is reinforced by the present study with no significant bilateral differences in hop height or girth measurements noted.

The differences in jump height in relation to company position is probably due to the choreographic demands paced on these dancers. Previous research by Wyon and colleagues[12] noted that principals and artists had significantly greater VO_2 peak than soloists and first artists, while the later had greater jump heights. This is in contrast to Xarez,[7] who suggested that expertise (dance ability) had a influence on jump height. The present research suggests therefore that supplemental training should be position specific, unlike that recommended for sport.[18,19] The self-reported supplemental training of dancers in the present study is gender specific with females carrying out significantly more cardiovascular training than males who focused on weight training. It is recognized that the training the dancers' are engaged in may not be specifically aimed at improving jump height, but it must also be recognized that jumping is integral to dance. The dancers that engage in weight training regimens do not have significantly greater jump heights than those who do not, thus suggesting that their training was either focused on the upper body or was ineffective in developing strength of the lower limbs. Sports has used a variety of supplemental training regimens (plyometrics and vibration training) that have been beneficial in developing jump height by focusing on the neuromuscular aspects of power development,[14,15] which would be beneficial for dance where increased muscle mass is not always a desired trait.

In conclusion, jump height in ballet seems to be specific to gender and company position, with thigh and calf girth circumferences having a significant influence. Greater insight into the relationship between jump height and strength would have been better with absolute values. A longitudinal study tracking dancers would indicate whether jump actually varies due to company position.

Practical Applications

This study has noted that first artists and soloists have developed greater jumping ability possibly due to the choreographic demands of these company positions. If this is the case, then appropriate supplementary training may enhance this ability. The present self-reported supplemental training that these dancers reported (and in which dancers often participate) appears to be ineffective in benefiting this skill and therefore we suggest more rigorous and possibly supervised sessions involving plyometrics training. The use of plyometrics as an intervention strategy needs to be implemented with care as it is a high-impact, high-strain training regimen that can cause injury if performed by fatigued participants.

References

1. Koutedakis YA, Stavropoulos-Kalinoglou A, Metsios G: The significance of muscular strength in dance. J Dance Med Sci. 2005;9(1):29-34.
2. Golomer E, et al: Unipodal performance and leg muscle mass in jumping skills among ballet dancers. Percept Motor Skills. 2004;98(2):415-8.
3. Fuster V, Jerez A, Ortega A: Anthropometry and strength relationship: male-female differences. Anthropologischer Anzeiger. 1998;56(1):49-56.
4. Izquierdo M, et al: Maximal strength and power, muscle mass, endurance and serum hormones in weightlifters and road cyclists. J Sport Sci. 2004;22(5):456-78.
5. Kraemer WJ, et al: Changes in muscle hypertrophy in women with periodized resistance training. Med Sci Sport Exerc. 2004;36(4):1124-31.
6. Harley Y, et al: Quadriceps strength and jumping efficiency in dancers. J Dance Med Sci. 2002;6(3):87-94.
7. Xarez L: Vertical jumping in dance: Feet positions, type of support, body composition, morphology, level of expertise and height flight. Portuguese J Human Perform Stud. 1993;9(2):47-50.
8. Davies B, Greenwood E, Jones SR: Gender difference in the relationship of performance in the handgrip and standing long jump tests to lean limb volume in young adults. Eur J Applied Physiol. 1988;58(3):315-20.
9. Mayhew J, Salm P: Gender differences in anaerobic power tests. Eur J Applied Physiol. 1990;60(2):133-8.
10. Golomer E, Ya F: Unilateral jump behaviour in young professional female ballet dancers. Int J Neurosci, 2001;110:1-7.
11. Crewther B, Cronin J, Keogh J: Possible stimuli for strength and power adaptation: Acute mechanical responses. Sports Med; 2005;35(11):967-89.
12. Wyon M, et al: The cardiorespiratory, anthropometric and performance characteristics of an international/national touring ballet company. J Strength and Condition Res. In Press.
13. Issurin V: Vibrations and their applications in sport. A review. J Sports Med Physical Fit. 2005;45(3):324-36.
14. Luo J, McNamara B, Moran K: The use of vibration training to enhance muscle strength and power. Sports Med. 2005;35(1):23-41.
15. Radcliffe J, Farentinos R: *High-Powered Plyometrics.* Champaign, Ill: Human Kinetics, 1999.
16 Isaacs JD: Comparison of the Vertec and Just Jump systems for measuring height of vertical jump

by young children. Perceptual Motor Skills. 1998;86:659-63.

17 Winter E: *British Association of Sport and Exercise Science Physiological Testing Guidelines* (Vol 2). London: Taylor and Francis, 2006.

18. Arnason A, et al: Physical fitness, injuries, and team performance in soccer. Med Sci Sport Exerc. 2004;36(2):278-85.

19. Sozen A, et al: Echocardiographic findings in professional league soccer players. Effect of the position of the players on the echocardiographic parameters. J Sports Med Physical Fit. 2000;40(2):150-2.