Time Motion and Video Analysis of Classical Ballet and Contemporary Dance Performance

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Key words
- ballet
- contemporary dance
- time motion
- gender differences
- video analysis

Abstract

Video analysis has become a useful tool in the preparation for sport performance and its use has highlighted the different physiological demands of seemingly similar sports and playing positions. The aim of the current study was to examine the performance differences between classical ballet and contemporary dance. In total 93 dance performances (48 ballet and 45 contemporary) were analysed for exercise intensity, changes in direction and specific discrete skills (e.g., jumps, lifts). Results revealed significant differences between the 2 dance forms for exercise intensity ($p<0.001$), changes in direction ($p<0.001$) and discrete skills ($p<0.05$) with gender differences noted in the latter ($p<0.05$). Ballet was characterised by longer periods at rest (38 s.min^{-1}) and high to very high exercise intensities (9 s.min^{-1}), whilst contemporary dance featured more continuous moderate exercise intensities (27 s.min^{-1}). These differences have implications on the energy systems utilised during performance with ballet potentially stressing the anaerobic system more than contemporary dance. The observed high rates in the discrete skills in ballet (5 jumps.min^{-1}; 2 lifts.min^{-1}) can cause local muscular damage, particularly in relatively weaker individuals. In conclusion, classical ballet and contemporary dance performances are as significantly different in the underlying physical demands placed on their performers as the artistic aspects of the choreography.

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Bibliography
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Introduction

A system of time-match analysis has been devised for sports such as soccer, rugby and gymnastics, where activities of specific intensities, such as walking or sprinting, are expressed as percentages of a given match [6,15,27]. Using advanced video and computer technologies, this system has also been used to analyse different activities including passing, tackling, and changes of direction. These methodologies have been shown to be valid and reliable observational analyses tools and have revolutionised both the technical and physiological preparation of sportspeople [6,15,27].

Observational analysis of dance has largely been based upon examining choreographic elements from an artistic point of view using techniques such as Benesh [34] and Labanotation [21]. These techniques provide vital aesthetic and technical information that can be used for enhancing dance repertoires. Recently published data revealed differing physiological demands between dance class, rehearsal and performance [48,49], changes in aerobic capacity during performance periods [39,49] and a link between physical fitness and aesthetic aspects of dance performance [3,40]. Further research is required to understand what is causing these differences. Preliminary studies on both contemporary and classical ballet performances have used video analysis to investigate partner work, transitory fields such as jumping and changes of direction, the segments of the body performing the action, and the descriptive nature of the action [38,45]. While biomechanical data regarding ground reaction forces [28,36] and muscle activity occurring in individual dance movements such as lifting, landing, and changes of direction [37,42] can be easily obtained, this information cannot be used to determine the demands of a specific performance without knowing, for instance, how many times the action is performed and at what rate.

One study has examined the physiological differences between the genres [14]; these investigators used heart rates to examine the different

demands of dance class in ballet, contemporary, folk and jazz dance classes and noted no difference between the genres. As previously reported the use of heart rate to calculate exercise intensity within intermittent exercise is flawed as during rest periods the heart rate remains high to aid ATP recovery, thereby providing a false impression of exercise intensity and duration [31]. The oxygen demand and heart rate of ballet performance excerpts have been examined [35] but the physiological demands of full ballet performances have not been reported and only a few on contemporary dance [46] due to the difficulty in collecting objective data. Therefore, the aim of this study was to examine the differences between ballet and contemporary dance performances using video analysis in order to provide insight in aiding the development of specific interventions that may improve performance.

Materials and Methods

By using video analysis techniques, the authors are sought to identify possible differences between classical ballet and contemporary dance performances in exercise intensity, changes in direction, discrete skills (e.g., jumps and lifts) and gender.

Subjects

45 professional contemporary dance performances by US and UK companies (21 males and 24 females) and 48 classical ballet performances (24 male, 24 female; 16 principals, 16 soloists and 16 artists) were randomly selected. The Ethics Committee of Research Centre for Sport, Exercise and Performance, University of Wolverhampton, UK, approved the study protocol and the study was carried out in accordance with the ethical standards of the IJSM [19].

Protocol

Movement analyses were conducted with the time motion (TM) and match analysis (MA) systems. 2 performance indicators were defined prior to movement analysis, namely exercise intensity and discrete skills (jumps, lifts). The exercise intensity field was used to provide qualitative description of the intensity of dance performance, directional change field included acute changes in direction of movement and movements to and from the floor, and discrete skills referred to movement of the dancer's centre of gravity such as jumps, pliés and partner work such as lifts and supports. Descriptors for each indicator can be found in **Table 1**.

The movement analyses were performed by a single observer for each genre, ballet and contemporary. Prior to data collection, inter- and intra-individual test-retest reliability was assessed, where the observers scored a single performance twice within a 7-day interval, as previously suggested [3]. No significant differences were found between observers or tests and ICCs were above r = 0.9.

Data analyses

To allow comparison between the different performances times (range 7.5–111 min) the observed data were normalised. Time spent at the different exercise intensities were converted to a ratio of seconds per minute and the other variables (jumps, pliés changes in direction, lifts etc.) were converted to number of occurrences per minute. Routine pre-analyses were conducted using Kolmogorov-Smirnov test of normality to detect the distribution of the studied variables. Factorial analyses were used to compare the differences between genre and style. All analyses were conducted via SPSS 16 (SPSS Inc, Chicago, IL, USA) while the level of significance was set at $p < 0.05$.

Table 1 Video analysis descriptors.

Descriptor	Description
exercise Intensity	
rest (R)	subject is standing still either on or off stage
very light (VL)	subject is undergoing very light work e.g., slow walk pace with little upper body movement
light (L)	subject is undergoing light work e.g., walk pace with upper body movement
moderate (M)	subject is undergoing moderate work e.g., jog pace with upper body movement, can include jumps (low)
hard (H)	subject is undergoing hard work e.g., fast jog, run, multiple jumps and lifts
very hard (H)	subject is undergoing very hard work e.g., run pace, static holds above shoulder height, multiple high jumps landing on one leg
changes in direction	
change in direction	subject abruptly/acutely changes the direction of movement
S>F	subject moving from standing to the floor
F>S	subject moving from floor to standing
discrete skills	
plié (P)	subject carries out either a full or demi-plié
jumps (J)	subject undergoing either a 2 footed or single footed jump/leap with both feet leaving the ground
assisted lift (AL)	lift with subject plus other(s) helping or with dancer being lifted helping by jumping in direction of lift
lift (L)	subject lifts another dancer on own.
support (S)	subject supporting another dancer who has one or both feet on the ground

Results

Contemporary dance (24.4 + 6.81 min) was significantly shorter in time than ballet (59 + 37.23 min; $p < 0.001$). In contemporary dance 3 pieces were usually performed to constitute an evening's performance, whilst in ballet, with the exception of triple bills, only one ballet piece was performed.

Exercise intensity

Factorial analyses indicated significant differences at all exercise intensities between the genres, apart from the "Hard" intensity (**Table 2**). Significantly more time was spent at "Rest" in ballet than contemporary ($p < 0.001$), which was also reflected in the percentage time spent dancing ($p < 0.05$). These data had an influence on the time spent at the other exercise intensities with contemporary reporting significantly longer periods at "Very Light" ($p < 0.05$), "Light" ($p < 0.001$) and "Moderate" ($p < 0.001$). At the "Very Hard" exercise intensity, ballet spent significantly longer periods dancing than contemporary ($p < 0.001$). Gender differences were noted at moderate exercise intensities with female dancers spending significantly more time dancing that their male counterparts ($p < 0.05$). When genre and gender were combined, significant differences were noted at hard exercise intensity ($p < 0.05$) with female ballet and male contemporary dancers dancing for longer periods.

Table 2 Standardised exercise intensity periods for ballet and contemporary dance performances.

Exercise Intensity	Gender	Genre: Ballet ($s.min^{-1}$)	Genre: Contemporary ($s.min^{-1}$)
rest	female	37.22 + 13.73	18.65 + 10.78
	male	38.50 + 14.51	20.06 + 7.69
	total	37.86 + 13.99	19.34 + 9.31
very light	female	4.88 + 3.81	8.33 + 10.95
	male	6.21 + 4.91	8.95 + 8.11
	total	5.54 + 4.39	8.64 + 9.56
light	female	3.55 + 3.75	16.41 + 10.79
	male	2.85 + 2.61	13.74 + 12.43
	total	3.19 + 3.21	15.11 + 11.57
moderate	female	8.34 + 7.05	13.77 + 7.19
	male	5.59 + 4.79	9.99 + 6.0
	total	6.97 + 6.13	11.92 + 6.83
hard	female	7.68 + 6.83	4.28 + 5.53
	male	4.61 + 3.79	6.59 + 7.27
	total	6.14 + 5.68	5.41 + 6.47
very hard	female	2.06 + 2.89	0
	male	3.34 + 4.04	0.589 + 1.08
	total	2.69 + 3.54	0.28 + 0.81
percentage dance time	female	62.76 + 13.74	71.28 + 18.18
	male	61.65 + 14.33	66.56 + 12.79
	total	62.19 + 13.91	68.97 + 15.78

Table 3 Directional change for ballet and contemporary dance performances.

	Gender	Genre: Ballet ($s.min^{-1}$)	Genre: Contemporary ($s.min^{-1}$)
changes in direction	female	2.84 + 1.92	0.59 + 0.63
	male	3.82 + 1.77	0.57 + 0.54
	total	3.34 + 1.89	0.58 + 0.58
standing to floor	female	0.21 + 0.21	0.42 + 0.34
	male	0.41 + 0.56	0.48 + 0.46
	total	0.31 + 0.43	0.45 + 0.39
floor to standing	female	0.19 + 0.22	0.4 + 0.31
	male	0.38 + 0.57	0.47 + 0.45
	total	0.29 + 0.44	0.43 + 0.51

Directional changes

The ballet performances had significantly more changes in direction than contemporary dance ($p < 0.001$), though there were no significant gender differences (**Table 3**). The other parameters (standing to floor, floor to standing) revealed no significant differences for style or gender.

Discrete skills

Ballet had significantly more lifting movements than contemporary; assisted lifts ($p < 0.001$); support ($p < 0.05$); solo lifts ($p < 0.05$). Full factorial analyses indicated that male ballet dancers carried out significantly more lifting variations than the other dancers: assisted lifts ($p < 0.001$); support ($p < 0.05$); solo lifts ($p < 0.05$) (**Table 4**). The ballet dancers also carried out significantly more jumps ($p < 0.001$) and pliés ($p < 0.01$). There were no significant differences between genders for jumps and pliés, though significant differences were noted for all assisted lifts ($p < 0.001$); support ($p < 0.05$); solo lifts ($p < 0.05$).

Table 4 Discrete skills for ballet and contemporary dance performances.

	Gender	Genre: Ballet ($s.min^{-1}$)	Genre: Contemporary ($s.min^{-1}$)
plies	female	12.33 + 7.08	8.44 + 4.08
	male	11.02 + 9.59	7.23 + 3.43
	total	11.67 + 8.36	7.88 + 3.79
jumps	female	5.29 + 4.97	1.85 + 2.63
	male	4.68 + 4.98	1.53 + 1.63
	total	4.99 + 4.93	1.71 + 2.21
support	female	0.282 + 0.43	0.02 + 0.04
	male	0.27 + 0.68	0.19 + 0.25
	total	0.28 + 0.56	0.11 + 0.19
assisted lift	female	0	0.02 + 0.05
	male	0.28 + 0.36	0.03 + 0.09
	total	0.14 + 0.29	0.02 + 0.07
lift	female	> 0.01 + 0.01	0.01 + 0.03
	male	1.94 + 3.33	0.25 + 0.29
	total	0.97 + 2.53	0.12 + 0.23

Discussion

The aim of this study was to examine the differences between ballet and contemporary dance performances using video analysis. The only previous study [14] that examined genre differences noted no differences, although the authors only assessed dance class and used heart rate as the dependent variable which has been shown to be a poor indicator of exercise done [31]. However, the present study found that contemporary dancers spent significantly more time dancing during performances than their counterparts in ballet. The contemporary dance performances had significantly longer periods at very light to moderate intensities, whilst ballet had significantly longer rest periods and time at very hard intensities possibly caused by the significantly higher amount of power movements (jumps and lifts), which require greater rest periods to aid recovery and maintain skill levels. These findings are in line with previous studies which concluded that both genres are high intensity intermittent exercise [2, 10, 11, 32, 33, 35, 44, 46, 47]. Previous research has provided direct measurement of dance exercise using heart rates and expired gas analysis but these studies have not been able to provide an in-depth understanding of the different intensities dancers work at, especially during performance, or the discrete skills a dancer has to perform. Only one study [46] has provided data on whole dance performance pieces and this was limited to 12 contemporary dress rehearsals rather than actual performances. They reported the exercise intensity data ($ml.kg^{-1}.min^{-1}$ and $b.min^{-1}$) as a percentage of total dance time which indicated that dancers spent more time at higher intensities ($> 35\ ml.kg^{-1}.min^{-1}$ and $> 160\ b.min^{-1}$) during dance performance than during class and rehearsals. The limited data on ballet performance recorded near maximal heart rates [10] and blood lactate levels of $11\ m.mol.L^{-1}$ after a 2 min ballet solo [35]. Studies on intermittent exercise [1, 4, 5, 7–9, 16] reported that recovery periods need to lengthen as exercise intensity increases if the intensity of subsequent bouts is to be maintained. This is especially important for high intensity exercise, as seen in ballet solos, as the creatine phosphate stores are the last to be replenished after maximal exercise [5, 16, 43]. The time motion analysis of contemporary dance performances on the other hand highlights an increased time spent dancing compared to ballet, which poten-

tially causes the observed lower exercise intensity, as the reduced recovery time limits the ability to engage in high intensity exercise [20]. Even though contemporary dancers are perceived to be performing at a lower exercise intensity previous research has indicated that the appropriate dance classes and rehearsals place a significantly lower aerobic and anaerobic stress on the dancers compared to dance performance [44,48].

It is interesting to note that there are few differences within the genres for gender. Within ballet at high exercise intensities females are dancing longer than males whilst the opposite is observed for contemporary. These differences are probably down to the choreography, as within ballet the genders have very different roles [18,26], which is especially noticeable within the soloist and principal positions [38]. Males are required to carry out explosive multi-jump routines (equating to very hard intensities), whilst the female dancer solos are more intricate and still require the image of the "sylph" to be portrayed thereby making the physiological demands slightly less. These differences can be seen in the discrete skill demands reported in **Table 4**. Contemporary dance, on the other hand, has promoted equality between the genders within its choreography and this can be seen within the observed exercise intensities and discrete skills (**Table 2, 4**, respectively).

The change of direction parameter has been a focus of research in other movement analysis studies [6,29] due to the eccentric nature of the movement and increased energy cost [30]. This acute movement occurred significantly more in ballet than contemporary dance performances and is a process of the different choreographic styles, with the latter more likely to use a circular trajectory to change direction. Contemporary choreographers have incorporated dancers falling and rising to the floor and having their whole bodies in contact with the floor [12,46] as part of their expressive language which has an increased local energy cost. The data from the present study have indicated that contemporary dancers spend more time on the floor than their ballet counterparts though the difference is not significant. Ballet performances on the other hand had significantly more jumps and pliés than contemporary performances, which is again a reflection of the movement vocabulary. Within ballet, the jump is a vital component of skill demonstration, especially for both male and female soloists and principal dancers [38].

Within the classical ballet tradition, one of the prime roles of the male dancer is to lift their female counterparts [17] and this is reflected within the present study where the male ballet dancers carried out significantly more lifting variations than the other participants. The contemporary performance data again indicated little difference between the genders though the male contemporary dancers carried out significantly less lifts than the ballet counterparts. Female ballet dancers rarely carry out any lifting though within some of the modern ballets they carry out supporting movements. The noted disparity in the present data cannot be compared as there are no published data.

In summary, the video analysis data implies that these 2 dance forms are considerably different in the physical stresses they place on the dancers' bodies. Classical ballet is perceived to place much more stress on the anaerobic energy systems with more lifts, jumps and changes in direction and longer rest periods than their contemporary counterparts. These movement characteristics have a strong element of muscle eccentric action which, coupled with reduced levels of muscular strength seen in dancers [23], can lead to injury [24]. It has been shown that, compared to other sportspeople, dancers have very poor lower body strength indices [23] and these are linked to increased injury rates [24].

Irrespective of the exercise form, the demands of performance should drive the physical and skill preparation of its participants. The skill demands of classical ballet and contemporary dance are quite different and the present study has demonstrated there are perceived physiological disparities too. Contemporary dance is performed at a more moderate intensity with a greater exercise to rest ratio than ballet, which has longer periods at high intensities and subsequently more rest. Male ballet dancers carry out more lifts than the others in the study and, therefore, upper body strength training should be considered as previously suggested by Koutedakis and Sharp [22]. Ballet performances have considerably more jumps than contemporary and as these are high impact anaerobic movements, a level of tolerance needs to be developed prior to the performance to prevent fatigue-induced injuries [25].

Conclusion

Although it has been recognised that there are fundamental artistic differences between classical ballet and contemporary dance [13], the present study is the first to show through video analysis that these differences manifest themselves also within the perceived physical stresses placed upon the dancers' bodies. Previous research has shown little variation in the physical demands of dance class across the genres [14] and therefore supplemental training is required to prepare dancers for the increased demands of dance performance [41,46]. Further research is required on other dance styles as well as examining the potential differences in movement and intensities during dance class, rehearsal and performance.

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