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The Dancer as a Performing Athlete

Physiological Considerations

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Abstract

The physical demands placed on dancers from current choreography and performance schedules make their physiology and fitness just as important as skill development. However, even at the height of their professional careers, dancers' aerobic power, muscular strength, muscular balance, bone and joint integrity are the 'Achilles heels' of the dance-only selection and training system. This partly reflects the unfounded view, shared by sections of the dance world, that any exercise training that is not directly related to dance would diminish dancers' aesthetic appearances.

Given that performing dance itself elicits only limited stimuli for positive fitness adaptations, it is not surprising that professional dancers often demonstrate values similar to those obtained from healthy sedentary individuals of comparable age in key fitness-related parameters. In contrast, recent data on male and female dancers revealed that supplementary exercise training can lead to improvements of such fitness parameters and reduce incidents of dance injuries, without interfering with key artistic and aesthetic requirements. It seems, however, that strict selection and training regimens have succeeded in transforming dance to an activity practised by individuals who have selectively developed different flexibility characteristics compared with athletes. Bodyweight targets are normally met by low energy intakes, with female dance students and professional ballerinas reported to consume below 70% and 80% of the recommended daily allowance of energy intake, respectively, while the female athlete 'triad' of disordered eating, amenorrhoea and osteoporosis is now well recognised and is seen just as commonly in dancers.

An awareness of these factors will assist dancers and their teachers to improve training techniques, to employ effective injury prevention strategies and to determine better physical conditioning. However, any change in the traditional training regimes must be approached cautiously to ensure that the aesthetic content of the dance is not affected by new training techniques. Since physiological aspects of performing dance have been viewed primarily in the context of ballet, further scientific research on all forms of dance is required.

Although differences exist between one dance form and another, and between dance and other forms of athletic activity, it is the similarities between the disciplines of sport and dance that count. As in sport, dance performance is not a single act. It is a rather complex phenomenon depending on a large number of elements with direct and indirect effects.[1] At a professional level, dancers must be experts in the aesthetic and technical sides of the art, psychologically prepared to handle the stress of critical situations and free from injury. They must also be physically 'fit'. However, only about 40% of fitness has been linked to genetic factors, leaving an estimated 60% within the dancers' control through regular exercise and appropriate diet.[2] Despite this, available data have indicated that certain forms of dance elicit only limited stimuli for fitness enhancement[3] and that dancers in general are not physically as well conditioned as equivalent athletes.[4,5] This is, perhaps, why correct identification of young dance talents is becoming increasingly important.

For most people, performing dance is about technique, style and (in the case of ballet) tradition. However, the physical demands placed on dancers from current choreography make their physiology and fitness just as important as skill development.[6] Therefore, the main purpose of the present review is to examine the professional dancer as a 'performing athlete'. Specifically, we will examine the physiological elements of dance, which are mainly used to assess physical fitness, and discuss other aspects of dance performance such as overtraining, haematology and biochemistry. The body-conditioning techniques of Pilates, Alexander and Feldenkrais will not be discussed as they have generally attracted little scientific attention.

1. Fitness for Dance

Physical fitness may be defined as "the individuals' ability to meet the demands of a specific physical task". As in most sports, dance fitness depends on the individuals' ability to work under aerobic[5,7] and anaerobic[1] conditions, and on their capacity to develop high levels of muscle tension, i.e. muscle strength.[8,9] Joint mobility/muscle flexibility[10] and body composition[11,12] are also important parts of dance fitness. However, no single fitness measurement can predict success in dance, as they vary markedly depending on numerous parameters including age, sex and level of performance.

1.1 Aerobic (Cardiorespiratory) Fitness

Aerobic (cardiorespiratory) fitness implies the ability for muscular work under aerobic conditions and it involves all aspects of uptake, transport and utilisation of oxygen to liberate energy from muscle fuels. In general, professional dancers[1] and dance students[4] demonstrate lower maximal oxygen uptake ($\dot{V}O_{2max}$) values compared with other athletes (table I). Within the dance world, however, modern dancers have shown higher $\dot{V}O_{2max}$ values than their counterparts in ballet.[13-15] For the professional ballet dancer, these values are close to those obtained from healthy sedentary individuals of comparable age. It seems, therefore, that unlike most athletes where aerobic fitness and performance levels increase in parallel during their careers, dancers develop these two parameters independently. The selection and dance-only training system currently in use may account for this.

Another contributing factor may be dance itself and its questionable ability to stimulate positive cardiorespiratory adaptations.[24] It has been reported that the relatively small aerobic fitness increments measured in professional dancers are not related to their class work, but to the duration and frequency of their performances.[14] It has also been suggested that ballet class work, especially at the barre (e.g. pliés, tendus), represents aerobic exercise of only low to moderate intensity.[7] Intensities of centre-floor work can reach 70–80% of $\dot{V}O_{2max}$,[15] which are similar to cardiorespiratory responses

Table I. Maximal oxygen uptake ($\dot{V}O_{2max}$) in elite males participating in different physical activities

Activity	$\dot{V}O_{2max}$ (mL/kg/min)	Reference
Long-distance running	77	16
Triathlon	75	17
Rowing	70	18
Middle-distance running	69	16
Squash	62	19
Swimming	58	20
Soccer	57	21
Gymnastics	55	22
Dance	48	7
Sedentary	44	23

during ballet stage performances,[25] but only for brief periods of up to 3 minutes. However, given that fairly strenuous exercise intensities for at least 20 minutes are needed to bring about aerobic fitness increases, it is probable that most ballet activities do not provide an adequate stimulus for such adaptations. This was supported by Rimmer et al.[26] in a study involving rehearsals for 'Sleeping Beauty'.

The notion that performing dance activities have little impact on the dancers' cardiorespiratory fitness may further be supported by the fact that dance students demonstrated no cardiac structure and cardiac function changes compared with matched controls.[27] Furthermore, cardiorespiratory responses to modern dance classes revealed no differences between university, graduate and professional dancers,[28] highlighting the need for supplementary aerobic fitness training at a professional level.[29] Working with modern dancers, Galanti and colleagues[30] noted improvements in aerobic parameters with routines in which intensity was specifically pitched at an optimal level to provide a genuine training stimulus. Similar results were also obtained from male and female professional ballet dancers where supplementary self-administered exercises brought about increases in $\dot{V}O_{2max}$ levels.[31] Whether aerobic fitness enhancements coincide with better dance performances, remains to be confirmed.

1.2 Anaerobic Fitness

This is the least studied fitness attribute in dancers. In general, there are two main anaerobic requirements. One is when a large surge of power is required, as in grand allées. In this case, muscular action lasts for just a few seconds and it is mainly energised by phosphocreatine. Powered mainly by glycolysis, the other prime anaerobic requirement comes into effect when relatively high power outputs must be sustained for about 30–60 seconds (e.g. a series of adagios or in an acrobatic modern sequence). This is also known as 'anaerobic endurance', often seen as the opposite to muscular fatigue.[1] In a somewhat imprecise way, anaerobic fitness describes a type of physical fitness in the centre of a continuum between aerobic fitness and muscle strength.

As with aerobic fitness, professional dancers demonstrate lower anaerobic values than other athletes[1] and modern dancers demonstrate higher anaerobic power outputs than their colleagues in ballet.[32] This is also the case when lactic acid measurements were conducted in both professional dancers[13] and dance students.[33] The fact that modern dancers often have an athletic background, that only a moderate anaerobic training effect has been found in the classical discipline,[26] and that ballet dancers demonstrate higher proportions of the more aerobic slow muscle fibres[34] partly explain the reported discrepancies between the two dance styles. It is interesting to note that, while a normal ballet class elicited a mean lactic acid blood level of 3 mmol/L in women, a choreographed solo part raised it to 10 mmol/L.[15] This value is as high as what top-class football, squash and hockey players achieve during the match.

1.3 Muscular Strength

Empirical and objective data suggest that muscle can undergo adaptations to physical training resulting in increased maximal tensile strength. For many centuries after the last Ancient Olympic Games in 393AD, people forgot the significance of strength training for both health and physical performance, and it is only during the last 60 years that strength training has been reintroduced as an important element of exercise and fitness.

Improvements in the muscle's ability to generate force seem to be a way for dancers to enhance their performance.[1] Soloist ballerinas are characterised, *inter alia,* by increased muscular strength.[35] Furthermore, questions such as "when should a young dancer attempt pointe?", may become less subject to a teacher's intuition or to parental pressure, if knowledge on the muscle and ligament strength is available.[36] However, strength has not generally been considered as a necessary ingredient for success in dance. This partly reflects the unfounded view, shared by sections of the dance world, that strength training and muscular strength would diminish dancers' aesthetic appearances.

In contrast, data on male[37] and female[38] ballet dancers revealed that supplemental resistance training for hamstrings and quadriceps can lead to improvements in leg strength, without interfering with key artistic and physical performance requirements. This supports earlier findings where significant muscle strength increases were not accompanied by proportional changes in muscle size[39] and reinforces the belief that resistance training is followed by changes within the nervous system, which play an active role in strength development.[40] An elevated neural involvement may account for some of the exercise-induced increases in muscular strength,[41] suggesting that, at least in the early stages of such training, hypertrophy is not a prerequisite for strength gains.

Isokinetic measurements have repeatedly indicated lower torque values in dancers than other athletes[14,32] and even untrained individuals.[1,42] Ballerinas have the least muscular strength, demonstrating only 77% of the weight-predicted strength norms.[43] This may be partly explained by the fact that, in these dancers, skeletal muscle accounts for just 38–43% of their bodyweight[44] and consists of predominately slow fibres.[34] It should be added here that suboptimal loading of the neuromuscular system may result in muscular strength decreases in both males and females,[45] which may also explain why young female dancers demonstrate lower hip flexors strength than control subjects.[42] However, male and female modern dancers are generally stronger than their counterparts in ballet, and in many cases can easily compare in strength with some athletes.[1] Unlike most professional ballet dancers, individuals involved in modern dance often have a multidisciplinary background (e.g. former gymnasts or divers), which may explain certain elements of 'athleticism'.

Contrary to the common belief that one side of the body is stronger than the other, relevant data revealed no differences between left and right legs in male and female dancers.[46] Furthermore, in a study designed to test whether different modes of activity and forms of preparation affect selected strength and muscle contractile characteristics, no differences were found between professional dancers, Olympic bobsleighers and Olympic rowers.[47] This finding tentatively suggests that different physical training and/or different levels of fitness do not differentially affect basic muscle contractile properties. What could change however, is the level of tension attainable by trained compared with untrained muscle.

1.3.1 Does Dance Alone Promote Strength Enhancements?

This hypothesis has been tested by examining the effects of supplementary strength-training programmes in professional male and female dancers.[37,38,42,48] Contrary to experimental groups, 'control' dancers showed no differences in peak torques after the monitoring period. Therefore, as in the cases of aerobic and anaerobic fitness, it could be argued that conventional dance-studio exercise alone confers little strength benefits.[26] It is noteworthy that 12 months of dance activities demonstrated greater muscular strength improvements in females aged 8–11 years compared with controls.[49] Whether these results were confounded by aspects such as baseline strength levels and dance training regimes are yet to be confirmed.

1.3.2 Dance Injuries and Strength

It has been generally assumed that dancers' movements are not capable of generating sufficient power to cause the muscular injuries seen in sports. To this end, aerobic dance appears to offer the potential for fitness enhancement with a minimal risk of injury.[50] However, dancers do get injured[51] and the effects of these injuries may be highly detrimental. Over a 12-month period, almost 50% of a large sample of professional dancers reported 1–6 days off exercise due to a musculoskeletal injury (figure 1). The lower back seems to be the most frequently injured site, which together with pelvis, legs, knees and feet, accounts for more than 90% of injuries.[52,53] Interestingly, only five injuries per 1000 hours of participation have been reported for young ballet dancers,[54] which is far less than some

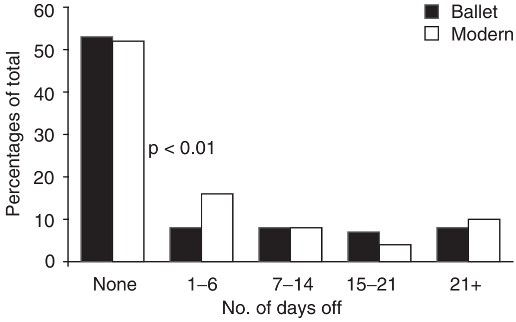

Fig. 1. Days off due to injuries in professional ballet and modern dancers. Data expressed as a percentage of the total sample (n = 324) [reproduced from Koutedakis et al.,[53] with permission].

of the more popular forms of youthful activity such as swimming and tennis.

Overwork, unsuitable floors, difficult choreography and insufficient warm-up are among the factors that may contribute to dance injuries.[55] Levels of physical fitness, particularly strength, have also been recently added to this list. An investigation of dancers' thigh-strength in relation to lower-extremity injuries indicated that the lower the thigh-strength levels, the greater the degree of injury.[52] In tune with others,[43,56] it was suggested that supplementary strength training might circumvent such problems and provide a relatively cost-effective way of reducing dance injuries. Strength training seems to be more beneficial to weaker dancers than to their stronger colleagues.[37,38]

Although often overlooked, another factor associated with injuries in active individuals is the simultaneous presence of strong and weak muscles, especially antagonistic muscles in the same limb.[57] This was the main finding of a study, the results of which appear in figure 2. It was shown that the smaller the knee flexors-to-extensors ratio, or the weaker the hamstrings compared with quadriceps, the worse the degree of injury.[58] Although rowers and dancers were involved in very different activities, with different objectives and aspirations, they demonstrated similar patterns in low-back injuries, while the introduction of specific hamstring strength-training brought about better knee flexion-to-extension ratios and a lower number of days off activity due to low-back pain.

Muscular strength and strength exercise have also been recommended as a means of preventing osteoporosis in dancers.[59] These authors reported that bone density was normal or elevated at weight-bearing sites whereas deficits were observed at non-weight-bearing sites. This was supported by another study involving aerobic dancers indicating that exercise, which includes versatile movements and high peak forces, are more effective in bone formation than training with a large number of low-force repetitions.[60]

1.4 Muscle Flexibility and Joint Mobility

Optimal muscle flexibility and joint mobility (MFJM) usually indicates that there are no adhesions or abnormalities in or around the joint and that there are no serious anatomical or muscular limitations. Any combination of some 17 known factors can potentially affect MFJM, including structure of bony surfaces and articular cartilage, fibrous connective tissue and muscle fat content.[1] However, as most of these factors are attributed to heredity[61] and as MFJM has been identified as an important predictor of dance performance,[62] strict auditions ensure that young candidates have the required MFJM levels at the point of entry in dance schools.[63]

Such strict regimes have succeeded in transforming dance to an activity practised by very flexible individuals who, through appropriate exercise procedures,[64] have selectively developed different

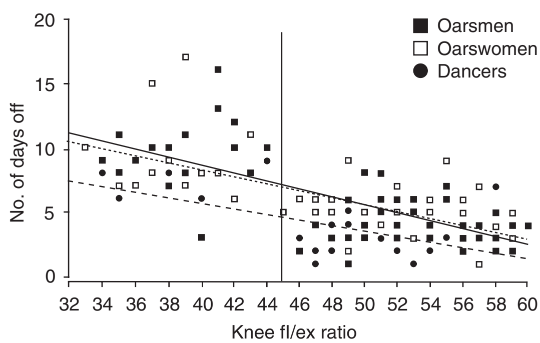

Fig. 2. Trends between days off serious physical activity due to low-back injuries and flexors-to-extensors (fl/ex) ratio in dancers and rowers (reproduced from Koutedakis et al.,[58] with permission).

characteristics compared with athletes. When MFJM levels were considered in professional dancers and dance students, no relationships were found with the frequency and severity of lower-back[58] and ankle[65] injuries, respectively. In athletes, however, inadequate lumbar flexibility was found to be associated with an increased incidence of low-back injuries[66] and flexibility imbalances led to higher injury rates.[67] It seems that 'flexible' dancers are able to withstand a stress in considerable excess of that which can be resisted by less flexible persons. However, it is noteworthy that the majority (88%) of acute dance injury occurs during flexibility training.[51]

A similar 'dancers versus non-dancers' scenario is also apparent with respect to sex. Although some authors have confirmed the long held view that female athletes are more flexible than their male counterparts,[68] no such sex differences have been found in elite ballet dancers.[69]

In line with other fitness parameters, MFJM demonstrates noticeable seasonal variations.[70] Aspects related to exercise training, detraining or even overtraining may account for these variations. Indeed, after 3–5 weeks of summer holiday in elite dancers, during which very little physical work was reported, MFJM measurements remained either unchanged or, in some cases, revealed some unexpected increases.[71] It was argued that the increased amount of physical work done prior to a holiday triggered an overtraining effect, which was alleviated during the rest from dance and which may then explain these controversial findings.

1.5 Body Composition and Body Mass

Appropriate active mass and body fat, are essential ingredients for optimising physical performance. Dancers normally show low waist-to-hip and waist-to-thigh circumference ratios,[72] which are aesthetically favoured by the profession. However, preliminary research has shown comparable lean body mass in dancers to that of untrained controls.[73] The bodyweight restrictions adopted by dancers appear to limit an increase in lean body mass, which could be beneficial to dance performance. Lean body mass in accomplished female ballet dancers can be adequately estimated from bodyweight alone, given the homogeneity of body size and body composition in female ballet dancers at this level.[11]

Total body electrical conductivity[74] and skinfold callipers[71] are amongst the methods used to assess body composition in dancers. However, as with other physiological parameters, body composition in dance has been viewed primarily in the context of ballet, where typical body fat values for ballerinas range from 16–18%.[5,73] The equivalent values in male ballet dancers range from 5–15%.[37] For the younger ballet students, these values have a mean of 20% and 15% for females[44] and males,[75] respectively. However, data obtained from ballet dancers may not be applicable to other dancers, as ballet dancers are the leanest.[76]

Given that levels of activity are closely associated with the amount of body fat in children and adolescents,[77] and that dance exercise in children significantly improves their relative lean body mass[78] the reported leanness in young dancers comes as no surprise. Growth patterns of female ballet dancers tend to show average heights but well below average weights throughout adolescence.[79]

Student ballet dancers are more preoccupied with thoughts of eating and body image, and report disordered eating more than ordinary school students.[80] The desire for reducing body mass has been expressed by female ballet dancers of all body types, with the highest difference between real and desired body mass in individuals of just 11 and 13 years of age.[81] These authors also found that ballerinas of all age groups sought to reach bodyweights below the 5th percentile or below 82% of normal body mass.

Bodyweight targets are normally met by low energy intakes, with female dance students and professional ballerinas reported to consume below 70%[82] and 80%[83-85] of the recommended daily allowance of energy intake, respectively. However, studies have indicated associations between reduced energy intakes and low bodyweight, low body fat and anorexia nervosa.[86,87] It might be worth adding that only a small percentage of dancers receive dietary advice from qualified specialists,[53] despite the fact that relevant reports have stressed that optimal diet and dietary habits can affect dance performance.[88,89]

The low bodyweight of female dancers, although a current aesthetic requirement, can cause several well recognised medical problems. Benson and colleagues[90] reported that very lean dancers are more prone to injury than their less lean counterparts, while the female athlete 'triad' of disordered eating, amenorrhoea and osteoporosis is now well recognised and is seen just as commonly in dancers.[91] If body fat falls below about 17% of total bodyweight,[92] or body mass index (BMI) is under 17,[80] amenorrhoea is likely to occur. Furthermore, intensive exercise, calorie restriction and, therefore, low body fat may account for the delayed menarche seen in dancers[86] and confirmed in those athletes whose sport has an emphasis on weight control (e.g. gymnastics).[93] It should be stressed that the low basal metabolic rates associated with menstrual irregularities in ballet dancers are more closely related to low nutrient intakes rather than to low serum thyroid hormone levels.[94]

2. Other Aspects of Physical Performance

2.1 Overtraining/Burnout

The pressures for more and better performances have transformed preparation for successful dance to virtually a year-round endeavour. As a result, an increased number of dancers also experience the symptoms of the recently described 'burnout' or 'overtraining' in dancers.[95] In general, if exercise is pursued to the level of overtraining, the immune system may be chronically affected.[96] Parry-Billings et al.[97] provided evidence in support of the hypothesis that the susceptibility to infections following periods of increased exercise training may be due to lower plasma glutamine levels. Muscle strength may also be affected even though intrinsic muscle function is not impaired, as evidenced by the ability to respond to external electrical stimulation.[98]

Overtraining in dancers does not seem to be due to the energy cost of dance exercise itself, which has been found to be similar to that of the low overtraining-incident events of badminton, basketball and light cycling. The actual energy cost values in dance range from 0.083 to 0.181 kcal/kg/min (table II). Nevertheless, both dancers and athletes are more likely to become overtrained towards the end of their stage-performance[71] and competition[99] seasons, respectively. Such patterns, however, have been associated with increased incidents of injuries in athletes[99] and have been anecdotally confirmed in dancers. A 3- to 4-week period of rest after the end of a demanding season has been linked to increases in most fitness-related parameters in both dancers[71] and athletes.[100] It is possible that overtraining and the associated fatigue before the resting period may have contributed to these findings.

2.2 Haematological and Biochemical Considerations

Physical activities with a strong aerobic element can alter haematological parameters, such as haematocrit, and erythrocyte and leucocyte counts.[105] However, the effects of dance on parameters that relate to the oxygen transfer system and the iron status of the body have not been intensively examined. A few reports indicate that the iron profile of aerobic dance instructors is either lower[106] or similar to that of other female athletes,[107] while subjects associated with dance exercise experience low ferritin levels and high total iron binding capacity.[108,109] Dancers might also experience increased mean erythrocyte cell volumes,[107] indicative of an

Table II. Energy cost of different types of dance

Type of dance	Energy cost (kcal/kg/min)	Reference
Aerobic dance	0.143	101
Ballet	0.085	7
Disco dance	0.143	102
Folk dance	0.181	103
Modern dance	0.120	28
Square dance	0.083	104

exercise-induced macrocytosis, and a favourable alteration in their metabolism and, therefore, lipidaemic profile. Kin Isler et al.[110] reported that 8 weeks of systematic aerobic dance training resulted in a decreased total cholesterol, elevated high density lipoprotein (HDL)-cholesterol and in lower total cholesterol : HDL ratio in female students.

High incidence of menstrual dysfunction and high rates of musculoskeletal injuries, as well as low bone mineral density, have been found in ballet dancers.[52,111] A possible explanation for these may be a dysfunction in the pulsatile secretion rate of corticorelin (corticotropin releasing hormone) and gonadotropin releasing hormone.[112] Dietary restriction and low BMI levels often found in these individuals[83-85] could alter gonadotropin isoforms resulting in menstrual dysfunction and insufficient peak bone mass.[113] Furthermore, intense ballet training results in reduced levels of insulin growth factor and in high cortisol levels (indicative of activation of hypothalamus) and it is possible that these factors could lead to unfavourable levels of trabecular bone. These authors have expressed an uncertainty as to whether such ballet dancers could reach normal values of bone mineral density even after the end of their dance careers.

3. Conclusions

While aesthetic goals are of the utmost importance, dancers remain subject to the same unyielding physical laws as athletes. Even at the height of their professional careers, dancers' muscular balance, muscular strength, aerobic power and bone and joint integrity are the 'Achilles heels' of the dance-only selection and training systems currently in use. In particular, dance injuries have been linked to poor levels of physical fitness, which often resemble those found in sedentary individuals. Preliminary data have indicated that supplementary off-studio exercise training can increase key fitness-related parameters without interfering with artistic and dance performance requirements.

The investigation into physiological and fitness components of dance and dancers has mainly concentrated on classical ballet dance. Relatively little has been published in relation to modern equivalents. More multidisciplinary scientific research is needed on the different forms of dance. This requires education of dancers and of the personnel working with them. However, any change in the traditional training of dancers must be approached cautiously to ensure that the aesthetic content is not affected by new training techniques.

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