



Research article

Influence of foot position and vision on dynamic postural strategies during the “grand plié” ballet movement (squatting) in young and adult ballet dancers

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ABSTRACT

Purpose: To analyse dynamic postural strategies during the “grand plié” in two different foot positions (parallel or turned out), with and without vision, and as a function of age in ballet dancers.

Method: Twenty young dancers (YD) aged from 8 to 16 years, and 20 adult dancers (AD) aged from 17 to 30 years were recruited. Center of pressure (CoP) and ground reaction forces (GRF) were recorded (500 Hz) during the grand plié (lowering, squatting and rising). This movement was tested with the feet parallel and with both lower limbs turned out (foot angle > 140°), with eyes open (EO) and eyes closed (EC). Groups were compared using Student *t*-tests. Repeated analysis of variance was used to examine the effects of eyes and foot conditions, with a significance level of $p < 0.05$.

Results: The results of this study showed that dynamic postural strategies during the “grand plié” ballet movement are influenced by age, foot position and visual condition. CoP displacement length ($p < 0.003$) and CoP speed ($p < 0.003$) were higher in YD compared with AD. CoP surface ($p < 0.05$), mediolateral CoP speed ($p < 0.048$) and GRF parameters, particularly the mediolateral ($p < 0.049$), were higher than in the parallel than the turned out position. In both groups all CoP ($p < 0.042$) and GRF parameters ($p < 0.049$), except the vertical component, were higher with EC than EO.

Conclusion: The effect of foot position was greatest with EO. The parallel position was less stable. The YD were more unstable in the parallel position, particularly with EC. For both groups, the lack of vision increased instability. These results show the importance of integrating balance training in a variety of foot positions and visual conditions, particularly during the initial stages of training to prevent injury.

1. Introduction

Ballet dancers maintain postural stability during challenging tasks more easily than non-dancers [1,2]. However, their postural capacity is affected by external factors such as sloped floors [3], lighting [4], footwear and costumes [5] and internal factors such as degree of expertise [6], errors during training [7], fatigue [6,8] and injury [9]. These factors can reduce stability, particularly in technical dance movements, increasing the risk of injury. The annual incidence of injuries in professional dancers is between 67% and 95% [10]. It is thus essential to develop specific exercises to improve postural control and prevent injuries [7].

The postural control system continuously manages the body's state of equilibrium through the interaction of sensory-motor processes [11].

Balance is constantly perturbed by body and limb motion and the relevant sensory information is selected and integrated by the postural control system to maintain stability [12]. The regulation of body position requires vestibular, visual, and somatosensory information, including proprioceptive [13]. Some people are dominant in one modality [14], however all three systems are essential for the organisation of balance, especially during complex movements [13].

Dance training improves balance and movement capacity by developing specific dynamic postural strategies relevant for dancing requirements [15]. Trepman et al. [16], showed that dance include three types of muscle activity: characteristic activity required for the execution of specific dance movements; varied activity, which is characteristic of different dance idioms and varied activity, which may depend on factors such as balance, personal habits, and individual training

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background. Young dancers (YD), for example, lack stability because they are still in the process of developing specific dance abilities [6]. Moreover, dynamic strategies seem to be influenced by accelerations in growth, which could disturb proprioceptive references and internal body representations [4].

It is important to understand the characteristics and needs of YD to prevent injuries from the very beginning of the dance training. However, few studies have compared YD and adult dancers (AD). In static balance, the postural control of YD is less efficient than that of AD and YD are more visually dominant [17]. In dynamic balance, this visual dominance has been shown to be related to age [4] and moreover, appears to be reinforced when the training involves visual feedback from mirrors [18]. Interestingly, it has been shown that practicing specific dance exercises with the eyes closed (EC) improves balance after only 4 weeks [7]. Few studies have investigated the effect of vision on balance training, despite the fact that visual conditions vary greatly between dance studios and theatre productions [7] and that postural control depends on the availability of visual information [2]. Unnatural lighting in the theatre reduces the effectiveness of the dancer's visual system, reducing postural control and increasing the risk of injury. It is therefore essential to evaluate visual dependence in ballet dancers to increase understanding of their strategies and develop appropriate balance exercises to improve performance.

The “*grand plié*” is a basic dance movement, learned at the by the youngest of dancers (Fig. 1). The movement is composed of three phases: lowering, complete squatting and rising [19]. Despite the importance of the “*grand plié*” in dance training, the effect of age and availability of visual information on postural strategies have never been investigated. Most studies have evaluated standard static balance tasks [2,4,17] that are not specific to ballet and thus do not highlight specific dance-related characteristics and requirements [16]. The “*grand plié*” movement has been shown to differentiate dancers with and without a history of ankle sprain [19] as well as contemporary and classical ballet dancers [16]. Thus, this movement seems to be a relevant marker to highlight specific dance abilities.

Six foot positions are trained in ballet. In the “*first position*”, both lower limbs are in external rotation and in “*sixth position*” the feet are parallel [20,21]. Foot position influences postural strategies in bipedal stance [20] and during turns [22]. Parallel and tandem foot positions are more stable than open foot positions in both ballet dancers and control subjects [20], although between-group differences are only significant for the dance-specific “*first position*”. In dynamic conditions, ground reaction force (GRF) parameters and joint moments during technical pirouettes are altered by the initial position of the feet [22]. We thus postulated that foot position would also affect postural control during the “*grand plié*”. We have chosen this movement because it is dance-specific and is a basic dance-exercise that all ballet dancers are very familiar with. Moreover, it is sufficiently simple to be carried out by YD and with EC.

The aim of this study was to assess the effect of age, foot position and visual condition on dynamic postural strategies during the “*grand plié*” in pre-professional and professional ballet dancers. We hypothesized that:

- instability would be greater in YD, particularly in the open foot position and with the EC;
- dynamic postural strategies would be modified by foot position and that the parallel position would be less stable than the turned out position because it is less frequently used in the ballet classroom;
- instability would be further increased by a lack of visual feedback, especially for YD who use the mirror to a greater extent during exercises.



Fig. 1. Ballet “*grand plié*” movement in the end of squatting phase in open feet configuration.

2. Material and methods

2.1. Participants

Forty high-level ballet dancers from the National Dance School of Marseille (France) were included in this study. They were allocated to one of two groups: YD (8–16 years) and AD (17–30 years). These age

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