International Journal of Orthopaedics and Physiotherapy
Online ISSN: 2664-8997, Print ISSN: 2664-8989
Received: 27-11-2020; Accepted: 12-12-2020; Published: 27-12-2020
www.orthopedicsjournals.com
Volume 2; Issue 1; 2020; Page No. 01-04

Vertical ground reaction force while performing an Indian classical dance, "Bharatanatyam"- A biomechanical study comparing three different surfaces

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DOI: https://doi.org/10.33545/26648989.2020.v2.i1a.10

Abstract

Introduction: Surface hardness of the dance floor has been implicated as a cause of repetitive strain injuries.The study aims to determine the peak ground reaction forces(GRF) on three different surfaces Wood (WD), Granite (GR) and Rubberised Polyvinyl (PV) Flooring) while performing Bharatanatyam.

Methods: Five pre professional dancers performed dance step [Tatta Adavu] and a jump over three different surfaces fixed over two identical force plates. The Peak GRF forces during the dance step from the right lower limb was acquired. Analysis was done with one-way ANOVA for three independent groups p-value (<0.05).

Results: Among the five participants, the mean peak GRF while performing the dance step on WD, Gr, PV was 1.05 (+/- 0.03), 1.11(+/- 0.01) and 1.09(+/- 0.04) respectively. The mean GRF while performing the jump among the surfaces, WD, Gr, PV was 1.79(+/- 0.16), 1.72 (+/-0.12) and 1.92(+/-0.17) respectively. The GRF while performing the dance step and the jump were lower on WD than on other surfaces. However, the results obtained were not of statistical significance (p value >0.05).

Conclusion: A non-resilient surface and an elastic surface both produce higher impact forces while performing dance steps. Hence, selecting an ideal surface for dance is imperative to avoid injuries.

Keywords: repetitive strain injury, dancing surface, vertical ground reaction force, bharathanatyam

Introduction

Most dance floors consist of two components: a surface floor and a subfloor. The surface floor provides appropriate friction and the sub floor provides the resilience or flexibility to help protect the joints and muscles from injury. Both are necessary to ensure a healthy safe environment. Pre-professional and professional dancers are at risk for mild and moderate lower extremity repetitive strain injury. Increased risk of injury might be associated with repetitive high impact ground reaction forces from non-resilient dancing surfaces [1]. Fritz *et al* had carried out simulations for landing on elastic, wooden and concrete flooring and shown that the peak ground reaction vertical forces were less in the wooden flooring compared to the concrete [2]. However, there have been other studies which have shown that peak vertical ground reaction forces have typically been found to be maintained at similar levels when running on surfaces with differing mechanical properties [3]. The injury prevalence among dancers was 26 to 50 % reported predominantly in ballet dancers [4]. In the context of Bharatanatyam, there have been studies which relate injuries to increased flexibility among the performers. As with any dance form, training of Bharatanatyam starts from a very early age and it takes a couple of years before one can master it. Repetitive strain injuries are one of the factors for dropout rates while training. The contributory role of the dancing floor is seldom explored, however, there exists a lacuna in literature about the ideal floor surface and its role in causing Bharatanatyam dance related injuries. Hence the authors feel it is imperative to quantify the forces generated while performing the dance which could probably gain more insight to the development of these injuries.

Methodology

Five subjects (three females and two males) and ranging in body mass from 47 kg to 56 kg performed Bharatanatyam dance step [Tatta Adavu] and jump which involved moderate to high impact forces after warming up exercises. All the subjects were pre- professional who had at least 8 hours of training per week for the past 4 years. Each subject performed steps barefooted on each of the three different surfaces, plywood, granite, and rubberised polyvinyl flooring., 480mmx480mmx 30mmwhich were clamped onto two identical force plates of 500mmx500mmx8mm made with 8 load cells in each force plate, maximum capacity of each load cell being 100 kg. The two force plates were fixed at the same level of the floor about 5mm apart to prevent cross stepping. The force plates were calibrated by placing known weights and noting down the change in voltage. Each subject performed for at least a minute and was rested for at least 5 to 8 minutes. Force plate data was collected at a sampling rate of 1 kHz. The magnitude of the peak impact force was determined using the vertical ground reaction force (GRF) data.

Statistical analyses for kinetic variables were calculated for both the dance sequence [Tatta Adavu] and the jump sequence using the mean values of at least 17 peaks of the ground reaction forces for the dance sequence and for at least 6 peaks for the jump sequences. One way ANOVA was used to compare the group mean for three different surfaces. For the five subjects, 17 consecutive peak impact forces were analysed on three different surfaces, for a desired effect size of 5 and a level of significance at 0.05.

Results

Among the participants (Males=2, Females=3), the Mean and Standard Deviation results for the three surfaces for both the dance sequence and the jump trials are presented in table 1 and table 2. For the dance step [TattaAdavu], the mean ground reaction force was highest for Granite (1.11 +/- 0.01) followed by rubberised polyvinyl flooring (1.09 +/-0.04) and wooden surface (1.05 +/-0.03) Figure 1. This demonstrates that the dance step [Tatta Adavu] generated the highest impact force on the least resilient surface i.e., Granite. This association was statistically significant *p* value <0.1. For the jump, the mean impact force was highest for the polyvinyl flooring (1.92 +/- 0.17) followed by granite surface (1.79 +/- 0.16) and wooden surface (1.72 +/-0.12) Figure 2. The higher values in the rubberised flooring could be due to more force required to produce the foot slap sound while landing, which is required by Bharatanatyam dancers. This association was statistically significant with a *p* value <0.05. Table 1.

Table 1: GRF data for each surface: peak impact force in body weights with Dance Steps [with standard deviations]

Subjects	Granite	Wood	Polyvinyl
1	1.12	1.07	1.08
	[0.01]	[0.04]	[0.03]
2	1.08	1.02	1.03
	[0.01]	[0.04]	[0.03]
3	1.09	1.01	1.08
	[0.02]	[0.05]	[0.04]
4	1.07	1.02	1.16
	[0.02]	[0.03]	[0.07]
5	1.16	1.09	1.11
	[0.02]	[0.02]	[0.05]
Group Mean	1.11 (+/- 0.01)	1.05 (+/- 0.03)	1.09 (+/-0.04)

Table 2: GRF data for each surface: peak impact force in body weights with jumps [with standard deviations]

Subjects	Granite	Wood	Polyvinyl
1	1.74	1.73	1.76
	0.2	0.11	0.11
2	1.63	1.49	1.99
	0.14	0.17	0.2
3	1.79	1.76	1.76
	0.17	0.04	0.2
4	1.9	1.74	1.99
	0.19	0.27	0.17
5	1.91	1.82	2.14
	0.1	0.02	0.17
Group mean	1.79 (+/-0.16)	1.72 (0.12)	1.92 (+/-0.17)

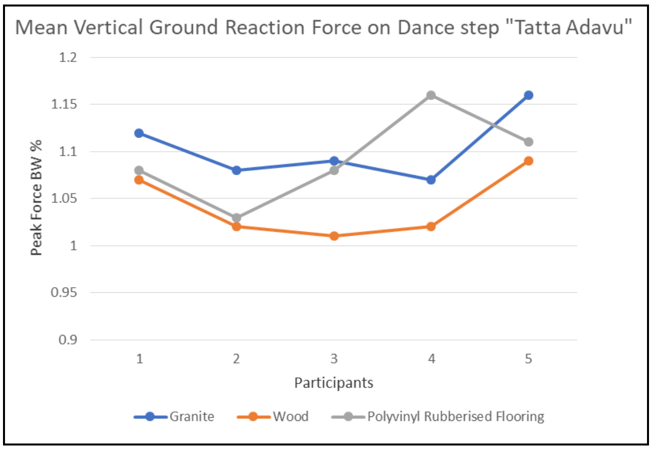

Fig 1: Mean Vertical Ground Reaction Force on Dance step "Tatta Adavu"

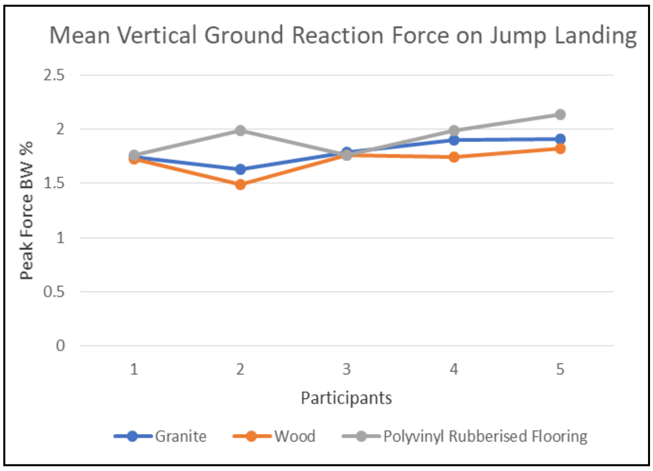

Fig 2: Mean Vertical Ground Reaction Force on Jump landing

Discussion

The practice of Bharatanatyam has undergone a paradigm shift from being an art practiced by Devadasi's in temples to modern day prime time television shows. Subsequently, the training of young dancers on mud flooring has been replaced by non-resilient surfaces such as concrete, granite etc. Coupled with the growing glamour of the art form, dancers had to focus more on the acrobatic aspects of the dance to captivate the audience. The change in practice to meet the new trends has undoubtedly raised concerns regarding the mobility and long-term performance of seasoned dancers. The professional dancers are subjected to early retirement due to various muscle and joint related injuries. The pattern of pain among Bharatanatyam dancers is usually restricted to lower back and lower limb. In a survey by Nair *et al* in 2008, back pain was the most common presenting complaint followed by knee pain [5]. The increased incidence of lower limb injuries has been attributed to the increased lower limb flexibility of these dancers [6, 7]. Although limited, there have been studies to analyse the problem of increased flexibility through kinematic analysis. Mullerpatan *et al* had concluded that the dancers with back pain had exaggerated pelvic tilt and obliquity and greater spine extension [8]. The findings from our study may provide some insight to the role of dance floor surface in the development of injuries.

Biomechanical calculation of vertical ground reaction forces was initially based on mathematical models and complex physics [9]. However, with recent scientific advances the GRF can be calculated using piezoelectric force plates with much ease. The reliability of these force plates has been time tested [10]. The application of calculating the landing force is to prevent injuries and better the performance. Hence this equipment has its place in most of the biomechanical labs. The utility of analysing the GRF and kinematic analysis is being regularly performed for many sporting activities [11]. However, with relation to dance the literature is sparse, and mostly confined to ballet dancing [12]. Among the Indian dance forms Shenoy *et al*. have studied the forces while performing a few dance steps in Bharatanatyam. [13]. Normalized vertical ground reaction forces measured over the three floor surfaces did not vary significantly in our study with dancers as shown by previous studies in running athletes, [14] and aerobic dancers [15, 16]. Peak ground reaction forces are not dependent on resilience of the surface alone; other factors which may contribute to the force generation are the velocity of the impact, comfort level of the subject and the area of contact of the foot on the surface [17]. These variables have been studied for running by Dixon SJ *et al* [3]. In the present study similar variables could not be assessed due to the complexity of the high speed, rate of repetition, and multiple areas of the foot coming in contact on the force plate.

Though the dance steps and jumps were common and the subjects had similar training periods, there were substantial differences in the mean GRF among the surfaces. The dance step [Tatta Adavu] had a mean impact force which was higher on Granite surface when compared with the other surfaces. As with regards to the impact forces while jump landing, contrary to our assumption that the mechanical impact absorption would be more in the polyvinyl surface than the wooden surface; we found that for the Jump landing, the ground reaction forces were higher on the polyvinyl surface as compared to the wooden surface. This could be possibly explained by the findings of Feehery *et al* in runners [17], that when the subject is on a less resilient surface their comfort level is higher, and thus there is a subconscious adjustment in the lower extremity kinetic chain segments which influences the landing or initial contact forces. Furthermore, an explanation for more force on the rubberised flooring could be that the dancer had to create a foot slap sound which adds to the raga component of the dance and therefore had to consciously tap the feet harder to create the sound on a resilient surface. Higher impact forces generated in non-resilient surfaces (Granite flooring) could possibly reduce the shock absorbing ability in the kinetic chain of the lower extremity and thereby cause higher incidence of injury in the musculoskeletal structures. The clinical implication of this data can be extrapolated to the present day training of Bharatanatyam dancers which is performed mostly at the trainer's house (Concrete flooring) which lacks the infrastructure to provide the choice of platform for the practice of this classical dance.

The limitations of our findings would be the lack of kinematic analysis, comparison among varying levels of proficiency and a small sample size. Also, as was the practice in yesteryears, surfaces like earthen floors with cow dung needs to be assessed. The authors feel that the findings in this pilot study would further pave way for future studies to determine the ideal surface for the practice of Bharatanatyam.

Conclusion

Old school of classical dancing focused more on expressions with gentle foot work whereas the recent dance style has a lot of aggressive foot work involved. The differences in the peak ground reaction forces are multifactorial and depend on the body mass, the speed of activity, contact area between the foot and the surface. Prevention is important in all overuse injuries; hence the duration, intensity and environment of the training programme needs to be evaluated on a regular basis. Having an ideal dance surface is imperative to prevent such injuries.

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