

# Comparison of cervical and ocular vestibular evoked myogenic potentials in dancers and non-dancers

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## Abstract

The objective of the study was to assess the sacculocollic and otolith ocular pathway function using cervical vestibular evoked myogenic potentials (cVEMP) and ocular vestibular myogenic potentials (oVEMP) in dancers and non dancers. Total 16 subjects participated in the study. Out of 16 participants, 8 were trained in Indian classical form of dance (dancers) and other 8 participants who were not trained in any dance form (non dancers). cVEMP and oVEMP responses were recorded for all the subjects. Non Parametric Mann-Whitney U test revealed no significant difference between dancers and non dancers for the latency and amplitude parameter for cVEMP and oVEMP, *i.e.* P13, N23 latency and P13-N23 complex amplitude and N10, P14 latency, N10-P14 complex amplitude respectively. The vestibular system comprises of several structures. It is possible that the dance style practiced by the dancer's group assessed in this study does not contribute towards improving the plasticity of the sacculocollic and otolith-ocular pathways. It can be concluded that not all forms of dance training brings about a change in the plasticity of the sacculocollic and otolith-ocular pathways.

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Key words: vestibular evoked myogenic potentials, sacculocollic pathway, otolith-ocular pathway, dancers.

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## Introduction

In recent years, cervical vestibular evoked myogenic potentials (cVEMP) have been utilized for the diagnosis of various disorders such as, Meniere's disease,<sup>1,2</sup> acoustic neuroma,<sup>2-5</sup> superior canal dehiscence,<sup>6</sup> vestibular neuritis,<sup>7</sup> benign paroxysmal positional vertigo,<sup>8</sup> noise induced hearing loss,<sup>9,10</sup> auditory neuropathy/audiovestibular neuropathy,<sup>10,11</sup> as well as other disorders such as cerebellopontine angle tumor,<sup>12</sup> and multiple sclerosis.<sup>2</sup> Similarly, ocular vestibular evoked myogenic potentials (oVEMP) also have been utilised in diagnosing superior semicircular canal dehiscence syndrome,<sup>13</sup> internuclear ophthalmoplegia,<sup>14</sup> to differentiate between cerebellar and brainstem lesions,<sup>15</sup> auditory neuropathy/audiovestibular neuropathy,<sup>16</sup> Meniere's disease,<sup>17</sup> and vestibular neuritis.<sup>18</sup>

The typical cVEMP waveform consists of a positive-negative wave complex, with the positive peak commonly labelled as P13, and the negative trough labelled as N23, corresponding to their mean latency in milliseconds.<sup>19</sup> The typical oVEMP waveform consists of a negative-positive wave complex, with the positive peak commonly labelled as P14, and the negative trough labelled as N10, corresponding to their mean latency in milliseconds. As revealed by few studies, N10-P14 component is vestibular in origin and most likely originates from the otolith-ocular pathway.<sup>20,21</sup> The cVEMP response is mediated by a primarily uncrossed pathway, whereas, the oVEMP response follows primarily a crossed pathway.<sup>22,23</sup> Additionally cVEMP represents a relaxation response in a tonically contracting muscles, whereas, oVEMP represents excitation of the extra ocular muscles via the otolith ocular pathway.<sup>23</sup>

Plasticity is a term used to describe a variety of physiological changes in the central nervous system in response to sensory experiences.<sup>24</sup> With training, these physiological changes might occur due to several different processes, such as; greater number of neurons responding in the sensory field, improves neural synchrony (or temporal coherence); and neural decorrelative processes whereby training decorrelates activity between neurons, making each neuron as different as possible in its functional specificity relative to the other members of the population.<sup>25</sup> The plasticity in the auditory system has been studied extensively. Using different types of auditory evoked potentials there is converging evidence that different types of stimuli alters evoked neural activity of the auditory system.<sup>26,27</sup>

Similar to the auditory system, the vestibular system can also undergo plastic changes when exposed to repetitive stimuli in order to adjust its reaction to the changing environment. Earlier studies have reported a substantial change in vestibuloocular reflex gain (eye velocity/head velocity) in response to a sinusoidal rotational stimulus,<sup>28</sup> changes of time constants after only a few cycles of low frequency stimulation during repeated steps of angular rotations<sup>29</sup> and also during altered gravity.<sup>30</sup>

Dance is an age-old practice for many people from all nations, and it

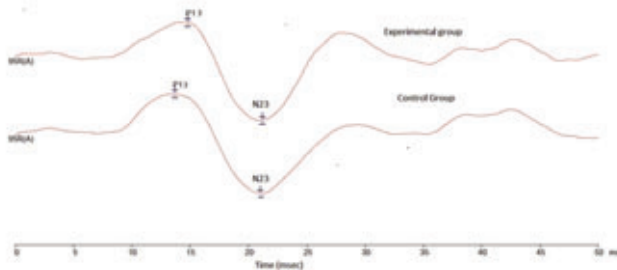
is a natural process in which most people have participated at some time in their lives. Physically, dance promotes movement of the head and trunk due to which the centre of gravity is shifted in every direction from the axis of support, in turn, contributing to balance and joint mobility. Training in dance forms has been utilised as a therapeutic intervention to effectively target balance and mobility in older persons.<sup>31</sup> Previous studies have reported significant improvement in balance for the middle aged and older participants following dance practice<sup>32</sup> and also improvement in balance and mobility following dance sessions for patients with Parkinson's, compared to traditional exercises.<sup>33</sup> In the past, few studies have been carried out on vestibular system in dancers and these studies explain plasticity of the vestibular system based on the changes in vestibule-ocular reflexes,<sup>34</sup> absence of nystagmus and vertigo in dancers,<sup>35</sup> better balance in dancers compared to non dancers on modified Foam and Dome test,<sup>36</sup> and better balance in experienced dancers compared to beginners,<sup>37</sup> better balance in female dancers compared to non dancers.<sup>38</sup> The above mentioned studies have used electronystagmography, or behavioural tests such as modified Foam and Dome test and one legged balance test to study the changes in the response of the vestibular system in dancers.

Also, none of the studies have exclusively concentrated on the plas-

ticity of the otolith organs in dancers. Few of the earlier studies have emphasised on the plasticity of the otolith organs which reveal an increased plasticity of the otolith end organs in animals exposed to microgravity,<sup>39</sup> and also in human divers.<sup>40</sup> The mechanism behind this improved plasticity may be an increase in otolith sensitivity, otolith-stereociliary coupling causing enhanced bundle deflection for a given movement, a pre or postsynaptic alteration in the strength of synaptic transmission<sup>39</sup> or morphological changes in the hair cells of the otolith organs.<sup>41</sup>

During the course of a dance session, a dancer is subjected to repeated rotational movements, various postures, jumping and side-wise movements during dance etc. which causes stimulation of the vestibular system. The participants in the present study were trained in Bharatnatyam and Kathak form of dance. These classical forms of dance pattern are performed by coordination of the movements of feet, hand, knees, arms and torso. During the dance, the dancers exhibit various kinds of movements including whirling, leaps and jumping, jumping with toes, sidewise movements of the body and also different variations are woven together.

As a consequence of various kinds of movements during the dance, the vestibular system might produce some sort of plasticity and the reactions from the organs of the vestibular system of the dancers might be different from that of the non-dancers. The purpose of the present study was to assess the otolith ocular pathway function as measured by cVEMP and oVEMP respectively.



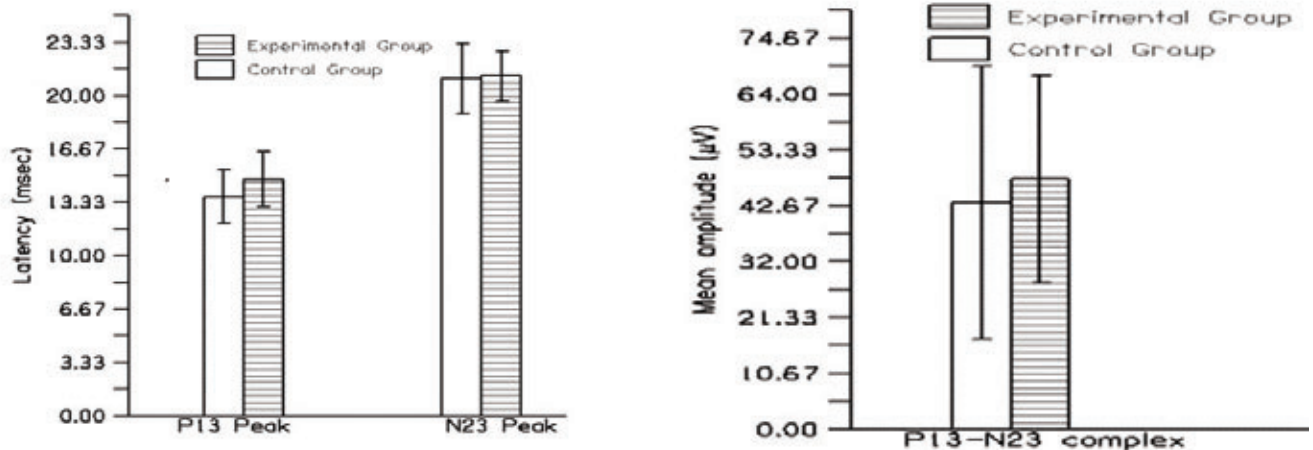
**Figure 1. Grand average waveform of cervical vestibular evoked myogenic potentials recorded from control and experimental groups.**

## Materials and Methods

### Participants

The experimental group consisted of 8 females (16 ears) in the age range of 18 to 23 years with the mean age being 20 years, who had received formal training in Indian classical dance form for a minimum of 2 years and have an experience of 4 to 5 years in the same. On the other hand, 8 females (16 ears) with no prior formal training in any dance form, in the age range of 18 to 23 years, with the mean age being 20 years, served as the participants of the control group.

The participants in experimental group had minimum 2 years of formal dance training experience in Indian Classical dance forms such as



**Figure 2. Bar graph of P13 and N23 latency and P13-N23 complex amplitude of cervical vestibular evoked myogenic potentials for the experimental and control group.**

Bharatnatyam and Kathak. All the participants had passed the junior level exam of dance training. The participants in the control group had not undergone any formal dance training and additionally had not been a part of any stage performances in any cultural activities. Through a structured interview, it was ascertained that none of the participants were athletes or involved in any kind of regular physical training.

### Participant selection criteria

All the participants had normal hearing sensitivity in both the ears as defined by pure tone thresholds of <15 dBHL at 500 Hz, 1000Hz, 2000Hz, 4000 Hz and 8000 Hz, with normal middle ear functions as revealed by A type of tympanogram and presence of acoustic reflexes present at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for both ipsi and contralateral stimulation. There was no history or presence of any other otological, neuromuscular and neurological problem among the participants. There was no history of intake of drug that may lead to vestibulotoxicity and no symptoms of vestibular problem such as vertigo, nausea, giddiness, blurring of vision in all the participants.

### Instrumentation

In order to find the air and bone conduction thresholds of the participants for pure tones, a calibrated (ANSI S3.6-1996) two channel clinical audiometer (Orbiter-922 V-2x, G N Otometrics, Taastrup, Denmark) with TDH-39 headphones (Telephonics, Farmingdale, NY, USA) and a B-71 bone vibrator (Radioear, KIMMETRICS, Smithsburg, MD, USA) were used. The TDH-39 headphones (Telephonics) were also used to find their uncomfortable levels. A calibrated middle ear analyzer system (GSI VIASYS Healthcare, WI, USA) was utilised to evaluate the middle ear functioning. Vestibular evoked myogenic potentials were recorded using an Intelligent Hearing Systems (Intelligent Hearing System, FL, USA) with an Insert ER-3A earphone (Etymotic Research, Inc., Elk Grove Village, IL, USA).

### Procedure

Pure tone thresholds were obtained using modified Hughson and Westlake procedure (given by Carhart *et al.*)<sup>42</sup> across octave frequencies, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz for air conduction and 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for bone conduction. Immittance audiometry was carried out with a probe tone frequency of 226 Hz. Acoustic reflex thresholds were measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for ipsilateral and contralateral stimulation. All the participants underwent an uncomfortable loudness level testing as the recording of vestibular evoked myogenic potential requires a higher intensity presentation. Uncomfortable level for speech was estab-

lished for all the participants using the two-down one-up procedure.

The electrophysiologic tests *i.e.* cVEMP was recorded for all the subjects with 500 Hz tone burst stimulus using Intelligent Hearing Systems. During the cVEMP's recordings the participants were instructed to sit straight and turn their head to the opposite side of the ear in which stimulus was presented, so as to activate ipsilateral sternocleidomastoid muscle. Participants were instructed to maintain the same posture throughout the test. In order to control the electrical effect of sternocleidomastoid muscles on the recorded cVEMP amplitude, participants were asked to maintain unilateral muscle contraction producing a tonic electromyography signal between 50 µv to 100 µv. This was assessed using the software supplied by the intelligent hearing systems. Thus, the vestibular evoked myogenic potential recorded were presumably due to the acoustic stimuli supplied, rather than the changes in the sternocleidomastoid muscle contraction. AgCl electrodes were used to record the cVEMP responses. Non-inverting electrode was placed on ipsilateral sternocleido-mastoid muscle, inverting electrode was placed on sternoclavicular joint and the ground electrode was placed on the forehead. The responses were filtered from 30 Hz to 1500 Hz. Analysis time was kept at 50-ms. A total of 100 stimuli with a repetition rate of 5.1/s were presented at 95 dB nHL intensity in an alternating polarity.

oVEMP was recorded for all the subjects with 500 Hz tone burst stimulus using Intelligent Hearing Systems. AgCl electrodes were used to

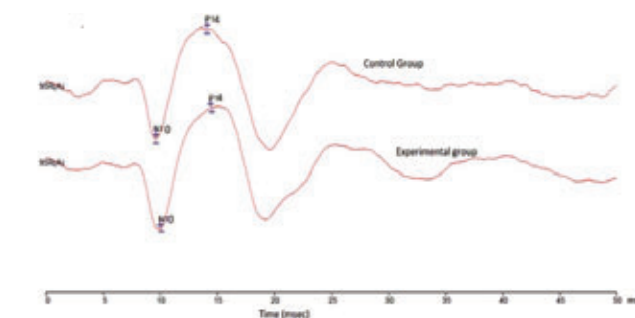


Figure 3. Grand average waveform of ocular vestibular evoked myogenic potentials recorded from control and experimental groups.

Table 1. Mean and standard deviation of latency and amplitude of cervical vestibular evoked myogenic potentials parameters.

	P13 Latency			N23 Latency			P13-N23 complex amplitude		
	Mean (ms)	SD	Range	Mean (ms)	SD	Range	Mean (µV)	SD	Range
Non-Dancers	13.68	1.68	11.00-16.60	21.08	2.19	17.15-25.05	43.26	26.05	5.29-99.48
Dancers	14.75	1.73	12.50-18.30	21.24	1.55	18.80-23.40	47.76	19.74	27.21-105.16

SD, standard deviation.

Table 2. Mean and standard deviation for latency and amplitude parameters of ocular vestibular evoked myogenic potentials.

	N10 Latency			P14 Latency			N10-P14 complex amplitude		
	Mean (ms)	SD	Range	Mean (ms)	SD	Range	Mean (µV)	SD	Range
Non-Dancers	9.46	0.88	7.60-10.50	14.01	1.06	12.20-15.60	4.77	1.98	2.26-8.09
Dancers	10.03	0.95	8.20-11.40	14.52	1.58	11.20-16.30	6.30	3.41	2.83-13.01

SD, standard deviation.

record the oVEMP responses. Non-inverting electrode was placed 1-3 cm below the eye, inverting electrode was placed directly below the non-inverting electrode on the cheek, and the ground electrode was placed on the forehead. The responses were filtered from 1 Hz to 1000 Hz and the analysis time was kept as 50-ms. A total of 100 stimuli with a repetition rate of 5.1/s were presented at an intensity of 95 dBnHL in an alternating polarity. The recording of the oVEMP was done in contralateral mode *i.e.* the electrodes were placed on the side contralateral to the ear stimulated. During the recording of oVEMP, the subjects were asked to look up at a fixed point *i.e.* the oVEMP recording was done in an upper gaze direction (as oVEMP has been reported to be present if recorded only in the contralateral mode and upper gaze direction).<sup>43</sup> Waveforms produced in response to the tone burst stimuli were recorded twice to ensure the replicability of the waveform. A 500 Hz tone burst was utilised to record the vestibular evoked myogenic potentials as the amplitude of the vestibular evoked myogenic potential by 500 Hz tone burst is higher compared to a click stimulus.<sup>44</sup>

For both cVEMP and oVEMP waveforms produced, tone burst stimulus were recorded twice to ensure the replicability of the waveforms. However, the waveforms obtained during the first recording in both the groups were taken for analysis. The latency of P13 and N23 waves and amplitude of P13-N23 complex for cVEMP was analysed, whereas for the oVEMP, the latency of N10 and P14 waves and amplitude of N10-P14 complex were analysed. For this analysis a non parametric Mann-Whitney U test was applied to compare the results of the two groups.

## Results

For each subject, the latency and amplitude parameters of cVEMP and oVEMP were obtained for both ears.

### Latency and amplitude of cervical vestibular evoked myogenic potentials

cVEMP could be obtained for all the subjects in both control (non-

dancer) and the experimental group (dancer). The grand total average waveform of the cVEMP recorded from the dancers and non-dancers are shown below in Figure 1.

Descriptive statistics was done to find out the mean and standard deviation for the latency of P13 and N23 waves and amplitude of P13-N23 wave complex for both the groups. The mean and the standard deviation for the same are given in Table 1.

It can be seen from Table 1 that the mean amplitude of P13-N23 complex was more for the experimental group compared to the control group, whereas the latency of P13 and N23 peak was early for the control group compared to the experimental group. The same can be seen in Figure 2.

Non parametric Mann-Whitney U test revealed statistically no significant difference between the control and the experimental group for P13 latency [ $Z=1.67$ ,  $P>0.05$ ], N23 latency [ $Z=0.01$ ,  $P>0.05$ ] and P13-N23 complex amplitude [ $Z=0.38$ ,  $P>0.05$ ].

### Latency and amplitude of ocular vestibular evoked myogenic potentials

Ocular vestibular evoked myogenic potential also could be recorded for all subjects in both the control and the experimental group. Grand averaged waveform of ocular VEMP for both the groups are given in Figure 3.

Descriptive statistics was done to find out the mean and standard deviation (SD) for the latency of N10 and P14 and amplitude complex of N10-P14 complex. The mean and SD of both the control group and the experimental group are given in Table 2.

It can be seen from Table 2 that the latency of N10 and P14 peak is early for the control group compared to the experimental group and the amplitude of N10-P14 complex is higher for the experimental group compared to the control group. The same can be seen in Figure 4.

Non parametric Mann-Whitney U test was done and was found to be statistically non-significant between the control and the experimental group for N10 latency [ $Z=1.77$ ,  $P>0.05$ ], P14 latency [ $Z=1.60$ ,  $P>0.05$ ] and amplitude of N10-P14 complex [ $Z=1.13$ ,  $P>0.05$ ]. To summarize, there were no differences in latency or amplitude parameters in either cVEMP or oVEMP between dancers and non-dancers.

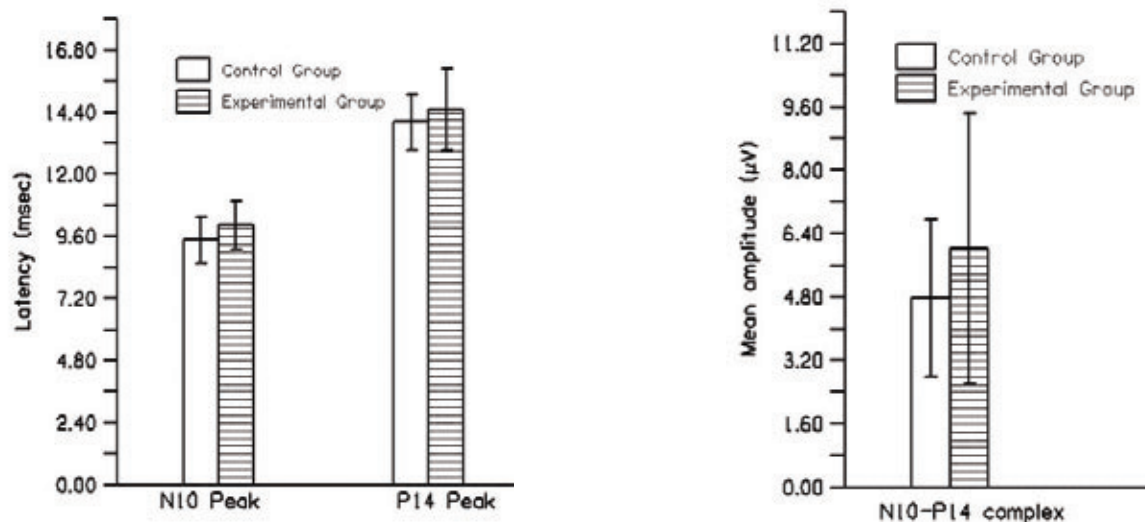


Figure 4. Bar graph of N10 and P14 of ocular vestibular evoked myogenic potentials latency and N10-P14 complex amplitude for control and the experimental group.

## Discussion

In the present study we could not find any significant differences in latency or amplitude parameters of cVEMP and oVEMP between the control and the experimental group. Based on these results we interpret that plasticity is not seen in both the sacculocollic pathway and the otolithocular pathway in the dancers. No significant differences in results between the control and the experimental group may be attributed to the dance form in which the participants were trained. The dancers who had participated for the present study were trained in Bharatnatyam or Kathak dance forms. In Bharatnatyam, dancers have more movements in terms of sitting postures or in knee bent postures whereas in Kathak, dancers dance throughout in a standing posture, with limited or no hip movements. Since the balance responses rely upon the visual, vestibular, and somatosensory systems,<sup>36</sup> it is possible that the dancers trained in the above mentioned dance forms might be using visual or somatosensory system to a greater extent compared to the vestibular system and thus no plasticity is observed in the sacculocollic or otolith ocular pathway. However, this is just a hypothesis which can be substantiated by further research.

In the past, studies have reported that under sensory challenged conditions, dancers are able to maintain their postures upright against gravity when compared with non-dancers.<sup>36,37</sup> This indicates that there is a presence of possible plasticity in dancers compared to non-dancers. However, in the above mentioned studies, subjective tests such as modified Foam and Dome test and one legged-balance test were utilised for assessing the balance function.

For the Foam and Dome test or one legged balance test, in order to establish balance, the participants require information from all the three sensory systems *i.e.* visual, vestibular and somatosensory system.<sup>45,46</sup> Hence these tests are not sensitive to physiological changes that occur along the sacculocollic pathway or the otolith ocular pathway.

However several other studies report the presence of plasticity of the vestibulo ocular reflexes in dancers.<sup>34</sup> This could possibly be due to the different population studied in the two studies *i.e.* in the study by Osterhammel *et al.* all the participants were trained in ballet dance whereas, in the present study the dancers were trained in Indian classical form of dance. The postures formed during ballet dancing and Indian classical dances such as Bharatnatyam and Kathak are entirely different. The differences also could be due to the pathway studied in the two studies *i.e.* Osterhammel *et al.* studied vestibulo ocular reflex whereas in the present study we studied the sacculocollic and otolith ocular pathway. Hence, it is reasonable to postulate that the different dance forms may lead to plasticity in different parts of the vestibular system.

However, certain other studies have reported plasticity of the sacculocollic pathway in persons who are exposed to microgravity<sup>47</sup> and professional divers.<sup>40</sup> However, we failed to show any significant plasticity in both the sacculocollic pathway and the otolith ocular pathway in the dancers. It can be due to the extent of dependence on the vestibular system during microgravity or diving which is more compared to the Bharatnatyam or the Kathak dance forms. Also the smaller sample size could have contributed to the absence of significant differences between the two groups of participants.

## Conclusions

From the above study, it can be concluded that Indian classical dance forms such as Bharatnatyam and Kathak may not lead to plasticity of either the sacculocollic and otolith ocular pathway. Although, we have

found no change in cVEMP or oVEMP results between the dancers and the non dancers, yet the result of the present study should be interpreted cautiously due to small sample size in the present study. Further, studies can be replicated on a larger sample size to confirm the results and also on dancers who are undergoing other forms of dance training.

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