

## Systemic Review

# Effects of sensory stimulation on balance and postural control in diabetic neuropathy: systematic review

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## ABSTRACT

Diabetic peripheral neuropathy is a complication of Diabetes Mellitus and is the most common noncommunicable disease. It involves decreases in the sensations and Lower extremity strength leading to reduce dynamic stability in balance and postural control. The purpose of the study is to review the effects of sensory stimulation interventions on Balance and Postural control in Diabetic peripheral neuropathy. A systematic review was conducted following the centers for Goggle scholar, PUBMED and science direct database using the keywords Sensory Stimulation, Balance, Postural control, Diabetic neuropathy. The time frame of the search was from 2006 to 2021. The review resulted in search of 18 articles with duration from 1 day to 26 weeks with a total population of 1,422 diabetes Mellitus type I and type II patients from the year 2006 to 2021. There were strong evidences of effects of sensory stimulation on postural control and Balance with noticeable difference in DPN. Based on our analysis results, most of the study stated that Vibration, Plantar Massages, Kinesiotaping, Rocker shoe, Vibromedical insole, Conventional exercises with proprioception stimulation, Mechanical noise have shown significant difference on balance and postural control. Whereas, offloading devices did not show any remarkable variance. The currently existing studies require a clear recommendation on whether which intervention is more effective. Thus, longer duration studies are required to improve balance and postural control in Diabetic Neuropathy.

**Keywords:** Diabetic neuropathy, Sensory stimulation, Balance, Postural control

## INTRODUCTION

Diabetes Mellitus, worldwide is one of the most common noncommunicable disease.<sup>1</sup> Studies have declared that, in 2019, a total of 463 Million, in 2030 an expected increase of 578 Million and in 2045 an expected increase of 700 Million people is estimated with a prevalence of Diabetes in women (2019) of 9.0% and 9.6% in men (2019) amongst 30%-50% of Diabetic Mellitus patients are affected with Diabetic Neuropathy.<sup>1,2</sup> The prevalence of Diabetes Mellitus in India in the year 2014.

Asian Indian people, which we widely define as individuals originating from the Indian subcontinent (the

countries of India, Pakistan, Bangladesh, Sri Lanka, Afghanistan, Nepal, Bhutan and the Maldives) constitute >17% of the world's population. India has the highest concentration of validated cases of the global diabetes mellitus epidemic and has the second highest number of people with the disease in the world (~69 million individuals as of 2015). It occurs in people as a comorbidity or may be age related, due to obesity or can be genetical. Diabetes mellitus is a group of metabolic diseases characterized by hyperglycaemia resulting from defects in insulin secretion, insulin action, or both.<sup>3</sup> There are two forms of Diabetes, earlier called as “juvenile onset” and “adult onset,” which are now referred to as insulin dependent, ketosis prone (Type I) and non-insulin

dependent, ketosis resistant (Type II), both may occur in any age. Type I diabetes mellitus can be associated with or follow the viral infection with the insulin levels low or unmeasurable.<sup>4</sup> Type I diabetes patients have immunological factors, antibodies to islet cell surface membrane and cytoplasm present in the serum. Genetic factors may have an inadvertent role. In Type II diabetes, in response to a glucose stimulus there is a rise in circulating insulin levels, even though the timing of insulin release is abnormal.<sup>4</sup> Complications of diabetes mellitus includes diabetic neuropathy, nephropathy, retinopathy, macrovascular complications and miscellaneous complications out of which diabetic neuropathy is one the most common complication.<sup>6</sup>

Diabetic peripheral neuropathy is defined as the presence of symptoms and/or signs of peripheral nerve dysfunction in people with diabetes, after exclusion of other causes.<sup>5</sup> Diabetic neuropathy involves a combine abnormality of sensory, motor and autonomic nerve fibres.<sup>4</sup> There are different types of diabetic neuropathy in which Distal symmetric neuropathy is the most common form of nerve injury.<sup>7</sup> Distal symmetric neuropathy includes small and large peripheral nerve fibers. Paraesthesia, sensory loss and muscle weakness is caused due to large nerve fibers and small nerve fiber damage is associated with pain, anesthesia, foot ulcer, and autonomic symptoms.<sup>8</sup> Patients with diabetic neuropathy have decreased sensations and lower extremity strength which led to reduce dynamic stability in balance and postural control. The loss of vestibular and somatosensory sensations may also cause dependency in postural control.<sup>9</sup> However, constant and subconscious postural sway is required to achieve

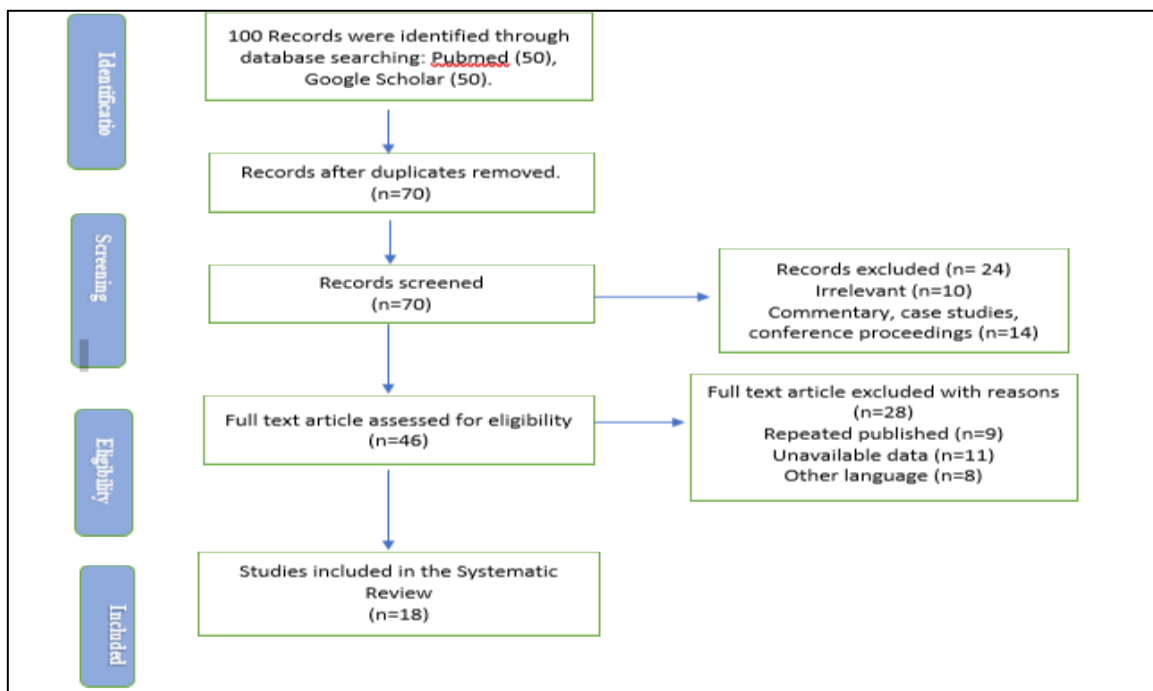
appropriate postural stability, balance and postural control.<sup>10</sup>

Kinesio taping, Placebo taping, electrical muscle stimulation, plantar massage, rough-textured surface, skin indentation, tactile stimulation, vibration, shoe's modification is few of the sensory stimulation therapies used. The contributors of postural control are direct contact of the bottom and body throughout standing still and plantar cutaneous information.<sup>10</sup> The spatial and temporal data regarding pressure variations is transmitted via Plantar skin afferents.<sup>10</sup> This feedback is provided by low threshold mechanoreceptors that stimulates the action of Glabrous skin of the foot.<sup>10</sup> Previous studies state that Glabrous skin mechanoreceptors provides accurate data concerning small changes in force magnitude externally or internally and that human hair skin is a lot of sensitive to the tangential force than the normal forces.<sup>11,12</sup> Other interventions and strategies used to reduce the effects of diabetic neuropathy are guided practice of sensory input, strengthening and stretching, education on sensation loss and fall risk, instruction on home modification and introduction of assistive devices to minimize balance dysfunction.<sup>13</sup>

**METHODS**

*Protocol*

This systematic review is done to analyse the effects of sensory stimulation on balance and postural control in diabetic neuropathy.



**Figure 1: Selection process and result of titles, abstracts and articles reviewed.**

### **Eligibility criteria**

Inclusion criteria included full text articles, articles which are published in the last 15 years, other systematic reviews, cross-sectional studies, observational studies, randomized control trails, pilot study articles which include both genders and age group from 18-99, articles representing both Type I and Type II diabetes mellitus, articles that represent only physical therapy interventions. Exclusion Criteria included case reports, duplicate articles, articles with only abstracts. articles that represent other pharmacological intervention, surgical intervention, acupuncture.

### **Search strategy**

Literature search was conducted using following sources: Google Scholar, Pubmed, Medline. The terms used for the search individually or combined are sensory stimulation, diabetic neuropathy, balance and postural control. The References of the published articles were also used to as an additional source for identification of other studies.

### **Study selection and data extraction**

Once a study was selected based on the Abstract content, it was considered appropriate for the Systematic Review if the eligibility criteria was met. All the study designs were eligible for this review. A study was included if the study population consisted primarily of adults with diabetic peripheral neuropathy. Every research study was selected on the basis of inclusion and exclusion criteria.

The following data was extracted from the studies that were included author, title, name of the journal, study design, outcome measures, study population and gender, year of publication, conclusion and results.

### **Data analysis**

After data extraction, a descriptive synthesis was performed taking in to account the study quality and its outcome measures.

## **RESULTS**

### **Description of studies**

The search procedure resulted in 100 articles (n=50) articles from Pubmed and (n=50) from Google scholar. (n=70) articles were excluded after duplicate analysis. (n=24) articles were excluded for irrelevant, commentary, case studies, conference proceedings. (n=46) articles were assessed Full text reading and Eligibility criteria out of which (n= 28) Full text articles were excluded for the following reasons repeated published (n= 9), Unavailable data (n=11) and Other language (n=8). Full review of (n= 18) articles were done. Finally, (n=18) Studies were

selected for this Systematic Review. Figure (3) shows the Flow chart for the Studies included.

Table 1 consists of characteristics of the various studies used in this systematic review. studies included individuals with diabetes mellitus Type I and Type II. The total study population of 1,422 and an age group of 18-97 years. Both genders were taken into consideration for all the studies which ranged from the year 2006 to 2021.

### **Intervention characteristics**

This systematic review includes the studies based on 12 different sensory based physical therapeutic intervention which are likely to improve the balance and postural control in patients with diabetic neuropathy. Interventions such as Kinesotaping, conventional exercises combined with touch, proprioception, visual and vestibular stimulation. electrical stimulation, plantar massages, offloading devices, whole body vibration, mechanical noise, foot and ankle devices, rocker shoe, vibromedical insoles. There was wide variation in regarding the type and quality of outcome measures used to measure the balance and postural control in the various studies.

### **Balance**

The search for literature resulted in (n=13) articles that studied the effects of sensory stimulation on balance. All the interventions of these articles lasted from 1 day to 8 weeks in which few also included the follow up sessions. (n=4) articles divided their participants in to two intervention group and control group and (n=1) (Priplata et al) article divided the participants in to three groups as diabetes, stroke and healthy individuals. (n=2) articles were systematic review consisting a study of 5 and 11 articles. Remaining (n=6) articles didn't divide the participants at all. Every article required the time period from 30s to 1 hr 20 mins to carry out the intervention. The conclusions for all the articles are mentioned in the table 1 below.

### **Postural control**

The search for literature resulted (n=5) articles that studied the effects of sensory stimuli on postural control. All the interventions in these articles lasted from 1 day to 26 weeks which included the before and after effects of the intervention. (n=1) articles divided the participants into two groups as Group A and Group B (Ibrahim et al). (n=1) article divided the participants into three groups healthy adult group (O), plantar sole deficit group (OD) and control Group (Y- Young healthy subjects) (Bernard-Demanze et al). (n=2) articles didn't divide the participants in any group. (n=1) article is a systematic review consisting a study of 8 articles. The conclusion and outcome measures for each article are mentioned in the table below.

**Table 1: Studies included in the systematic review.**

Author	Title	Name of journal and year of publication	Sample size	Age/ Gender	Outcome measures	Conclusion/ Result
<b>Akbari et al<sup>27</sup></b>	Effects of skin stretch sensory stimuli on Balance in patients with diabetic neuropathy	J Nov Physiother 2011	(n=17)	44.99 ±3.93years/ Both Genders	Balance indices: Overall stability index, Antero-posterior Stability Index, Left- Right Stability Index	The study concluded that sensory stimuli especially in legs is able to reduce of body sway and improve balance.
<b>Maruboynia et al<sup>24</sup></b>	Significance of sensory specific intervention on balance in Type II Peripheral diabetic neuropathy individual	International journal of health sciences and research 2019	(n=30)	50-65/ Both Genders	Exercises: Pain, Touch, Proprioception, Visual and vestibular stimulation	The study concluded that sensory specific balance exercises are more effective in making the neuropathic individuals more stable
<b>Ibrahim et al<sup>26</sup></b>	Effects of Kinesiotape VS Resistive Exercises on Dorsiflexors Functional Performance in Diabetic Peripheral Neuropathy	Medical journal of Cairo University 2020	(n=40)	50-60/ Both Genders	Parameters: Muscle strength, Functional performance.	The present study concluded that both resistive exercises and KinesioTM tape improved strength and patients' functional performance in DN.
<b>Ghomian et al<sup>15</sup></b>	Rocker outsole shoe is not a threat to postural stability in patients with diabetic neuropathy	SAGE Journals 2016	(n=17)	49.29 ± 7.48 years/ Both Genders	Motor Control test: Center of force displacement, Response strength scale, Response latency.	The particular study has concluded that the Rocker shoe is used to protect the insensate foot and results show that the shoe doesn't negatively impact on the postural stability in patients with diabetic neuropathy.
<b>Bernard-Demanze et al<sup>31</sup></b>	Can tactile plantar stimulation improve postural control of persons with superficial plantar sensory deficit?	Aging Clinical and Experimental Research 2008	(n=30)	30.3±6, 64.2±9/ Both Genders	Analysis: Sway area, CoP mean velocity and mean RMS	The Findings of this study conclude that application of tactile plantar stimulation may compensate a loss of superficial plantar sensitivity.
<b>Hijmans et al<sup>17</sup></b>	Effects of vibrating insoles on standing balance in diabetic neuropathy	Journal of Rehabilitation Research & Development 45 2008	Disabled (n=17) nondisabled (n=15)	40-60/ Both Genders	Mean velocity of the Center of Pressure displacements in Millimetres per second, Root-Mean-Square of the Anteroposterior	The study concludes that Random vibrations applied to the plantar surface of the feet improved balance only when attention was distracted.

Continued.

Author	Title	Name of journal and year of publication	Sample size	Age/ Gender	Outcome measures	Conclusion/ Result
					8 and Mediolateral COP Velocity.	
<b>Najafi<sup>18</sup></b>	Using Plantar Electrical Stimulation to Improve Postural Balance and Plantar Sensation Among Patients with Diabetic Peripheral Neuropathy: A Randomized Double Blinded Study	Journal of Diabetes Science and Technology 2017	(n=28)	57.8 ± 10.2/ Male	Parameters: FES -1 Questionnaire (Fear of falling), Balance, Gait.	The research concludes that the effects seen with the plantar electrical stimulation system offers the potential for significant clinical benefit, with very low risk.
<b>El-Wishy et al<sup>25</sup></b>	Effect of Proprioceptive Training Program on Balance in Patients with Diabetic Neuropathy: A controlled randomized study	Bull. Fac. Ph. Th. Cairo Univ., Vol. 17 2012	(n=28)	35-50/ Both Genders	Analysis: overall stability index; anterior–posterior stability index, medial–lateral stability index and Berg balance scale.	The research concludes that Proprioceptive training along with conventional physiotherapy was more effective than conventional physiotherapy alone in improving functional balance and reducing balance indices in diabetic neuropathy
<b>Ahmad et al<sup>21</sup></b>	Effect of sensorimotor training on balance measures and proprioception among middle and older age adults with diabetic peripheral neuropathy	Gait and Posture (74) 2019	(n=37)	Intervention : 52.87 ± 4.58 to 66.75 ± 4.15, Control G: 51.75 ± 5.7 to 64.77 ± 4.6/ Both Genders	Measures: Functional reach test, Time up and go, One leg Stance, Postural assessment, Proprioception.	It is concluded that, sensorimotor training improves static and dynamic balance measures. Proprioception shows similar improvement in both age groups.
<b>Thakral et al<sup>19</sup></b>	Electrical Stimulation as an Adjunctive Treatment of Painful and Sensory Diabetic Neuropathy	Journal of Diabetes Science and Technology 2013	(n=476)	18-87/ Both Genders	Measures: Pain VAS, Paresthesia, Numbness, Burning sensations, Sleep disturbance, Vibration perception, Daytime pain, night-time pain, Neuropathic Symptom VAS,	The research concludes that the Electrical stimulation is an effective alternative and adjunctive therapy to current interventions of Diabetic neuropathy for sensory and pain neuropathy.

Continued.

Author	Title	Name of journal and year of publication	Sample size	Age/ Gender	Outcome measures	Conclusion/ Result
<b>Yümin et al<sup>29</sup></b>	The effect of foot plantar massage on balance and functional reach in patients with type II diabetes	An International Journal of Physical Therapy 2017	(n=38)	>_ 40/ Both genders	Measures: Time up and go test, One-Leg standing test, Functional Reach test.	This study concluded that plantar massage provides significant gains in balance, functional mobility and reach immediately after the intervention.
<b>Paton et al<sup>14</sup></b>	Getting the right balance: insole design alters the static balance of people with diabetes and neuropathy	Journal of Foot and Ankle Research 2016	(n=50)	Not given	Measures: Standing Balance, Perceived Stability, Step Reaction Time.	The particular study conclude that Insoles have an effect on Static Balance but not on Stepping Reaction time and is also independent of neuropathy severity.
<b>Priplata et al<sup>20</sup></b>	Noise-Enhanced Balance Control in Patients with Diabetes and Patients with Stroke	Annals of Neurology 2006	(n=42)	38-81 for Diabetes and 31-90 for stroke / Both Genders	Five traditional sway parameters were computed: the mean stabilogram radius (measured in millimetres), the area swept by the stabilogram over time (mm <sup>2</sup> ), the maximum radius of sway (mm), and the range of the AP and ML excursions (mm), respectively	This study concludes that noise-based devices can provide benefit to patients with sensorimotor deficits that are of a peripheral origin and also reduce postural sway. (diabetic neuropathy).
<b>Horstink et al<sup>30</sup></b>	Effects of offloading devices on static and dynamic balance in patients with diabetic peripheral neuropathy: A systematic review	Reviews in Endocrine and Metabolic Disorders 2021	(n=160)	22-71/ Both Genders	Measure: Static Balance and Dynamic Balance.	The study concluded that the offloading device shows negative effect on the static balance control and doesn't show any evidence of negative effect on dynamic Balance control.
<b>Cham et al<sup>22</sup></b>	Effects of vibro-medical insoles with and without vibrations on balance control in diabetic patients with	Journal of Biomechanics 2020	(n=20)	40-60/ Both Genders	Center of Pressure, Standard Deviation (Anteroposterior, Mediolateral)	The Particular study Concludes that the Vibro-Medical Insoles improve Patients Balance control.

Continued.

Author	Title	Name of journal and year of publication	Sample size	Age/ Gender	Outcome measures	Conclusion/ Result
	mild-to-moderate peripheral neuropathy					
<b>Cham et al<sup>28</sup></b>	The clinical and biomechanical effects of subthreshold random noise on the plantar surface of the foot in diabetic patients and elder people: A systematic review	The International Society for Prosthetics and Orthotics 2016	(n=337)	25-84/ Both Genders	Balance stability, Spatial Gait Parameters, Gait variability, VPT, Balance Control, Postural sway, Fine touch sensitivity, Vibrotactile detection threshold.	The conclusion of the study was that the subthreshold random noise on the plantar surface of the foot improved balance and sensation in the Diabetic Patients and the elderly people.
<b>Cham et al<sup>16</sup></b>	The Effects of a Vibro-Medical Insole on Sensation and Plantar Pressure Distribution in Diabetic Patients with Mild-to-Moderate Peripheral Neuropathy	Clinical Biomechanics 2018	(n=20)	40-60/ Both Genders	Shoe mean pressure, Vibro medical insole with random noise mean pressure, Vibro-medical insole without random noise mean pressure.	The Results obtained from the study concluded that vibro-medical insole can alter the peak plantar pressure and random noise can improve pressure sensation in diabetic patients.
<b>Cloutier et al<sup>23</sup></b>	Prolonged Mechanical Noise Restores Tactile Sense in Diabetic Neuropathic Patients	The International Journal of Lower Extremity Wounds 2009	(n=20)	21-80/ Both Genders	Vibration perception threshold	The Conclusion of this study is that Prolong application of mechanical noise in can cause improvement in the nerve function of diabetic neuropathy patients

## DISCUSSION

The aim of this review was to highlight the sensory stimulation interventions effects on the balance and postural control. The systematic review has shown that among the stated outcome measures Berg balance scale, Time up and Go, VAS, fear of falling, proprioception and postural sway are the primary studies used for the assessment of the balance and postural control. The 18 studies related to the effects of sensory stimulation on balance and postural control imply that in Kinesiotaping the particular stimuli apply a skin stretch force which provides an additional sensory input rather than a fixed spatial reference frame enhancing the detection of movement, instead of providing a direct stabilizing torque. Kinesiotaping with resistive exercise have also shown a remarkable improvement in muscle strength and functional performance. Whereas in case of sensory specific exercises the somatosensory input can increase the

sensitivity of the receptors by improving balance. Adding the visual, vestibular inputs and altering the support surfaces forced the participants to regulate balance. Proprioceptive training can produce swaying movements by firing the cutaneous mechanoreceptors in the foot. In proprioceptive training the old age group shows less improvement in static balance as compared to middle age group due to the physiological factors of ageing, such as the difference in the presentation of muscular power, reduced neuromuscular control, and increased severity of diabetic neuropathy with increasing age.

The Rockers outsole shoes are indicated either for precaution of metatarsal head ulcers related to diabetic neuropathy. The negative heel rocker sole within which the height of the outsole beneath the heel is that the same as, or lesser than the height beneath the ball of the foot, shifts weight-bearing forces to the foot and midfoot. It does not affect the Posture negatively and is prescribed for

foot ulceration. Softness of insole may compromise the stability as multiple contact areas causes decreased pressure, decrease in somatosensory feedback, causing decrease in Balance. Textured covers decrease negative effects of insoles on balance. The textured surfaces create focal points of skin stretch and indentation pressure to generate increased SAI and SAI afferent firing. Quiet standing provides the stable indentation stimulus at the fundamental position required for afferent firing. On the other hand, Vibro-medical insoles increases local pressure due to vibratory motors. The longitudinal arch support and the metatarsal pad, the material, thickness, and stiffness of the insole may also affect the balance. In a recent study the vibrating insoles state that the improvement in tactile sensation was present only when SR was active and that the therapeutic effects diminished once the SR stimulation was removed. Hence, long term application of this technique may conclude in improvement in tactile perception.

Recent study stated that decrease in RMS for CoP motions in ML axis leads to increases in patient sensitivity to data within the ML axis. Thus, the postural sway in the ML direction that our subjects exhibited after training indicate higher balance performance. In case of interaction between the vibration and attention there is decrease in COP velocity within the AP direction and not the ML direction. One Explanation is that COP velocity within the AP direction was comparatively more influenced by the added ADT (without vibration) than within the ML direction. A second explanation can be that plantar cutaneous mechanoreceptors play a more important role in the control of COP within the AP direction.

Plantar electrical stimulation has shown improvement in plantar skin perfusion which explains the recovery of plantar sensations. Diminished local blood flow will initiate oxidative stress and the release of component that impede the normal passage of neurological signals. Bosi and co-authors stated decrease in vibration perception threshold and a rise in monofilament detection when electrical stimulation treatment provided. A specific improvement in symptoms of paresthesias and numbness with electrical stimulation were noticed. Plantar massages on the other hand once a week were given for 10 weeks to one group and other group was given Relaxation exercise, the authors discovered that tactile massage and relaxation exercises caused an increase in the subjects' quality of life.

Recent studies have stated that mechanical noise causes little changes in strain on the receptor membrane that translate to little fluctuations in receptor transmembrane potentials through changes in ion permeability. Because the membrane part depolarizes, the potential of the neuron is brought nearer to the brink for firing an action potential within the presence of a weak signal. It effectively becomes supersensitive to extra mechanical stimulation or input. Similarly, the subthreshold random noise would affect the permeability of ion channels by directly stimulating the nerve receptor ending such as muscle

spindle. According to the gate-control theory of pain, the impulses transmitted through the large fibers incline to be blocked in the spinal cord. The transmission of impulses by the small fibers is more accelerated.

## CONCLUSION

Based on our analysis results, most of the study stated that vibration, plantar massages, Kinesiotaping, rocker shoe, Vibromedical insole, conventional exercises with proprioception stimulation, mechanical noise have shown significant difference on balance and postural control. Whereas, offloading devices did not show any remarkable variance. The currently existing studies require a clear recommendation on whether which intervention is more effective. Thus, longer duration studies are required to improve balance and postural control in diabetic neuropathy.

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