

Original Research

The Influence of Elastic Taping on Dynamic Muscular Control (Dynamic Control Ratio) Evertor-Invertor Ankle in Type 2 Diabetes Mellitus Male with Complications of Peripheral Neuropathy

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ABSTRACT

Background: Type 2 Diabetes Mellitus (DM) with Peripheral Neuropathy often have impaired control of muscle strength that increases the risk of fall. Elastic taping (ET) is a special elastic band that can stretch up to 140% and could facilitate muscle contraction.

Aim: To prove the influence of ET on the dynamic muscular control balance between evertor and invertor muscles of the ankle in type 2 DM male with peripheral neuropathy.

Material and method: This study used a pre-post one grup study, with 10 type 2 DM male with peripheral neuropathy. All subjects were examined for ankle evertor-invertor dynamic control ratio (DCR) with isokinetic dynamometer at 60⁰/sec and 120⁰/sec before elastic taping (ET), 30 minutes after ET, at the third day of ET application and 3 days after ET was released. Elastic taping was applied with functional techniques on the both ankles.

Result: There were no significant differences between with and without the application of KT in the ankle evertor-invertor DCR in both side. The *p value* were same in both sides, at 60⁰/sec after 30 minute ET (*p*=0.72), at the third day of ET application (*p*=0,24), 3 days after released ET (*p*=0,88) and at 120⁰/sec after 30 minute ET (*p*=0,17).

Conclusion: Elastic taping did not improve the ankle evertor-invertor DCR in type 2 DM male patients with peripheral neuropathy.

Keywords: *elastic taping, dynamic control ratio, DCR, ankle evertor-invertor, diabetes mellitus, DM, peripheral neuropathy.*

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Introduction

The most frequent complication of type 2 diabetes mellitus (DM) is sensory motor peripheral neuropathy that is symmetrical, length dependent, and is caused by metabolic and microvascular alterations due to hyperglycemia and other cardiovascular risk covariates. The prevalence of diabetic peripheral neuropathy (DPN) is thought to be around 50% and the prevalence increases along with longer duration of the disease and poor glucose control. In type 2 DM, peripheral neuropathy can occur before the diagnosis is established, but the risk of developing it increased after 3 years from onset of DM.¹⁻³ DPN manifestations are weakness, muscle atrophy especially at the distal muscles (lower limbs and legs), and impaired dynamic muscular control. It can increase the risk of foot ulcers and risk of falling due to balance disturbance when walking.^{4,5}

The management of these impairment include muscle strengthening exercise, muscles endurance exercise, aerobic exercise and also balance exercises, but these exercises need time and patient compliance.⁶ The study from Yam *et al* (2019) showed that elastic taping could improve lower limbs muscles strength in individuals with chronic musculoskeletal disease and individuals who experiences muscle fatigue.⁷

Elastic taping (ET) is an adhesive tape that can stretch up to 140% of its original length, and is widely used in musculoskeletal disorders. The advantages of ET is, it can support the joint and tissues without restricting any structure around the joint and also has minimal side effect, therefore it is more tolerable for patients. Elastic tapping can facilitate muscle contractions when applied from

the origin of the muscle to its insertion point. One of the proposed mechanisms is that recoiling force from the ET may be transmitted to the fascia and helps muscle contraction by increasing the excitability of the motor unit and the muscle spindle reflexes.⁷⁻⁹

This study aims to determine the influence of elastic taping on dynamic muscular control through examining the dynamic control ratio (DCR) of the ankle evertor-invertor muscles in type 2 DM male patients with peripheral neuropathy complications. It was hypothesized that using ET on the ankle would improve DCR of the ankle evertor-invertor muscles in type 2 DM male with peripheral neuropathy.

Material and Methods

This study is an experimental design with pre-post one group study, on diabetic patients with peripheral neuropathy. The subjects of this study were 10 male patients from Endocrinology Outpatient Clinic of Dr. Soetomo General Hospital. Inclusion criteria were male 35 until 50 years old, had type 2 DM with peripheral neuropathy (screened using Michigan Neuropathy Symptoms Instrument (MNSI) score), good cognitive function, and willing to be study subject and follow study protocol, also had signed the informed consent. Exclusion criteria were hypersensitive to ET, history of cardiac disease, skin disorder that could restricting an elastic taping application, limitation of ankle range of motion, ankle pain (Wong Baker Face Scale > 4), injury of the muscles or ligament less than 2 weeks, unstable fracture of the lower limb, and weakness of the lower limb that was not caused by DPN.

Subjects were taped with functional technique, used usually for lateral ankle sprain, in both ankle. This study used *Leukotape® K 5* cm x 5 cm with “I” and “Y” strip. Each subject’s foot was placed in relaxed position while they sat on a chair with the ankle in slight plantar flexion. The first strip of tape was placed from the anterior midfoot, stretched approximately to 120% of its maximal length and attached just below the *anterior tibial tuberosity* over the *tibialis anterior muscle*. The second strip began just above the medial malleolus and wrap around the heel like a stirrup, attaching just lateral to the first strip of tape. The third strip stretched to 140% of its maximal length and attached across the anterior ankle, covering both the medial and lateral malleolus. Finally, the fourth strip originated at the arch and stretched slightly, measuring 4-6 inches above both the medial and lateral malleolus.

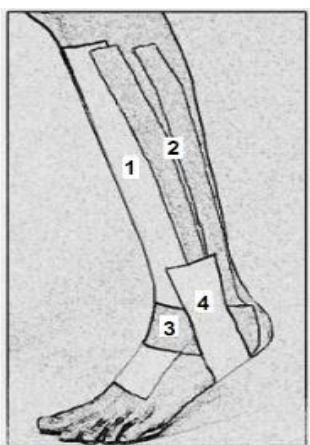


Figure 1. Elastic taping application method.

The DCR of ankle evertor-invertor measurement was done by calculating the reciprocal group muscles strength ratio. It described the peak torque ratio between eccentric contraction of evertor muscles and concentric contraction of invertor muscles of the ankle ($EV_{ECC} : INV_{CON}$) using an isokinetic dynamometer (*Cybex NORM™ CSMI USA*)

with angular velocity 60° per second and 120° per second. The DCR of ankle evertor-invertor was assessed before the application of ET, 30 minutes after application of ET, the third day of application of ET and three days after ET was released.

The independent variable was the elastic taping procedure, and the dependent variable was DCR of ankle evertor-invertor. Data normality was confirmed using the Kolmogorov-Smirnov test. Results were evaluated for statistical significance ($p < 0.05$) using paired t-test (parametric) or Wilcoxon Signed Ranks test (non-parametric). All subjects had signed the informed consent form and the study was approved by the ethics committee in Dr. Soetomo General Hospital.



Figure 2. Isokinetic dynamometer position

Result

All subject followed the study protocol from the start to the end while still consuming antidiabetic, antihypertension, antidyslipidemia or other oral medications routinely. There were no adverse events reported with the ET application. The mean age of the subjects was 47 ± 3.53 years old. The mean duration of diagnosed with DM (DM) was 4.3 ± 3.43 years. Nine subjects (90%) were at the stage of possible diabetic polyneuropathy (DPN) with Michigan Neuropathy Symptoms Instrument (MNSI)

scores approaching the minimum value threshold of peripheral neuropathy diagnosis. Characteristic of the subjects were displayed in table 1.

There were improvements found on ankle evertor-invertor DCR after ET application (table 2). However, there were no significant

difference found in DCR value of the ankle evertor-invertor in both sides, compared before ET application, 30 minutes after ET application, on the third day of ET application, and 3 days after ET was released (See table 3 and table 4).

Table 1. Demographic Data

	N	Min	Max	Mean±SD
Age (years)	10	40	50	47 ± 3.53
Sex (%)				
- Male	10 (100)			
Body height (cm)	10	157	170	164.7 ± 4.62
Body weight (kg)	10	47	90	69 ± 9.58
BMI (kg/m ²)	10	21.3	29.8	25.67 ± 3.03
Duration of DM (years)	10	1	11	4.3 ± 3.43
MNSI score	10	2.5	7	3.55 ± 1.44
Neuropathy severity (%)				
- Possible DPN	6 (60)			
- Probable DPN	1 (10)			
- Confirmed DPN	3 (30)			
Comorbidity (%)				
- Smoking	1(10)			
- Dyslipidemia	3(30)			
- Hypertension	6(60)			
Neurotropic consumption (%)	2(20)			
Metabolic syndrome (%)	7(70)			
Sedentary life style (%)	8(80)			

Table 2. DCR mean value of the ankle

	DCR pre ET (Mean±SD)	DCR 30 minute (Mean±SD)	DCR day 3 rd (Mean±SD)	DCR ET released (Mean±SD)
Right ankle				
60°	- 1.47 ± 0.81	- 1.34 ± 0.79	- 1.20 ± 0.63	- 1.50 ± 0.67
120°	- 1.54 ± 1.41	- 2.11 ± 1.53	- 1.43 ± 0.43	- 1.49 ± 0.50
Left ankle				
60°	- 1.47 ± 0.81	- 1.34 ± 0.79	- 1.20 ± 0.63	- 1.50 ± 0.67
120°	- 1.55 ± 1.41	- 2.11 ± 1.54	- 1.43 ± 0.43	- 1.49 ± 0.51

DCR : Dynamic Control Ratio; SD : standard deviation

Discussion

The present study investigated the influence of elastic taping (ET) in dynamic muscular control of ankle in type 2 DM with complication of peripheral neuropathy. Age of the subjects were limited since the increase of

the age will cause changes in muscle fiber composition and decrease active tissue that may lead to decreasing physiological ability such as decreases of muscles strength and velocity. Decreases of muscle strength and muscle mass occurs gradually starting at age 30 years, and

decreases further after the age of 60 years, which in the lower limb commonly occurred in the knee extensor muscles and ankle evertor muscles. Muscle strength and muscle motor control are influenced by several things including gender, age, and obesity. In women, motor control occur slower and muscle endurance thresholds earlier, making fatigue easier. The body height and body weight of

subjects did not correlate directly to muscle strength, but the overload of body mass index (BMI) can affect the results of this study. Individuals with high fat mass, will experience declining muscle strength gradually relative to their body size. In turn, this may expose obese adults to more risks of suffering from neuromuscular declines, and consequently being injured.^{10,11}

Table 3. Comparison of DCR mean value before application ET, 30 minute after application, day 3rd of the application of ET, 3 days after ET released in both ankle (velocity 60⁰/second)

	Right ankle		Left ankle	
	Mean±SD	p	Mean±SD	p
DCR 60 pre ET	- 1.47 ± 0.81	0.72	- 1.47 ± 0.81	0.72
DCR 60 30 minute post ET	- 1.34 ± 0.79		- 1.34 ± 0.79	
DCR 60 pre ET	- 1.47 ± 0.81	0.24	- 1.47 ± 0.81	0.24
DCR 60 day 3 rd ET	- 1.20 ± 0.63		- 1.20 ± 0.63	
DCR 60 pre ET	- 1.47 ± 0.81	0.88	- 1.47 ± 0.81	0.88
DCR 60 3 days of released ET	- 1.50 ± 0.67		- 1.50 ± 0.67	
DCR 60 30 minute after ET	- 1.34 ± 0.79	0.96	- 1.34 ± 0.79	0.96
DCR 60 day 3 rd ET	- 1.20 ± 0.63		- 1.20 ± 0.63	
DCR 60 30 minute after ET	- 1.34 ± 0.79	0.44	- 1.34 ± 0.79	0.44
DCR 60 3 days of released ET	- 1.50 ± 0.67		- 1.50 ± 0.67	
DCR 60 day 3 rd ET	- 1.20 ± 0.63	0.58	- 1.20 ± 0.63	0.58
DCR 60 3 days of released ET	- 1.50 ± 0.67		- 1.50 ± 0.67	

DCR : Dynamic Control Ratio; ET : elastic taping; SD : standard deviation

Table 4. Comparison of DCR mean value before application ET, 30 minute after application, day 3rd of the application of ET, 3 days after ET released in both ankle (velocity 120⁰/second)

	Right ankle		Left ankle	
	Mean±SD	p	Mean±SD	p
DCR 120 pre ET	- 1.54 ± 1.41	0.17	- 1.55 ± 1.41	0.17
DCR 120 30 minute post ET	- 2.11 ± 1.53		- 2.11 ± 1.54	
DCR 120 pre ET	- 1.54 ± 1.41	0.88	- 1.55 ± 1.41	0.88
DCR 120 day 3 rd ET	- 1.43 ± 0.43		- 1.43 ± 0.43	
DCR 120 pre ET	- 1.54 ± 1.41	0.51	- 1.55 ± 1.41	0.51
DCR 120 3 days of released ET	- 1.49 ± 0.50		- 1.49 ± 0.51	
DCR 120 30 minute after ET	- 2.11 ± 1.53	0.24	- 2.11 ± 1.54	0.24
DCR 120 day 3 rd ET	- 1.43 ± 0.43		- 1.43 ± 0.43	
DCR 120 30 minute after ET	- 2.11 ± 1.53	0.33	- 2.11 ± 1.54	0.33
DCR 120 3 days of released ET	- 1.49 ± 0.50		- 1.49 ± 0.51	
DCR 120 day 3 rd ET	- 1.43 ± 0.43	0.45	- 1.43 ± 0.43	0.45
DCR 120 3 days of released ET	- 1.49 ± 0.50		- 1.49 ± 0.51	

DCR : Dynamic Control Ratio; ET : elastic taping; SD : standard deviation

The mean duration of DM from the time of diagnosis in this study was four years, so there were no symptoms of peripheral

neuropathy. Most of the subjects were at the stage of possible DPN with Michigan Neuropathy Symptoms Instrument (MNSI)

scores. This condition is in accordance with studies from Nisar *et al* (2015) and Bril *et al* (2018) that explained the incidence of peripheral neuropathy in type 2 DM could occur before the diagnosis of DM is established, but the risk increases after three years.^{3,12} Studies from Andersen *et al* (2004) suggest that 14% of type 2 DM patients with or without peripheral neuropathy have decreased muscle strength in ankle flexor and extensor muscles.⁵ Bokan (2011) showed that the incidence of muscle weakness in DPN is progressive, irreversible and found in patients who were diagnosed with type 2 DM for more than 10 years and its related with the severity of peripheral neuropathy.¹³

Comorbidities can influence the onset and increase the level of DPN severity in type 2 DM. Papanas *et al* (2018) showed that there are several risk factor that can influence the occurrence of peripheral neuropathy in type 2 DM such as hypertension, dyslipidemia and smoking.¹⁴ The neurotropic drug effects in this study could not be evaluated because the subjects did not consume routinely, but another study showed that vitamin B12 with oral administration is not associated with improvement in clinical symptoms or nerve conduction studies.¹⁵ Metabolic syndrome can disrupt the regeneration process of muscle integrity due to chronic inflammation and infiltration of fat into the muscles¹⁶. Sedentary lifestyle also can affect the muscles by increased muscle protein degradation, its conditions can cause muscle atrophy¹⁶. Most of the subjects in this study had both condition, so the results obtained in this study could be influenced by those things that had occurred before the diagnosis of DM was established.

All subjects in this study were treated with application of elastic taping in both ankle,

with facilitation techniques on the dorsiflexor and evertor ankle muscles. Measurement of the DCR of the ankle evertor–invertor muscle is performed before the elastic taping application, 30 minutes of ET application, on the third day of ET application and 3 days after ET was released. Subjects were asked to use a shoes, to reduce possibility of ankle pain during examination. After ET was applied, subjects were asked to wait until 30 minute in sitting position and were provided with education related to activity restrictions that can cause the ankle muscles fatigue.

All value of ankle evertor-invertor DPN in this study have an average value of more than one, which means that there is muscles imbalance between ankle evertor and invertor muscles in patients with DPN. Previous studies have explained that ankle invertor muscle is stronger than evertor muscle and the isokinetic value of evertor-invertor ratio is always less than one in healthy individuals. The average ratio of evertor-invertor muscle strength (EV_{ECC} / INV_{CON}) is an important indicator of the possibility of ankle inversion trauma in patients with type 2 DM with peripheral neuropathy.^{17,18} The result of this study are in accordance with the study of Parasoglou *et al* (2017), which explained that in type 2 DM with peripheral neuropathy patients, there is a significant decrease in skeletal muscle function due to loss of motor axons, and many reported on the intrinsic muscles and ankle dorsiflexor muscles.¹⁹ Muscle atrophy will cause decrease of muscle effort (force) and an extended time to reach the peak force. These study results are also in accordance with study of Almurthi *et al* (2016) about lower limb muscles performance in type 2 DM patients stating that in patients with type 2 DM, with or without peripheral neuropathy, there are significant reduction in

proximal and distal muscle strength and a proximal but not distal reduction in muscle volume.⁴ Andersen *et al* (2004) also showed that in patients with type 2 DM with peripheral neuropathy, there are a significant reduction in the maximum strength of the knee and ankle muscles (knee flexor muscles, ankle flexor and extensor muscles) and its directly proportional to the severity of neuropathy, but there is no relationship between degree of nephropathy, retinopathy or other metabolic complications due to DM.⁵

The ankle evtor-invertor ankle DCR in this study showed that in 30 minutes after ET was applied, there was a decrease of DCR mean values in right and left ankle. In the third day of ET application, the mean values of DCR was still decreased, but they become higher after ET was released. The changes in DCR value indicates that after ET application, the peak torque of evtor muscle when performing eccentric contraction and the peak torque of invertor muscle when performing concentric contraction is better than without ET application. This result is also supported by a meta-analysis study from Yam *et al* (2019) that showed ET application could improve the lower limbs muscle strength, hop test and vertical jump performances in individual with muscle fatigue and in chronic musculoskeletal disease.⁷

The result of DCR values in this study were not statistically significant. It might be influenced by several factors such as the duration of type 2 DM and the severity of neuropathy that could affect the muscle performances. In this study, only two subjects who had type 2 DM for more than 10 years and only three subjects who had confirmed diagnosis of DPN. This condition can influence result of this study as explained by the study from Bokan (2011) stating that muscle

weakness and advanced complications in the ankle and legs in type 2 DM with peripheral neuropathy occurred after 10 years or longer (15 years).¹³ The different methods of ET application also could affect the result of this research. The application of ET used was a taping application method for lateral ankle sprain. In lateral ankle sprain, there is disruption in the tibialis anterior muscles and the peroneal muscles. However, in type 2 DM with peripheral neuropathy, the muscles weakness not only in both muscles, but also in intrinsic muscles and plantarflexor muscles of the ankle.¹⁸

Muscle fatigue can also affect the peak torque value of isokinetic examination. This study was conducted in three meetings and there was a pause between meetings, but no active control to prevent activities that can cause muscle fatigue, especially for ankle muscles. The subjects only have been given an education for limiting activities that can induce muscle fatigue.

In the same context, studies from Hua Lin and Hung Wu (2004) found that there was no significant effect of ET application on ankle muscles peak torque in healthy young adult, but there was increased peak torque in the evtor ankle muscles compared to before ET was applied.²⁰ The elastic taping was given to the anterior tibial muscle and the peroneal muscle group, then the isokinetic values of dorsiflexion-plantarflexion and eversion of the ankle were measured. Another study from Hwan Lee *et al* (2011) explained that there was no significant difference between the application of ET with no application of ET on the conduction velocity of motor neuron in the median, ulnar and radial nerves.²¹ Additionally, Alexander *et al* (2008) proved that if the taping length is shortened according to the length of

the muscle, then the length of the muscle will also shorten, and the muscle spindles in the intrafusal fibers will decrease in stress.²¹ Shortening of muscle length will result in reduced average release of muscle spindle pressure, so that the nature of motor neurons to receive stimulation is reduced. This process results in a significant decrease of the muscle activity. Another explanation of it is α motor neurons which supply the skeletal muscle and γ motor neurons that supply the muscle spindle are activated simultaneously (alpha-gamma coactivation). The contraction of muscle spindle fibers results in the sensitization of Ia afferent and II afferent nerve fiber groups not to be reduced, but will be continuously maintained in easily stimulated state, so the motor neuron excitability also maintained at the same level. Muscle shortening that occurs when ET was applied, will also not changes the latency, amplitude, or conduction velocity of motor neurons due to the continuous input from afferent muscle spindle nerve fiber.²¹

The action mechanism of elastic taping in muscles is still unclear. The first probable mechanism, elastic taping can increase blood circulation in the application area. Second, elastic taping can reduce pain byway the gate control theory mechanism, through stimulation of the large diameter nerve fibers, so it can reduce muscle pain and increase the muscle strength. Third, elastic taping can increase muscle strength by improving the movement of fascia in muscle and increase muscle spindle reflexes, increase motor unit excitability and facilitate muscle contraction. The application of elastic taping can also increase the sensitivity of stretch reflex through activation of the primary endings of muscle spindles that are regulated through activation of efferent fibers.^{7,23}

Conclusion

This research indicates that elastic taping of ankle dorsiflexor and evertors in patients with type 2 DM with peripheral neuropathy did not demonstrate significant effects on the ankle evertor-invertor DCR. When the ankle was taped, the ankle evertor-invertor DCR showed no improvement, which was compared with those under untapped conditions before and after.

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