Original Research

Does Treadmill Training Improve Balance Function of Healthy Untrained Young Adult Male?

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Abstract

Background: Number of falls increase among elders and young adults prior to any cause. Occult balance disorder may become one of the morbidity factors that causes fall in young adults and eventually elders. One leg stance test reflects static balance function that might show occult balance disorder in healthy population. Closed eyes crossed arms one leg stance (CECAOLS) used to eliminate balance factors such as visual and arms sways that can elevate limit of stability (LOS). Treadmill used as a dynamic balance exercise with inclination and speed level as its' component to challenge the balance function.
Aim: to compare CECAOLS value in subjects with gradual increase of speed versus inclination in moderate intensity treadmill exercise.
Methods: Nineteen healthy young adults male with sedentary lifestyle aged from 26 to 37 years old were recruited. Nine people in inclination group, ten people in speed group. Treadmill exercise with moderate intensity (70% maximal heart rate), exercise duration was 30 minutes (5 minutes warming up, 20 minutes core exercise, 5 minutes cooling down), 3 times/week, for 4 weeks. Measurement of CECAOLS value were done prior to first exercise and after completion of exercise in 4th week.
Results: Significant increase of CECAOLS value at right leg inclination group with p=0.038. No significant increase of CECAOLS value in speed group ($p>0.05$).
Conclusion: Moderate intensity treadmill exercise with gradual inclination increase 30 minutes duration, 3 times/week, for 4 week was proven to increase CECAOLS value in young adult healthy untrained male.

Keywords: *closed eyes crossed arms one leg stance, CECAOLS, occult balance disorder, balance function, treadmill training, healthy adult male.*

Introduction

Number of falls among young adult at 20-45 years of age has reached 18% of population and gradually increased according to age, rising to 35% of 65 years old population. Balance disorder is one of the cause of mortality prior to fall.[1] Balance is influenced by neurological system: somatosensory, sensory-motor integration, motoric planning; also by musculoskeletal system: verticality, postural and movement control. Contextual system integrates all of those systems, such as environment, support surface, lighting, gravity, and physical characteristic.[2] One leg stance (OLS) test is a simple static balance measurement that is easy to apply with minimal equipment. One leg stance abnormality relates to frailty, dependency of daily living activities, and high risk of fall status.[3,4]

A brief observation of one leg stance test in Rehabilitation Medicine Outpatient Clinic on healthy young subjects aged 26-54 years old showed 78% of 57 subject had < 50 seconds OLS with eyes closed. This balance disturbance phenomenon of the young and productive age might contributes to 18% of falls in young age. Treadmill exercise is an aerobic training commonly used to improve gait function. There are two variables of treadmill exercise, which are inclination and speed. Steib et al showed perturbation using treadmill stimulates specific adaptation in dynamic balance control during ambulation. Treadmill creates constant challenge of postural control system during walking.[5] Pirouzi et al showed a significant increase of Berg Balance Score in healthy older adult population after treadmill exercise.[6] Shimada et al revealed there were increased value of functional reach test and OLS in older adult population after bilateral separated treadmill exercise. This showed an improvement of stability and mobility in upright position.[7] We found little evidence about OLS test in healthy young adult and there were no clear comparison between inclination and speed treadmill exercise.

Closed eyes crossed arms one leg stance test (CECAOLS) were proposed to eliminate visual control over balance, and provide an active, constant stimulation of proprioceptive sense especially in both legs due to decreasing limit of stability. We hypothesized that moderate intensity treadmill exercise with gradual increase of inclination and speed would significantly increase CECAOLS value, and we also hypothesized there would be significant difference of CECAOLS value between inclination group and speed group. The aim of this study is to compare CECAOLS test value before and after moderate intensity treadmill exercise with gradual speed increase and gradual inclination increase to young healthy adult untrained male.

Material and Methods

The design of this study was randomized pre-test and post-test group. Twenty young healthy males were recruited in the study. Subjects were randomized into two groups: inclination group and speed group. Inclusion criteria were healthy adults according to WHO guidelines, aged within 26-37 years old with body mass index (BMI) 18-22,9 kg/m^2, and signed the informed consent form. Participants were excluded if they had routine aerobic exercise at least 2 times per week, ischemic heart disease history, restrictive/obstructive respiratory tract disease history, neuromusculoskeletal disease history, systole blood pressure exceed 120 mmHg and diastole less than 60 mmHg, had vestibular and proprioseptive disturbance, and range of motion of both ankles for plantar flexion < 45° and dorsoflexion < 30°. This study wes approved ethically by ethical committee of Dr. Soetomo General Hospital Surabaya Indonesia with ethical approval number 0168/KEPK/IV/2018.

EN-Mill® 2007 Treadmill was used as walking exercise device in this study. Polar H10 heartbeat sensor was used for the heartrate sensor, installed at participants chest during exercise connected via bluetooth to smartphone application (Figure 1). Balke protocol used for Inclination group, and athlete led protocol was used for speed group. The duration for each session was 30 minutes with 5 minutes of warming up period, 20 minutes of core exercise and 5 minutes cooling down, frequency was 3 times per week for each group, the program lasted for 4 weeks straight.

All groups were tested for OLS test prior to exercise. Participants were asked to close both eyes, crossed their arms on their chest and raised one of his leg (CECAOLS). Stopwatch was used to measure the time the subject could stood on one leg. The test repeated for the contralateral leg. Normal value for the test is if participants stood more than 45 seconds (Figure 3). Inclination group was subjected to 3 km/h speed with gradual increase of inclination from 2,5%, 5%, 7,5%, 10%, 12,5%, 15%, 17,5%, 20%, 22%. The inclination was raised every 1 minute until the participant reached the target heart rate (70% maximum heart rate). The heart rate was recorded every minute during the exercise. Speed group was subjected with 5 km/h starting speed and increased 1 km/h every minute with 0% inclination until participants reached the target heart rate (70% maximum heart rate) (Figure 2). After 4 weeks of training, all participants were tested for CECAOLS.

Statistical analysis were measured using Saphiro-wilk, Independent sample test, Wilcoxon Signed Rank test in IBM SPSS statistic 23 system.

Result

This study was conducted for 4 weeks with 20 young healthy untrained male participants. All participants were divided into 2 groups. The participants were employees and resident medical doctors of Physical Medicine and Rehabilitation in Dr. Soetomo General Hospital Surabaya, ten were subjected into the inclination group, and ten in the speed group. There was one participant excluded from the inclination goup because of having an outlier value, leaving 9 participants remained at the inclination group and 19 participants in total. The demographic data normality was tested using saphiro-wilk test and showed normal distribution in both groups with p<0,05 (Table 1).

We used closed eyes crossed arms one leg stance test as a dependent variable. Variable characteristic measurement did not show normal distribution so we used non-parametric test. There were no significant difference of the CECAOLS mean value in inclination and speed groups (Table 2).We found significant increase only in inclination group using Wilcoxon Signed Ranks test with p value < 0,05 (Table 3).There were no significant statistical calculation in the difference (delta) of CECAOLS test in inclination and speed groups at all variables (Table 4).

Table 1.Demographic characteristic

	Groups	N	Mean ± SD	*p*
Age (years)	Inclination	9	31.33 ± 3.04	0.443
	Speed	10	32.3 ± 2.31	
Body weight (kg)	Inclination	9	64.11 ± 6.62	0.843
	Speed	10	64.80 ± 8.15	
Height (cm)	Inclination	9	169.22 ± 7.21	0.876
	Speed	10	168.7 ± 7.18	
BMI (kg/m^2)	Inclination	9	22.2 ± 1.14	0.492
	Speed	10	22.64 ± 1.54	

*Significant if p<0,05 using Independent sample T test

Table 2. Mean CECAOLS test value before training

	Groups	N	Mean (seconds)	SD	*p*
Closed eyes, crossed arms, Left, pre	Inclination	9	25,39	± 12,11	0,338
	Speed	10	34,44	± 25,78	
Closed eyes, crossed arms, Right, pre	Inclination	9	18,97	± 15,98	0,555
	Speed	10	24,51	± 23,02	

*Significant if *p-value*< 0,05 using Independent T test (based on positive ranks)

Table 3. CECAOLS test value in both groups before and after training

	CECAOLS test value (Left), pre versus post (second)	CECOLS test value (Right), pre versus post (second)
Inclination	0.515	0.038*
Speed	0.386	0.139

*Significant if p-value <0,05 with Wilcoxon Signed Ranks Test

Table 4. The Difference of CECAOLS test value in both groups

	Levene's Test for Equality of Variances		t-test for Equality of Means	
	F	Sig.	t	Sig. (2-tailed)
Delta Closed eyes, Crossed arms, Left	0,005	0,943	0,195	0,847
Delta Closed eyes, Crossed arms, Right	2,260	0,151	-0,243	0,811

*Sigificant if p-value< 0.05 with independent sample test

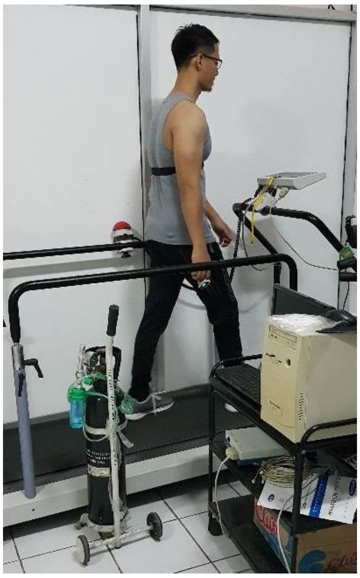

Figure 1. Inclination group participants using Polar H10 (Figure permissions had been approved by subject)

Figure 2. Speed group participants using Polar H10 (Figure permissions had been approved by subject)

Figure 3. One leg stance measurement (Figure permissions had been approved by subject

Discussion

The demographic characteristic had normal distribution showing homogenecity of age, weight, height, and BMI of participants in both groups (Table 1).There were no significant differences of CECAOLS in both groups using the right / dominant leg and left / non-dominant leg in baseline (Table 2). Our findings were in accordance with Muehlbauer et al who reported there was no significant difference of CECAOLS test results between non-dominant and dominant leg in healthy young adult.[8] There are findings that showed the dominant leg are activated at times of maintaining the stability without visual involvement faster. Proprioceptive feedback increased the muscles activation on maintaining balance through hip and ankle strategy of the dominant extremity.[9] The baseline of CECAOLS value was homogen in both groups (table 3).

In inclination treadmill exercise groups, CECAOLS increased significantly on the right leg, but not on the left leg, there were no significant difference of CECAOLS values when using the left leg. These reports support the initial hypothesis which was proposed in relation of postural verticality towards the leg dominancy reciprocal motor coordination which in our study was the right leg. Postural verticality depends on proprioceptive input, vestibular input, and vestibular-motor phenomenon (ocular and postural). Pirouzzi et al reported vestibular involvement in forward walking as one of human function.[6] Meanwhile, Bisdorf et al reported that verticality element will be achieved mostly using the proprioceptive organs. This evidence might be one of the reason for the improvement of balance after inclination treadmill training.[10] The dominant leg were the chosen leg to do functional activity, usual evaluation were by kicking or one leg hopping. Our study showed a significant improvement of the right leg CECAOLS value more than the left leg, this might be caused by the dominancy capacity created along the brain to bones, joints, muscles, skin to control movement, thus better stability. Reed et al reported that young adult commonly used the dominant leg for stability necessity more than mobility function[11].

Our study were in accordance with Leroux et al who reported that during inclination proprioceptive input were enrolled by the thalamus and cerebellum from various organs such as ankle, knee, hip joints, lumbosacral, vertebra body, anterior tibial, gastrocnemius, hamstring, quadriceps, iliopsoas, gluteus, and flexor-extensor trunk muscles.[12] Information given were about trunk orientation, inclination adaptation, position sense of lower extremity relative to the trunk and the treadmill. All of which were integrated to maintain balance. This also might be the reason during inclination progress, there were more muscles recruited than speed treadmill.[12] Barbieri et al reported that vibration stimulation in Achilles tendon induce backward tilting about 2,7° ± 0,8° with $p < 10^{-3}$.[13] This evidence concluded that vibration effect might stimulate static perturbation through the spontaneous frequency of lengthening-shortening of Achilles tendon. Meanwhile, treadmill exercise using inclination benefits the constant and active readjustment of Achilles tendon through the lengthening-shortening movement that will amplify the dynamic perturbation function.

Inclination walking with steady speed benefited from a more efficient energy usage compared with speed walking although there were more muscles recuited.[14] Postural adaptation during inclination training comes from the stimulation of the somatosensory input to corticospinal, reticulospinal, and vestibulospinal neurons, through the changes of neurons amplitude.[15]

Our study showed speed treadmill exercise group showed no improvement of CECAOLS value in both legs (table 3). Speed walking exercise caused the increasing of speed, stride length, cadence and decreased double limb support. Speed walking exercise affects the centre of gravity of the body (COG), centre of mass (COM), especially at lateral border of base of support (BOS) which will affect the limits of sway.[16] Our findings were in accordance with Goodworth et al who reported there was significant decrease of perturbation sensitivity the faster the walk / speed. The perception of stability were developed indirect to trunk movement in fast walking, however, the stability perception were significantly triggered by relative trunk movement that occurred between stable and unstable condition[17], which the condition was not available in our study. Horizontal translation that occur during speed treadmill generated the same amount of forces to both legs but each had different amplitude, the forces were results from muscles responses in individual toward the perturbation angle produced.[15] In our speed study group, there were no changes of inclination angle during treadmill exercise, therefore these statements might cause the unsignificant CECAOLS value in speed group.

Table 4 showed there were no significant difference of CECAOLS test in inclination and speed groups at all variables. However, the inclination group showed significant improvement than the speed group due to constant changes of COG that will stimulate proprioceptive sense. As for the speed walking exercise, the gradual speed changes creates movement pattern in the brain. Perturbation changes in 0° inclination angle will only stimulate the central nervous system to maintain the trunk in upright position unaffected by the perturbation so that forward horizontal translation did not need active readjustment. Disparate to speed, inclination angle change will evoke responses in corticospinal, reticulospinal, vestibulospinal neurons that will produce amplitude modulation changes and eventually result in more perturbation challenge.[15]

Movement controls are arranged inside the brain somatotopically. Constant stimulation of precentral gyrus/motoric cortex leads to coordinated recruitment toward intracortical synapse to corticospinal neurons resulting in regular motoric planning.[18] Central pattern generators (CPG) are capable of generating a rhythmic and patterned output from a tonic input, the pattern provides framework for motor neuron activation which coordinates muscles for stereotypic movements such as breathing, chewing and swimming.[19]

Human naturalization of walking shows that central nervous system regulates reflex excitability in a way that matches its functional requirements with respect to the walking phase, in particular regarding the stretch reflex response during human walking.[20] Walking automation is developed through elimination, correction, and external matters along the ages, consistent learning, and environment stimulation. Postural correction is a product of corticofugal neurons responses from Gaba-ergic interneurons.[15] Gomez-Pinilla et al reported that actively contracting muscles increase the brain derived neurotropic factor (BDNF) modulation, this play a role in inducing neuroplasticity and neuron growth. BDNF stimulates the motoric excitability network at the spinal cord, acetylcholine release in neuromuscular junction, neuron tenacity, synapse plasticity, and neural circuit development.[21,22]

Conclusion

There were significant increased value of CECAOLS after moderate intensity treadmill exercise with gradual inclination escalation, however there were no significant increase of CECAOLS value before and after treadmill exercise with gradual speed escalation, and also there were no significant difference (delta) of CECAOLS value between inclination and speed group after 4 weeks of treadmill training in young adult healthy untrained male.

Study limitation

There were no objective measurement or description about the habit, occupation or the usual physical activity of the participant, these variables might relate to the occult balance disorder. It is necessary to have the understanding of occult balance disturbances in normal individual because the occult balance disturbances might increase the potential risk of falling.

We suggest further study needed to be conducted about occult balance disturbance. The treadmill exercise particularly with gradual inclination increase is beneficial as balance exercise with frequency 3 times per week in 4 weeks straight to young adult healthy untrained male.

Acknowledgment

Author thanked all subjects who was willingly following all rules during research that greatly assisted the research.

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