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A comparison of treadmill and overground running on physical performance in sedentary individuals

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ABSTRACT

This study aimed to compare the effects between treadmill and overground running on lower extremity muscle strength, balance, and agility. Forty-six sedentary healthy participants with a mean age of 20.59±1.44 years were randomly allocated into treadmill, overground, or control groups. The participants in treadmill and overground groups completed 4 weeks of training sessions, while control group did not participate in any training. Results showed that there was a significant increase in lower extremity muscle strength and balance in both treadmill and overground groups (p-value<0.05), but only treadmill group showed a significant increase in agility (p-value=0.001) when compared with pre-intervention values. When comparing between treadmill and overground groups, there were no significant differences found in all parameters (p-value>0.05) after receiving intervention. Nevertheless, treadmill group tended to show more balance and agility than overground group. This was because treadmill group showed a significantly higher balance (posterolateral direction) and agility than control (p-value=0.017 and p-value=0.020, respectively), while overground group did not (p-value=0.069 and 0.196, respectively). Four weeks of both treadmill and overground running could improve physical performance. Interestingly, treadmill running might be a more beneficial training than overground running among sedentary healthy individuals.

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Introduction

At present, people tend to have more sedentary lifestyle, which includes prolonged sitting or sustained postures in any position for a long time. Previous studies reported that sedentary lifestyle has negative effects on person's health, including impairment to cardiovascular system(1) and musculoskeletal system(2). For this propose, the World Health Organization (WHO) suggested that people should have moderate intensity of physical activity for at least 150 minutes per week. Thus, the simple exercise as running is an interesting method to increase physical activity in general public.

Running is one type of physical activity or exercise in this trend, and it is also a basic skill in most sports. Statistics in 2016 showed that there were 18.2% of all people in Thailand who exercised by running(3). These statistics indicated that running is a popular choice for exercise in Thailand. Moreover, running is a low-cost exercise because it requires only a few pieces of equipment. Additionally, people can choose the location of running according to their convenience, such as a public park or stadium. People who cannot go to these places may choose to run on a treadmill that is located in a house or at a nearby fitness center instead. Running has many benefits and requires low-skill performance. Therefore, running is an appropriate exercise to reduce risk of disease and improve people's health(4, 5).

Previous studies reported that running could improve physical performance on musculoskeletal system includes an increase in muscle strength(6) and an improvement to the balance system(7). Nevertheless, overground running (OG) and treadmill running (TM) have differences in some aspects. Firstly, there were differences between OG and TM in biomechanical analysis, such as kinematic, and kinetic parameters(8, 9). Moreover, the people who undergo TM had to adjust their strategy of movement (e.g., cadence, and step length) when compared with OG. Lastly, many participants reported that they have to keep balance during running on a treadmill because of feeling unstable(10). Therefore, the OG and TM might demonstrate the difference effects on physical performance.

There were many studies that reported on the effect of running on the cardiovascular system with a training period of at least 6 weeks. To the author's knowledge, there were few studies that reported on the effect of running on other physical performance. Moreover, no study has compared the effects of training between TM and OG on physical performance before. Therefore, the aim of this study was to compare the effects between TM and OG training for 4 weeks on lower extremity muscle strength, balance, and agility.

Materials and methods

Participants

This study employed a randomised controlled trial. The population of this study was 46 sedentary healthy individuals of both males and females. The participants were randomised into three groups that included TM group, OG group, and control group. All of them were measured for baseline data and post-data again after 4 weeks of intervention. This study was approved by the ethics committee of Walailak University (WUEC-19-008-01). The sample size was calculated by the G*Power (version 3.1.9.4) from the relevant study(7), was set to 0.05, was set to 0.95, the effect size was equal to 1.665, and estimated 20% dropout rate.

Participants who were between the ages of 18-25 years old, had a body mass index (BMI) between 18.5-22.9 kg/m^2, had good cooperation, and able to follow instructions were included in this study. On the other hand, Participants who had at least a moderate intensity of physical activity (3 Metabolic Equivalents Task: METs) for more than 150 minutes per week, pain in the lower extremity or trunk, a recent history of trauma or fracture, underlying diseases such as cardiovascular disease, and vertigo were excluded from the study.

Procedure

Randomization

All participants signed an informed consent prior to participation in this study. Participants were randomly allocated into three groups (i.e., TM, OG, and control) using simple randomization.

Intervention

For intervention group, participants were trained during 12 sessions over a period of 4 weeks. The schedule of training was set at 2-4 sessions per week, and participants who were absent for 2 consecutive days of training session were excluded from the study. Before training, participants had to warm up with dynamically stretch the lower extremities through such as hip flexors, hip extensors, knee flexors, knee extensors, and ankle plantarflexors for 5 minutes, and cool down with statically stretch for 5 minutes after each training session. For TM, participants performed all training sessions on a treadmill (Lode: Valiant-17745 model). The intensity of training was increased progressively with each consecutive week. In the first week, participants ran at 2 kilometers for 20 minutes. In the second week, participants ran at 2.8 kilometers for 25 minutes. In the third week, participants ran at 3.6 kilometers for 30 minutes. In the last week, participants ran at 4.4 kilometers for 35 minutes(6). For OG, participants performed all training sessions on a standard 400-m oval running track. The intensity of training was the same as the treadmill group, and participants were asked to control intensity by time. For example, if they were slower than expected, they would be encouraged to run quickly.

For control group, participants were asked to perform their activities regularly during a period of 4 weeks, and they were asked to avoid any intense activities and sports during this period. After 4 weeks, the intensity of each participant's activities or sports in each week were inquired and recorded.

Assessments

To evaluate the effect on physical performance of the intervention, all outcome measures were assessed before and after 4 weeks of intervention.

Outcome measures

Lower extremity muscle strength

The lower extremities strength was measured by a hand-held dynamometer (HDD) (JTECH Commander Powertrack Muscle Dynamometer MMT: JT-AA104 model). This equipment had high intra- and inter-rater reliability (ICC=0.949-0.992)(11). The measurements included hip flexor, knee flexor, ankle dorsiflexor, and ankle plantarflexor strength. Hip flexors and knee flexors were conducted in a sitting position with hip and knee joints flexed to 90°. The HDD was placed at the anterior aspect above the knee 2 inches for hip flexors and at the posterior aspect above the heel 2 inches for knee flexors. Ankle dorsiflexors were conducted in a supine position with the ankle in a neutral position, and the HDD was placed at the metatarsophalangeal joint (MTPJ) of the dorsal aspect of the foot. Lastly, ankle plantarflexors were conducted in a prone position with the ankle in a neutral position, and the HDD was placed at the MTPJ of the plantar aspect of the foot(12). After that, participants exerted the maximum effort against the HDD for all muscle groups. Each muscle group was measured 2 times with a 1-minute rest between each contraction and between each muscle group to avoid fatigue. The maximum value for each of the muscle group was recorded.

Balance

Dynamic balance was measured by the modified Star Excursion Balance Test (mSEBT). This test had high intra- and inter-rater reliability (ICC=0.87-0.94)(13). There were three directions which consisted of the anterior, posteromedial, and posterolateral direction. Firstly, the testing leg was placed at the center of the grid line on the floor with three reach lines (in Y-shape), while both hands were maintained at the waist. The participants were allowed to practice 2 times, and then they were instructed to reach their leg as far as possible along each of the three lines, touch the line with their big toe, and return the reaching leg back to the center without swaying or displacing their hands from their waist(14). Each direction was measured 3 times with 15 seconds of rest between each reach and 2 minutes of rest between each direction. The average value for each direction was recorded.

Agility

Agility was measured by the Illinois agility test. This test had high intra-rater reliability (ICC=0.80-0.89)[15]. The length of the test was 10 meters, and the width was 5 meters. Four cones were placed as the starting, finishing, and two turning points, and another four cones were placed at the center of the area at 3.3 meters apart. Participants were instructed to run as fast as possible from the starting to the finishing point, where the time was started after the word "go" and stopped when the participants reached the finishing point. Between trials participants were instructed to avoid any contact with the cones or cross the cones. In this test, participants had to accelerate, decelerate, run in different angles, and turn in different directions[16]. This test was measured for two times, and the best value was recorded.

Statistical analysis

Baseline characteristics were summarised as mean and standard deviation (SD). The Shapiro-Wilk test was used to verify the normality of the data. One-way analysis of variance (ANOVA) was used to compare the baseline data between groups. Paired t-test was used to compare outcome variables at baseline with 4 weeks of intervention within a group. Since the randomised allocation did not confirm that the baseline characteristics would be the same between groups, analysis of covariance (ANCOVA) was performed. If ANCOVA detected the difference of outcome variables, the Bonferroni test would be performed to identify this difference between pairs. Outputs of the paired t-test and ANCOVA were reported as mean and adjusted mean with *p*-value. All data were analysed using the SPSS (version 17).

Results

One hundred potential participants were assessed for eligibility. Of these participants, 46 met the inclusion and exclusion criteria (14 males at 30.43%, and 32 females at 69.57%) and signed the informed consent. Sixteen participants were randomly allocated to TM group, 14 participants were randomly allocated to OG group, and another 16 participants were randomly allocated to control group.

Demographic and baseline characteristic data

The details of the demographic and baseline characteristics are shown in Table 1. The average age of the participants was 20.59±1.44 years old. The average BMI of the participants was 20.18±1.6 kg/m^2. The comparison of all variables is also shown in Table 1, and there were differences between groups in age and lower extremity muscle strength variables.

Comparison within a group

All of the parameters were normally distributed. In TM group, there was a significant increase in all lower extremity muscle strengths, all directions of balance, and agility (*p*-value<0.05) after training for 4 weeks when compared with pre-intervention values. For the OG group, there was a significant increase in all lower extremity muscle strengths and all directions of balance (*p*-value<0.05) after training for 4 weeks when compared with pre-intervention values, but no significant difference was found in agility (*p*-value=0.183). In contrast, no statistical differences were found in control group, except for balance in the anterior direction (Table 2).

Table 1 Demographic and baseline characteristic data, and comparison of the baseline data between all three groups (ANOVA)

Parameters		**All (n=46)**	**TM (n=12)**	**OG (n=14)**	**CON (n=16)**	***p*-value**
Gender [n(%) female)]		32 (69.57)	11 (68.75)	10 (71.43)	11 (68.75)	-
Age (yr)		20.59±1.44	20.38±1.45	19.79±1.19	21.5±1.15*†	0.002
Height (cm)		161.57±5.97	163.69±6.2	160.57±5.5	160.31±5.88	0.213
Weight (kg)		52.8±6.23	55.5±5.29	52.07±6.79	50.75±5.97	0.082
BMI (kg/m^2)		20.18±1.6	20.70±1.48	20.15±1.91	19.69±1.31	0.202
Leg length (cm)	Left	82.16±3.9	83.96±3.46	81.25±4.07	81.16±3.74	0.069
	Right	81.92±3.89	83.5±3.45	81.14±4.07	81.03±3.87	0.132
Hip flexor strength (lb)	Left	19.62±5.86	23.34±7.29	16.57±3.41*	18.56±3.87*	0.003
	Right	21±5.49	24.38±6.43	18.21±4.01*	20.06±3.84	0.004
Knee flexor strength (lb)	Left	20.37±6.72	24.22±8	17.18±2.8*	19.3±6.17	0.009
	Right	22.97±7.15	27.25±8.91	19.54±3.3*	21.69±5.68	0.006
Ankle dorsiflexor (lb)	Left	19.9±6.47	22.06±7.75	15.32±2.2*	21.75±5.76†	0.004
	Right	20.53±6.56	22.97±8.66	16.93±2.08*	21.25±5.59	0.033
Ankle plantarflexor (lb)	Left	31.77±12.34	36.47±15.35	24.61±5.99*	33.34±10.78	0.022
	Right	31.61±12.37	38.81±15.35	23.79±5.8*	31.25±9.04	0.002
Balance (cm)	A	63.23±5.38	63.79±4.71	64.03±4.49	61.98±6.68	0.519
	PM	63.92±9.96	62.49±8.73	60.32±9.41	68.5±10.38	0.059
	PL	76.22±7.4	76.13±8.06	75.49±6.53	76.94±7.84	0.871
Agility (s)		25.13±2.05	24.75±2.29	25.57±2.21	25.13±1.67	0.560

Note: All continuous parameters were reported in mean±SD; Gender parameter was reported in number (percentage). TM, treadmill; OG, overground; CON, control; A, anterior; PM, posteromedial; PL, posterolateral. *difference from TM (*p*-value<0.05); † difference from OG (*p*-value<0.05).

Table 2 Comparison of the parameters between pre-intervention and post-intervention of the three groups (paired t-test)

Parameters		Groups	Pre-intervention	Post-intervention	*p*-value
Hip flexor strength (lb)	Left	TM	23.34±7.29	28.97±6.19	<0.001*
		OG	16.57±3.41	27±6.12	<0.001*
		CON	18.56±3.87	18.31±3.42	0.745
	Right	TM	24.38±6.43	30.56±7.11	<0.001*
		OG	18.21±4.01	28.32±7.07	<0.001*
		CON	20.06±3.84	19.07±3.87	0.221
Knee flexor strength (lb)	Left	TM	24.22±8	33.75±10.07	<0.001*
		OG	17.18±2.8	29.11±5.71	<0.001*
		CON	19.3±6.17	18.53±4.6	0.585
	Right	TM	27.25±8.91	37.75±11.28	<0.001*
		OG	19.54±3.3	33±6.42	<0.001*
		CON	21.69±5.68	20.44±5.25	0.254
Ankle dorsiflexor (lb)	Left	TM	22.06±7.75	35.19±11.29	<0.001*
		OG	15.32±2.2	31.71±5.73	<0.001*
		CON	21.75±5.76	21.94±5.8	0.841
	Right	TM	22.97±8.66	36.94±11.16	<0.001*
		OG	16.93±2.08	33±5.14	<0.001*
		CON	21.25±5.59	21.22±5.69	0.972
Ankle plantarflexor (lb)	Left	TM	36.47±15.35	58.97±19.08	<0.001*
		OG	24.61±5.99	50.46±13.58	<0.001*
		CON	33.34±10.78	32.63±8.84	0.577
	Right	TM	38.81±15.35	61.72±20.92	<0.001*
		OG	23.79±5.8	50.32±13.49	<0.001*
		CON	31.25±9.04	31.78±7.97	0.581
Balance (cm)	Anterior	TM	63.79±4.71	68.39±5.58	0.003*
		OG	64.03±4.49	71.23±6.18	<0.001*
		CON	61.98±6.68	66.04±6.47	0.002*
	Posteromedial	TM	62.49±8.73	72.36±6.58	<0.001*
		OG	60.32±9.41	70.6±6.39	<0.001*
		CON	68.5±10.38	66.04±8.59	0.168
	Posterolateral	TM	76.13±8.06	87.01±7.27	0.001*
		OG	75.49±6.53	85.56±6.71	<0.001*
		CON	76.94±7.84	79.33±9.27	0.329
Agility (s)		TM	24.75±2.29	23.63±2.63	0.001*
		OG	25.57±2.21	24.71±2.05	0.183
		CON	25.13±1.67	25.44±1.59	0.312

Note: All parameters were reported in mean±SD. TM, treadmill, OG, overground, CON, control.

* significant difference at *p*-value<0.05.

Comparison between groups

Because the baseline characteristics were not equal, ANCOVA was therefore performed to manage these differences. There were significant differences found in all parameters (p-value<0.05), except for balance in the anterior direction (p-value=0.101) when comparing between all groups. In lower extremity muscle strength, all variables of both TM and OG showed higher values than the control group (p-value<0.05). In balance, the posteromedial direction of both TM and OG showed higher values than the control group (p-value=0.001 and p-value=0.030, respectively), whereas the posterolateral direction of TM only showed higher values than the control group (p-value=0.017). Lastly, the agility of TM showed lesser values than the control group (p-value=0.020) (Table 3).

Table 3 Comparison of mean post-intervention measures between all three groups after adjustment for differences in baseline values (ANCOVA)

Parameters		Treadmill (n=16)	Overground (n=14)	Control (n=16)	*p*-value
Hip flexor strength (lb)	Left	26.31 (1.06)	29.18 (1.1)	19.07 (0.98)	<0.001*
	Right	27.54 (1.18)	30.81 (1.22)	19.91 (1.09)	<0.001*
Knee flexor strength (lb)	Left	30.65 (1.43)	31.67 (1.49)	19.39 (1.35)	<0.001*
	Right	34.02 (1.6)	35.99 (1.65)	21.55 (1.49)	<0.001*
Ankle dorsiflexor (lb)	Left	33.26 (1.62)	35.8 (1.85)	20.29 (1.61)	<0.001*
	Right	35 (1.61)	35.87 (1.77)	20.65 (1.57)	<0.001*
Ankle plantarflexor (lb)	Left	55.3 (2.95)	56.06 (3.25)	31.4 (2.88)	<0.001*
	Right	55.55 (3.24)	57.03 (3.47)	32.09 (3.01)	<0.001*
Balance (cm)	Anterior	68 (1.22)	70.78 (1.31)	66.9 (1.23)	0.101
	Posteromedial	72.99 (1.51)	72.2 (1.65)	64.01 (1.57)	<0.001*
	Posterolateral	87.03 (1.92)	85.76 (2.05)	79.12 (1.92)	0.013†
Agility (s)		23.91 (0.38)	24.39 (0.41)	25.44 (0.38)	0.020†

Note: All parameters were reported in adjusted mean (SE). TM, treadmill; OG, overground. * significant difference between control and both TM and OG (p-value<0.001); † significant difference between control and TM (p-value<0.05).

Discussion

The aim of this study was to compare the effects between TM and OG training for 4 weeks on lower extremity muscle strength, balance, and agility. Even though mean age of all groups was different, age range of participants was young adulthood[17]. Therefore, this difference did not influence the effect of training for both TM and OG. The main finding of this study was that the different types of running elicited similar outcomes of physical performance in lower extremity muscle strength, balance, and agility. However, there were minor differences in balance and agility when compared with untrained participants.

The present study revealed that the lower extremity muscle strength was found to increase for both TM and OG groups after training. This result was supported by previous studies that reported that training had positive effects on muscular strength[6, 18]. This improvement was in accordance with the results of Franks et al. (2012), which reported that treadmill running for 4 weeks improved strength in quadriceps and hamstrings in non-running individuals. This improvement could be explained by the effects of training, where the running consisted of concentric and eccentric contraction of the leg muscles. Previous study reported that contraction of muscle could increase muscle strength and muscle size in healthy untrained subjects[19]. The effect of training on muscle strength could be explained by these mechanisms: muscle protein synthesis, exercise-induced muscle damage (EIMD), enhanced extra-cellular matrix remodeling, and gene responses and cellular signaling pathways[20]. In addition, another previous study found that muscle protein synthesis could be observed in acute condition (4.5 hours after exercise) and also in chronic condition (within the period of 4 weeks)[21]. When comparing the effects of training on lower extremity muscle strength, non-significant differences were found between TM and OG (*p*-value>0.05). Although, there were differences in the biomechanics, OG showed a higher ROM for knee flexion and ankle dorsiflexion than TM. In kinetic analysis, OG showed a higher knee flexion moment, ankle dorsiflexion moment, anterior ground reaction force (GRF), and medial GRF than TM[8, 9], these differences were not enough to alter muscle strength between TM and OG. In contrast, the study of Fellin et al. (2010) reported that the kinematic curves of the lower limb during the running were similar between TM and OG[22]; therefore, this previous study may explain the similar effects of TM and OG in this study. Consequently, lower extremity muscle strength could be improved after 4 weeks for both TM and OG.

In regard to balance, the present study found that after training by TM and OG, balance was improved in all directions. This study was supported by previous studies that reported that training has positive effects on balance[7,23]. The improvement of dynamic balance was in accordance with the results of Pirouzi et al. (2014), where treadmill training for 4 weeks improved balance and the six-minute walk test (6MWT) in elderly people. In addition, this finding was also in accordance with the study of Asl et al. (2014), where running on a treadmill for 6 weeks improved balance in elementary students. In humans, the postural control (balance) consisted of three main systems including the visual, proprioceptive, and vestibular systems. The running could improve postural control, which especially stimulates the somatosensory or proprioceptive system, resulting in increased balance in this study. Additionally, the improvement of balance could be affected by the raised lower extremity muscle strength. Previous studies reported that lower limb strengthening exercise could improve balance[24,25]. For example, the study of Mohammadi et al. (2012) reported that 6 weeks of lower limb strength training could improve both static and dynamic balances in young male athletes. Therefore, the improvement of balance of both TM and OG in this study could be explained by the enhancement of proprioception and lower limb strength. In contrast, this study revealed that there was no significant difference in the anterior direction of dynamic balance between all groups. In the control group, there was a significant increase after intervention (*p*-value=0.003). The possible explanation was that the feedback mechanism played a major role in this situation. In anterior direction of mSEBT, participants received visual feedback from the reaching leg as they reached and observed the score in each trial, whereas the other directions could not be observed[26]. Therefore, participants made an effort to reach further than the latest trial, until they reached a plateau in this direction. Because this study allowed the participants to practice mSEBT for only 2 times in each direction, this might not be enough to reach the plateau value of the participants in anterior direction among control group. A previous study recommended that participants should perform six practice trials before recording the values of mSEBT[27]. There were no significant differences between TM and OG in all directions of balance. Nevertheless, TM tended to show more effects than OG when compared with the control. Only TM showed significantly greater posterolateral balance than control (*p*-value=0.017). The differences between TM and OG might be explained by the different proprioceptive input in TM, which included the following: the belt always pulled legs which resulted in instability while running and disturbance of the proprioceptive sense[28], and the compelled speed on the narrower path on TM[29]. As mentioned above, TM required more adjustment to the strategy of postural control than OG and tended to have more balance in this study.

The present study revealed that agility was significantly increased only in TM after training (*p*-value=0.001), whereas OG was not (*p*-value =0.183). In addition, there were no significant differences between TM and OG in this parameter. However, TM tended to show more effect than OG when compared with the control. After training, TM showed a higher agility than the control (*p*-value=0.020), whereas OG showed not (*p*-value =0.196). So far as we know, there was limited literature about the effect of running on agility. However, the slightly higher agility in TM might be influenced by dynamic balance that tended to be higher in TM than OG because dynamic balance helped to improve ability to change directions resulting in improved agility. The present study was in accordance with a previous study reported that 4 weeks of dynamic balance training improved agility in basketball players[30]. Moreover, as running on a treadmill could increase cadence and step length, it may improve speed which is a component that influences agility. The previous study reported that treadmill running improved speed due to increased neuromuscular response[31]. In addition, 4 weeks of training was enough for agility improvement with TM. Interestingly, this was the first study that revealed the effects of running on agility.

The present study had certain limitations. One limitation was the lack of blinding the assessor, which might have led to the risk of bias. Therefore, future studies should consider blinding the assessor to reduce the risk of bias. Another limitation was that we measured only strength of flexor muscles of the lower extremity. Therefore, future studies should consider about the extensor muscle strength of the lower extremity.

Conclusion

Both TM and OG revealed an improvement of lower extremity muscle strength and dynamic balance, while agility was only improved in TM after training. When comparing between TM and OG, TM tended to show more dynamic balance and agility than OG. In addition, TM showed a higher dynamic balance and agility than the control, whereas OG did not. Therefore, our results may suggest that only 4 weeks of both TM and OG could improve physical performance, and TM might be a more beneficial training than OG among sedentary healthy individuals.

Take home messages

Treadmill running help to improve muscle strength of lower extremities, balance, and agility among sedentary people. Thus, running on a treadmill regularly may result in enhanced physical performance.

Conflicts of interest

The authors declare no conflict of interest.

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No.

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