

The Effect of ThermoCare Heat Wraps on Balance and Mobility in Seniors with Impaired Gait - A Cross Over Study

Jerrold Petrofsky^{1*}, Michael Laymon¹, Iman Akef Khwailed¹ and Haneul Lee²

¹Department of Physical Therapy, Touro University, Henderson Nevada, USA

²Gachon University, Incheon, South Korea

Abstract

To examine if the use of heat at home can result in better quality and safer mobility in the elderly with gait and balance impairments.

Setting: Randomized longitudinal cross over study design in a clinical setting.

Methods: 20 people with impaired mobility (assessed as a score of more than 4 on the Stepping On questionnaire) were tested with a multi-camera gait analysis system, a treadmill with pressure sensors, a balance platform and the timed up and go and walking speed tests before and after using ThermoCare continuous heat wraps on their legs and knees for 6 days at 4 hours per day. The loss in mobility could not be due to pain killers or other drugs that reduced mobility.

Results: Muscle tremor was reduced, mobility of the joints was improved, balance was significantly improved, and gait was improved after 6 sessions of heat application on the legs. As per the literature, this should reduce the chance of falls in this population.

Conclusion: Using continuous heat wraps may be an important adjunct for improving gait in the elderly with gait impairments.

Keywords: Ageing; Mobility; Heat; Gait; Elderly

Introduction

Falls are one of the most prevalent causes of injury and death in the elderly population [1]. One in every three adults ages 65 and older falls each year [2]. In 2010, 2.4 million non-fatal fall injuries in older adults were treated in emergency rooms and over 22,000 older adults died from unintentional fall injuries [3]. The length of hospital stay is about twice that of a younger person after a fall [4]. Falls reduce the quality of life by reducing confidence and independence [5] even if people don't fall due to apprehension alone [6]. The elderly can present with greater postural sway, which is strongly associated with a greater risk of falling [7].

Between 30 and 50% of the elderly will fall annually and in people 65 and older and 50% of those fall routinely [1,5]. About 5% of the falls result in fracture and is the 6th leading cause of death in the elderly [8]. Poor balance places the elderly at risk for falls during gait as well. Some of the contributing factors are muscle strength deficits [9], lack of good muscle control and loss of coordination [10], impairments in vision and the vestibular system [11], and lack of proprioception in the joints and feet [12]. Thus many body systems are altered by ageing and can contribute to poor gait and falls. The lack of muscle control or muscle weakness (sarcopenia) and stiffness in joints causes the elderly to adopt a slower gait and wider stance to avoid falls [13,14]. Loss of cognitive thinking ability can also lead to poor gait and increased risk of falls [15]. A Cochrane review of falls in the elderly identified the importance of attacking multiple factors in reducing falls and not just one item [16]. One solution in reducing falls is the application of heat to the limbs.

Heat used to reduce inflammation in muscle and tendons and increase the laxity in ligaments [17,18]. Heat reduces pain [19,20]. This is an immediate effect that takes minutes. Heat increases blood flow to tissue [21,22]. Finally, the third effect of heat is to increase the rate of healing of tissue [23,24]. Finally, heat increases flexibility and extensibility of muscle, tendons and ligaments [18,25,26]. Added together it would seem that heat would be beneficial for impaired gait by increasing balance and flexibility. There is some evidence that this

does occur. Recently, heat was applied to the knees of people with nonspecific knee pain. This study examined exercise, heat alone and exercise and heat. The authors found that heat and exercise produced the largest improvement in gait by reducing knee pain and improving physical function [27]. Similar results were seen in another study on arthritic knees [28]. Hot and dry heats were applied for 20 minutes and temporal gait parameters were assessed in another study [29]. The results showed an improvement in gait and in foot pressure during steps but little difference between wet and dry heat. But here, heat was only applied for 20 minutes. Body fat reduces heat transfer even with moist heat and there was probably little heating of deep tissue [30].

While high temperature heat such as hydrocollator heat packs must be carefully watched since they can damage the skin, numerous papers have shown safe and beneficial effects of continuous low level heat [31-33].

In the present investigation we looked at the effect of continuously applied heat on the legs of the elderly with gait impairments and balance impairments for 4 hours a day for 1 week to see if repeated heat treatments make their balance and gait better. Balance impairments have been shown to be correlated very highly to the incidence of falls [34-36].

Previous studies have shown poor heat penetration with heat sources such as hydrocollator heat packs which are commonly left on

***Corresponding author:** Jerrold Petrofsky, Professor and Director of Research, Department of Physical Therapy, Touro University, Henderson Nevada, USA, Tel: 07557388811; E-mail: jpetrofsky@outlook.com

Received: December 21, 2015; **Accepted:** March 20, 2016; **Published:** March 28, 2016

Citation: Petrofsky J, Laymon M, Khwailed IA, Lee H (2016) The Effect of ThermoCare Heat Wraps on Balance and Mobility in Seniors with Impaired Gait - A Cross Over Study. Physiother Rehabil 1: 105. doi: [10.4172/2573-0312.1000105](https://doi.org/10.4172/2573-0312.1000105)

Copyright: © 2016 Petrofsky J, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

for only 15-20 minutes [18]. Continuous low level heat increases range of motion and tissue temperature and blood flow [18]. Further, after use, there is a carryover in the effect of heat for hours after the heat is removed. It is also safer for the elderly than more rapid heat modes in that skin temperature is better controlled [25].

While we couldn't study fall incidence in a 1 week period, it can be implied that if balance and gait are improved, so should the incidence of falls be reduced. An important consideration is the potential increase in quality of life from having better mobility.

Subjects

There were 20 subjects in the study. Subjects that were free of any headaches, diabetes mellitus, and orthopedic or neurological conditions were recruited. Subjects were sedentary individuals that were not participating in any balance exercises regularly. Subjects filled out the "Steeping On" mobility questionnaire and needed to have a score of at least 4 to qualify since this translated to increased fall risk. Subjects were instructed not to take any medication or central nervous stimulants that might affect their balance the day before and during the study. The experimental protocol was approved by the Solutions Institutional Review Board and all protocols and procedures were explained to each subject and the subjects gave their written informed consent for the study. The demographics of the subjects are shown in Table 1.

Methods

Subjects

There were 20 subjects in the study. Exclusion criteria were that subjects that were free of any headaches, diabetes mellitus, and orthopedic or neurological conditions, were sedentary individuals that were not participating in any balance exercises regularly. They could not be taking any medication or central nervous stimulants that might affect their balance the day before and during the study. Subjects filled out the "Steeping On" mobility questionnaire and needed to have a score of at least 4 to qualify since this translated to increased fall risk. The experimental protocol was approved by the Solutions Institutional Review Board and all protocols and procedures were explained to each subject and the subjects gave their written informed consent for the study. The demographics of the subjects are shown in Table 2.

Fall questionnaire

A fall questionnaire (stepping on) was used to screen the subjects. It has been developed and validated in other studies [37]. A score of greater than or equal to 4 is considered as an indicator of high risk for falls.

Measurement of postural sway

To assess the postural stability, a force platform was used. Variables such as the displacement of the Center of Pressure (COP), mean COP positions, length of the COP path, sway velocity, area of COP path and Root Mean Square area have been used to determine the postural sway. However, due to the variability of the subjects' body characteristics, normalization of the data using subjects' height and weight is necessary prior to statistical analysis [38]. Some studies used coefficient of variation of the weight displacement as measures of the postural sway [39-44]. Used coefficient of variation of the vector magnitude and angle of movement as measures of the postural sway. In this study, coefficient of variation of the polar vector of weight displacement was used as the measurement of postural sway. It is a unit-less measure of the dispersion of the displacement of the center of pressure.

	Age (years)	Height (cm)	Weight (kg)
Mean	60.3	162.4	94.8
SD	8.3	10.6	13.5

Table 1: Demographics of subjects.

Feet position	Firm Surface		Foam	
	Eyes open	Eyes closed	Eyes open	Eyes closed
Feet apart	FAEO-FIRM (Control task)	FAEC-FIRM	FAEO-FOAM	FAEC-FOAM
Tandem	TEO-FIRM	TEC-FIRM	TEO-FOAM	TEC-FOAM

Table 2: 8 Balance Tasks in the study. (FIRM = No Foam On The Platform; FOAM = Aeromat Foam Block On The Platform; FA = Feet Apart; EO = Eyes Open; EC = Eyes Closed; T = Tandem)

The balance platform was 1 m by 1 m in size and 0.1 m in height. The validity and reliability of this force platform has been established in a previous study [42]. Four stainless steel bars, each with four strain gauges, were mounted at the four corners under the platform (TML Strain Gauge FLA-6, 350-17, Tokyo, Japan). The output of the 4 Wheatstone strain gauge bridges was amplified by a BioPac MP35 low-level bio-potential amplifiers and were digitized through a 24-bit A/D converter. The sampling rate was 1000 samples per second [42].

To calculate the load and the center of the pressure of the force on the platform, the output of the four sensors was used to measure the X and Y coordinates of the center of gravity of the subject. This data was converted to a movement vector giving a magnitude and angular displacement. By averaging this movement vector over 6 seconds, mean and standard deviation (SD) were obtained for this measure. From this, the Coefficient of Variation (CV) of the polar coordinate was calculated ($SD \div Mean \times 100\%$) as a measure of the postural sway [42]. The average CV of each task was determined over a 5 second sample of the data.

Outcome Measures

Analog visual scale for difficulty of gait: Participants were asked to mark on a 10 cm AVS to rate the degree of difficulty with walking each day. One end of the AVS was to indicate no difficulty while another end extreme difficulty. Measurement were taken from the line and converted to readings between 0 to 100.

Balance

Eight quiet standing balance tasks, each lasting for 10 seconds, were measured. Sensory variables such as the vision, base of support and surface compliance were altered individually or simultaneously in the balance tasks. To alter the visual input, 2 levels of vision (eyes open and closed) were used in the balance tasks. To alter the somatosensory input, 2 different surface compliances (firm surface & foam) were used. The Aero mat balance block, a PVC/NBR foam with size 16 x 19 x 2.5 inches and density around 0.04-0.06 g/cm³ (AGM Group, Aero mat Fitness Product, Fremont, CA), was placed on top of the balance platform as the foam surface in this study. Participants were asked to stand in two different stance positions with feet apart (centers of the calcaneus in the same distance as the two Anterior Superior Iliac Spine) or in tandem (feet in a heel-toe position with non-dominant foot in front) [45]. The total sway was analyzed with a fast Fourier transform to assess muscle tremor. Two bands were used, 8-10 Hz for spindle tremor and 22-26 Hz for central motor control error.

Gait testing

Gait testing was accomplished in 2 ways. The first test was a

treadmill test. Subjects stood for 30 seconds to obtain static pressure measures under the feet. Next subjects walked on a treadmill at 2.5 mph at 0% grade. The treadmill has pressure sensors (7168) under the belt to measure temporal gait parameters and ground reaction forces. Two infrared cameras at 120 frames per second captured motion of the body (myovideo high speed analysis system). Sensors were placed on the hip, knee and ankle and foot to capture motion. Finally, EMG was recorded via a telemetry system (myomuscle) as part of the Noraxon treadmill for the medial and lateral quadriceps, hamstring, gastrocnemius and tibialis anterior muscles at a sample rate of 1500 samples per second per channel.

Treadmills produce different gait than that seen during normal walking since the belt is moving under power. For normal gait, a Protokinetics Zeno walkway was used. The walkway was 3 feet wide and 18 feet long with almost 20000 pressure sensors. It was scanned at 100 frames per second and used 2 cameras to record movement during gait. The walkway provided timing and pressure and was used for 2 tests. These were the Timed Up and Go (TUG) and walking tests. The TUG started with the subject sitting in a chair and on visual command would stand up and walk 3 meters. This was repeated two times. The second walking test involved walking 13 meters on the walkway at a self-paced speed. Temporal and pressure characteristics were recorded under the two test conditions.

Home heat use compliance score

Subjects kept a home heat compliance log. They scored for each day they were to participate and used heat as a percent score for how much they left the heat on. For example, if they used it for 3 hours and were to use it for 4 hours, they scored 75%.

Heat wrap

Heat was applied with a dry heat wrap (ThermaCare, Pfizer Consumer Healthcare, Richmond, VA). The warm wrap kept the average skin temperature about 42°C and was applied as per manufacturer's instructions around the thighs and knees. It was kept on for 4 hours.

Procedures

The study was a single blinded cross over design. There were 20 subjects in the study. All subjects were initially tested for balance, walking on the treadmill and the time up and go and walking test on the protokinetics walkway. Next Half of the subjects waited one week and then were tested again. The other half used heat for 6 days and then were tested again. This was then reversed and the heat group used no heat for one week and the no heat group used heat. All measurements were repeated after the first and second week.

Results

Balance

Figure 1 shows the results of the balance experiments. The tests are arranged from the simplest (feet apart eyes open on the aluminum platform (firm surface) to the most challenging test (feet tandem on the foam block eyes closed). When subjects used no heat (cold), the results of the tests from easiest to most challenging tests were not different. Since this was a cross over study it showed no bias in the test with learning. The greatest sway (poorest balance) was standing with eyes closed on a foam surface with the feet tandem. For example, comparing sway with eyes open and feet apart on a firm vs. feet tandem on foam eyes closed, sway increased by 19 fold.

When heat was used for 1 week, the results were different. For standing on foam with either their eyes opened or closed and the feet tandem or feet apart, sway was less than in the control group. In fact, for the most challenging condition, tandem feet on foam eyes closed, sway only increased just over 7 fold compared to feet apart on a firm surface eyes open. These differences between the subjects with heat compared to no heat were significant ($p < 0.01$).

Tremor

Figure 2 shows similar results for tremor during standing when using the 8 most difficult balance tasks. The use of heat reduced tremor on standing for the most difficult balance tasks.

As can be seen here for tremor in the 6-10 Hz bandwidth, tremor increased significantly ($p < 0.01$) in the control and post no heat (cold) group for the 4 most difficult balance tasks ($p < 0.01$). But after heat, tremor was significantly lower for the 4 most difficult tasks but not different than either of the other 2 groups for the 4 easiest tasks ($p < 0.01$) compared to the no heat and control group.

Treadmill walking

The results of the treadmill walking tests are shown below. For the control groups with no heat intervention, there was no difference in forces or gait temporal parameters while walking. Therefore, the graphs only show the control condition compared to heat. After heat was applied for 1 week, there were significant differences between the heat and control condition as outlined below.

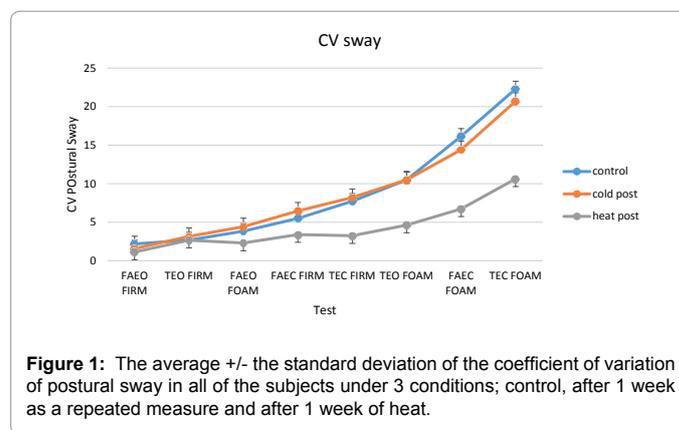


Figure 1: The average +/- the standard deviation of the coefficient of variation of postural sway in all of the subjects under 3 conditions; control, after 1 week as a repeated measure and after 1 week of heat.

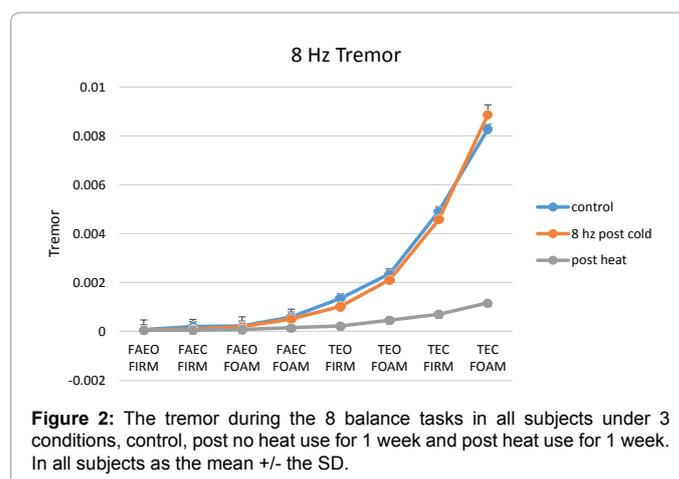


Figure 2: The tremor during the 8 balance tasks in all subjects under 3 conditions, control, post no heat use for 1 week and post heat use for 1 week. In all subjects as the mean +/- the SD.

Range of motion of the knee

The range of motion of the knee while walking at a speed of 2.5 mph on the treadmill was increased after heat application from 14.7 ± 2.1 degree at weight acceptance in the control condition to 18.8 ± 3.1 degrees after the week of using heat. This increase was significant ($p < 0.01$). As a percentage, the range of motion at the knee increased by 26% after application of heat for 1 week.

Muscle activity at the knee

There was also a significant increase in muscle activity controlling the knee after heat application. The EMG activity at the 2 heads of the quadriceps, the vastus medialis and lateralis. Showed significantly more ($p < 0.01$) EMG activity during walking after application of heat for 1 week compared to the control condition. This signifies more active control of the knee. During the weight acceptance phase, for example, when loading was applied to the knee, there was a significant increase in muscle force at the knee after the use of heat (Figure 3). This would have a tendency to stabilize the knee better since it would overcome ligament laxity in the knee and in the lateral and medial collateral ligaments. This was true for the other muscles examined and other phases of the gait cycle.

Ground reaction forces

As might be expected, with greater muscle activity at the knee and lower leg, the ground reaction forces were significantly reduced ($p < 0.01$) after application of heat for one week. The ground reaction force for the 2 conditions where heat was not used (control and with no heat for one week), averaged 72.5 ± 9.6 neutons/kg body mass and after application of heat for one week, it averaged 63.4 ± 15.1 neutons/kg body mass.

The spacial and temporal gait characteristics are shown in Table 3, as control data before heat and Table 4 as the difference between the control and the 1 week post heat data. There were also significant differences in treadmill temporal and spacial gait measures as shown by the p values on Table 4.

Walking mat data

As stated above, the treadmill forces gait speed by its nature of a motor moving the belt. The Zeno walkway allowed subjects to walk at a comfortable speed for the TUG test and walking tests. The Time up and go (TUG) is a standard measure of gait that is used by the National Institutes of health. It shows a measure of motor control and muscle strength. The faster a person can stand up and walk the less chance of falling [46-48].

TUG- the time to complete the time up and go test averaged 14.5 ± 3.9 seconds in the control and no heat conditions while after heat, there was a significant improvement to 11.4 ± 3.5 seconds, a significant improvement in time ($p < 0.01$). Of interest were the first 2 steps since standing and overcoming inertia of the body takes the greatest strength and coordination. Here the time was reduced after 1 week of heat from 8.2 ± 2.5 seconds to 5.9 ± 1.7 seconds a significant reduction in time by about 25% ($p < 0.01$).

Gait symmetry

Gait symmetry is the key to preventing falling. It was measured in 2 ways, the coefficient of variation of side to side movement of the body in the stance phase and in the swing phase.

When examining the change in center of pressure in either one

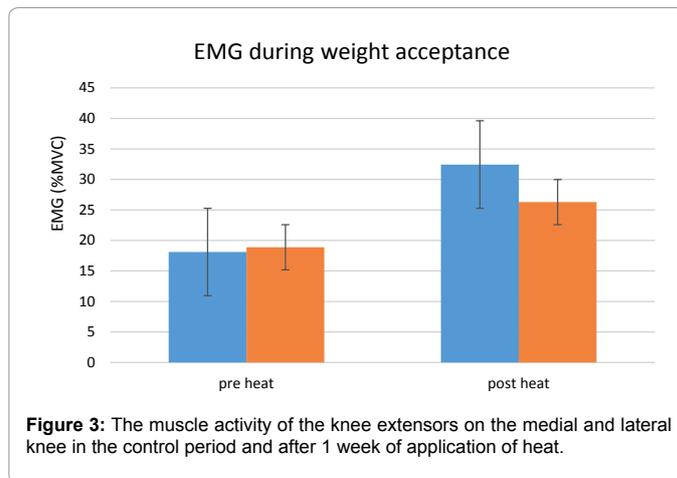


Figure 3: The muscle activity of the knee extensors on the medial and lateral knee in the control period and after 1 week of application of heat.

	Spatial Parameters	PRE		Temporal Parameter	PRE	
	Step Length (cm)	Stride length (cm)	Step Width (cm)	Step Time (seconds)	Stride Time (seconds)	Cadence (steps/min)
Mean	52.93	106.81	12.27	0.63	1.26	97.88
SD	4.54	8.75	3.56	0.05	0.09	7.95

Table 3: Spatial and temporal gait parameters before heat.

leg stance or 2 leg stance during the gait cycle, the smoother the leg progressed forward, the less side to side variation in the center of mass over the direction of movement making gait steadier. For example, Figure 4 shows the center of pressure variation during one leg stance (the other leg is off of the floor) during gait. As shown here, the variation in mass was reduced significantly with heat. The same was true for the movement of mass in the double stance phase where symmetry was significantly better.

Another interesting observation during free walking is shown in Figure 5. Here there is significantly less variation in the internal external rotation of the foot during gait after the application of heat ($p < 0.01$), in other words, the gait was steadier.

The greater the side to side sway, the greater the chance of falling [49-51]. The measure is called the coefficient of variation of the center of pressure. The single stance variation in center of pressure during gait was significantly less in the heat group ($p < 0.05$).

Compliance for heat use and the effect of Heat on ability to walk.

Use of heat: The subjects filled out a questionnaire to assess their compliance on using heat each day. The average was $61.1 \pm 26.1\%$. In some cases subjects only used heat for 25% of the time they should have but other times 100%, accounting for the large standard deviation.

Benefit of heat in walking as assessed by the subjects

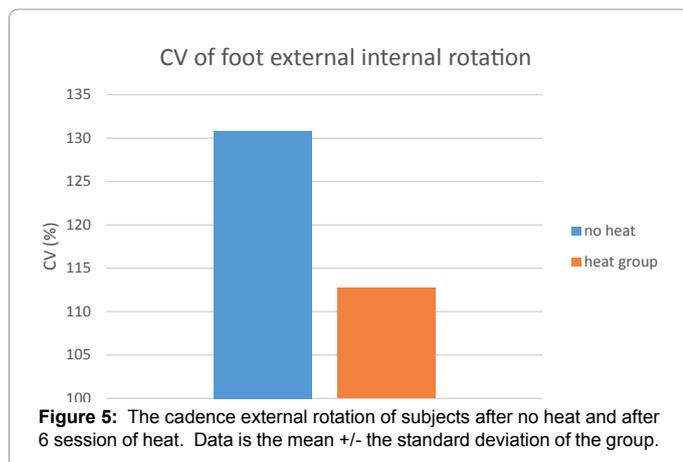
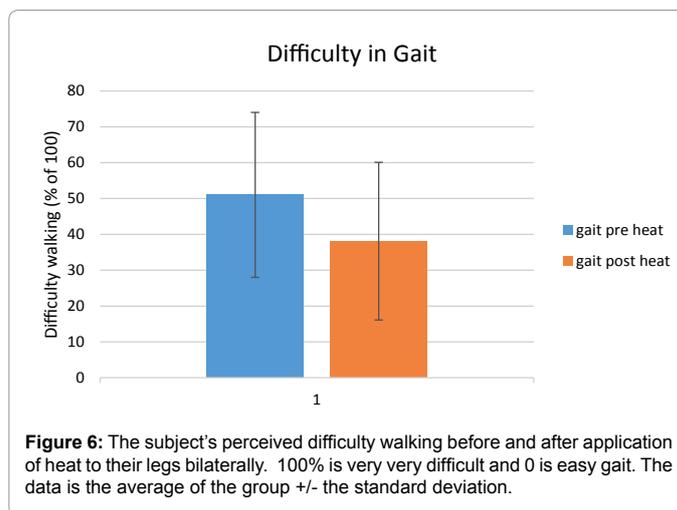
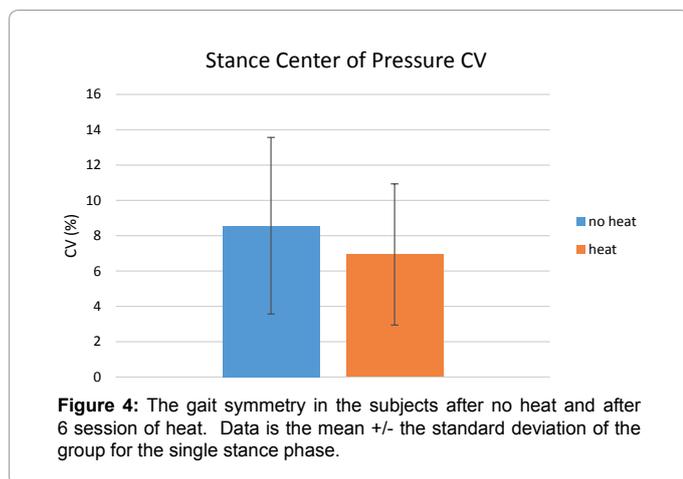
As shown in Figure 6, the subjects felt that gait was significantly easier after the application of heat ($p = 0.02$) comparing pre and post heat gait averaged over 6 days.

Discussion

This review systematically identified and appraised to create an evidence-based review for the diagnosis A consensus has defined falls as "an unexpected event in which the participant comes to rest on the

	Spatial Parameters			Temporal Parameter		
	Step Length (cm)	Stride length (cm)	Step Width (cm)	Step Time (seconds)	Stride Time (seconds)	Cadence (steps/min)
mean	-2.99	-5.35	0.47	-0.03	-0.09	5.65
SD	4.85	4.15	2.83	0.05	0.09	5.81
p	0.032	0	0.533	0.022	0.002	0.002

Table 4: Spatial and temporal gait parameters after heat as the difference of pre vs. post heat data. The p value under each column is the significance.



In contrast, continuous low level heat wraps have been shown to have good tissue penetration of heat and can be used at home [19,31,57,59]. This deep heat penetration increases blood flow to tissue and increases flexibility and elasticity of tendons and ligaments and reduces viscosity in muscle [17,18,26,44]. Heat also reduces pain and increases range of motion [17,26,60]. In women, there are fewer injuries to the knee and ankle when flexibility of tissue is greatest, at ovulation [17,26]. Further, in women, when body temperature is elevated at ovulation, as was the case here after heat, there is increased muscle activity in the leg to protect the leg by active stabilization of joints that is associated with less tissue injury and better control of impact forces during running [61]. It is not unreasonable in older people that increased flexibility and increased metabolism due to heat will lead to fewer falls and injuries.

ground, floor, or lower level” [52]. With an ageing population in the United States, mobility is a major concern in health care [2,53]. Poor mobility, leads to unsteady gait and falls [7,54,55]. Falls are a major cause of morbidity in the elderly and even if they survive, fractures can lead to high medical costs from hospitalization [3]. The risk of fall related injuries increases with age [5,56]. In the elderly, multifactorial intervention has proved best to reduce fall incidence [54]. Exercise and education has been shown to reduce the risk and fear of falls [54].

Previous studies have pointed to the need to address more than one disability to reduce fall incidence. This was the main conclusion of a recent Cochrane review on preventing falls [16]. The items that were identified to contribute to falls were fear of falling [62], improper use of balance aids such as canes, inappropriate footwear, reduced neuromuscular function (control and strength), poor balance, impaired proprioception, impaired vestibular function, impaired cognition, illness, female gender, and advanced age [1,5,63,64]. For gait, one study showed that even just gait speed is inversely correlated with falling [13]. Another study found an inverse correlation between falls and gait speed and stance time [65].

Poor gait is related to the incidence of falling. Anything that increases temporal and spacial gait parameters can reduce fall risk [6,14,15]. Heat packs and moist heat packs have been shown to improve gait in the elderly [29]. But this study used a 20 minute exposure to hydrocollator heat packs through layers of towels. While therapeutic heat sources such as hydrocollator heat packs and ultrasound can cause pain relief, their penetration to deeper tissues is poor [44,57,58]. In spite of this, there was an improvement in gait speed. This is probably due to a peripheral effect of heat in increasing elasticity in tendons close to the skin and pain reduction.

In the present investigation, there was a marked improvement in a number of gait parameters. Balance was better, motor control was better, gait was more symmetrical, and range of motion at the knee was greater and ground impact forces less after the use of heat. All of these factors should contribute to more stability and less chance of falls. While this was only a 6 session study, it did show the importance and potential of the use of continuous heat wraps to increase mobility in seniors.

Conclusions

As people age, mobility impairment becomes a major issue in life. While the importance of muscle strength training and exercise cannot be underemphasized, stiffness in joints and in the foot remains a major issue in impaired mobility. Here, by using continuous heat wraps, joint stiffness was reduced and all gait parameters were improved. The effect on fall incidence was not measured but by predictors like side to side sway, gait speed and balance, heat should reduce fall incidence.

Conflict of Interest

There are no conflicts of interest in these studies by any investigator.

References

1. Tinetti ME, Speechley M (1989) Prevention of falls among the elderly. *N Engl J Med* 320: 1055-1059.
2. Hausdorff JM, Rios DA, Edelberg HK (2001) Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehabil* 82: 1050-1056.
3. Jørgensen TS, Hansen AH, Sahlberg M, Gislason GH, et al. (2015) Nationwide time trends and risk factors for in-hospital falls-related major injuries. *Int J Clin Pract* 69: 703-709.
4. Scott VJ, Gallagher EM (1999) Mortality and morbidity related to injuries from falls in British Columbia. *Can J Public Health* 90: 343-347.
5. Tinetti ME, de Leon CFM, Doucette JT, Baker DI (1994) Fear of falling and fall-related efficacy in relationship to functioning among community-living elders. *J Gerontol* 49: 140-147.
6. Arfken CL, Lach HW, Birge SJ, Miller JP (1994) The prevalence and correlates of fear of falling in elderly persons living in the community. *Am J Public Health* 84: 565-570.
7. Fernie GR, Gryfe CI, Holliday PJ, Llewellyn A (1982) The relationship of postural sway in standing to the incidence of falls in geriatric subjects. *Age Ageing* 11: 11-16.
8. Baker SP, Harvey AH (1985) Fall injuries in the elderly. *Clin Geriatr Med* 1: 501-512.
9. Petrofsky JS, Lind AR (1975) Aging, isometric strength and endurance, and cardiovascular responses to static effort. *J Appl Physiol* 38: 91-95.
10. Schalow G (2001) Time axis calibration in human CNS organization for judging dysfunction. *Electromyogr Clin Neurophysiol* 41: 485-505.
11. Dowiasch S, Marx S, Einhäuser W, Bremmer F (2015) Effects of aging on eye movements in the real world. *Front Hum Neurosci* 9: 46.
12. Mueller MJ, Minor SD, Sahrman SA, Schaaf JA, Strube MJ (1994) Differences in the gait characteristics of patients with diabetes and peripheral neuropathy compared with age-matched controls. *Phys Ther* 74: 299-308.
13. Moreira BS, Sampaio RF, Kirkwood RN (2015) Spatiotemporal gait parameters and recurrent falls in community-dwelling elderly women: a prospective study. *Braz J Phys Ther* 19: 61-69.
14. Dohrn IM, Hagströmer M, Hellenius ML, Ståhle A (2016) Gait Speed, Quality of Life, and Sedentary Time are Associated with Steps per Day in Community-Dwelling Older Adults with Osteoporosis. *J Aging Phys Act* 24: 22-31.
15. Bridenbaugh SA, Kressig RW (2015) Motor cognitive dual tasking: early detection of gait impairment, fall risk and cognitive decline. *Z Gerontol Geriatr* 48: 15-21.
16. Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG, et al. (2003) Interventions for preventing falls in elderly people. *Cochrane Database Syst Rev* (In press).
17. Lee H, Petrofsky JS, Daher N, Berk L, Laymon M (2014) Differences in anterior cruciate ligament elasticity and force for knee flexion in women: oral contraceptive users versus non-oral contraceptive users. *Eur J Appl Physiol* 114: 285-294.
18. Petrofsky JS, Laymon M, Lee H (2013) Effect of heat and cold on tendon flexibility and force to flex the human knee. *Med Sci Monit* 19: 661-667.
19. Malanga GA, Yan N, Stark J (2015) Mechanisms and efficacy of heat and cold therapies for musculoskeletal injury. *Postgrad Med* 127: 57-65.
20. Petrofsky J, Berk L, Bains G, Khwailed IA, Hui T, et al. (2013) Moist heat or dry heat for delayed onset muscle soreness. *J Clin Med Res* 5: 416-425.
21. Yim J, Petrofsky J, Berk L, Daher N, Lohman E (2012) Differences in endothelial function between Korean-Asians and Caucasians. *Med Sci Monit*, 18: 337-3343.
22. Petrofsky JS, Alshammari F, Lee H, Hamdan A, Yim JE, et al. (2012) Reduced endothelial function in the skin in Southeast Asians compared to Caucasians. *Med Sci Monit* 18: 1-8.
23. Petrofsky JS, Lawson D, Berk L, Suh H (2010) Enhanced healing of diabetic foot ulcers using local heat and electrical stimulation for 30 min three times per week. *J Diabetes* 2: 41-46.
24. Petrofsky JS, Lawson D, Suh HJ, Rossi C, Zapata K, et al. (2007) The influence of local versus global heat on the healing of chronic wounds in patients with diabetes. *Diabetes Technol Ther* 9: 535-544.
25. Stark J, Petrofsky J, Berk L, Bains G, Chen S, et al. (2014) Continuous low-level heatwrap therapy relieves low back pain and reduces muscle stiffness. *Phys Sportsmed* 42: 39-48.
26. Lee H, Petrofsky JS, Daher N, Berk L, Laymon M, et al. (2013) Anterior cruciate ligament elasticity and force for flexion during the menstrual cycle. *Med Sci Monit* 19: 1080-1088.
27. Kim H, Suzuki T, Saito K, Kim M, Kojima N, et al. (2013) Effectiveness of exercise with or without thermal therapy for community-dwelling elderly Japanese women with non-specific knee pain: a randomized controlled trial. *Arch Gerontol Geriatr* 57: 352-359.
28. Seto H, Ikeda H, Hisaoka H, Kurosawa H (2008) Effect of heat- and steam-generating sheet on daily activities of living in patients with osteoarthritis of the knee: randomized prospective study. *J Orthop Sci*, 13: 187-191
29. Shim JM (2014) The effects of wet heat and dry heat on the gait and feet of healthy adults. *J Phys Ther Sci* 26: 183-185.
30. Petrofsky J, Goraksh N, Alshammari F, Mohanan M, Soni J, et al. (2011) The ability of the skin to absorb heat; the effect of repeated exposure and age. *Med Sci Monit* 17: 1-8.
31. Mayer JM, Mooney V, Matheson LN, Erasala GN, Verna JL, et al. (2006) Continuous low-level heat wrap therapy for the prevention and early phase treatment of delayed-onset muscle soreness of the low back: a randomized controlled trial. *Arch Phys Med Rehabil* 87: 1310-1317.
32. Kesiktas N, Paker N, Erdogan N, Gülsen G, Biçki D, et al. (2004) The use of hydrotherapy for the management of spasticity. *Neurorehabil Neural Repair* 18: 268-273.
33. Lewis SE, Holmes PS, Woby SR, Hindle J, Fowler NE (2012) Short-term effect of superficial heat treatment on paraspinal muscle activity, stature recovery, and psychological factors in patients with chronic low back pain. *Arch Phys Med Rehabil* 93: 367-372.
34. Tinetti ME, Kumar C (2010) The patient who falls: „It's always a trade-off". *JAMA* 303: 258-266.
35. Lord SR, Ward JA, Williams P, Anstey KJ (1994) Physiological factors associated with falls in older community-dwelling women. *J Am Geriatr Soc* 42: 1110-1117.
36. Lord SR, Sambrook PN, Gilbert C, Kelly PJ, Nguyen T, et al. (1994) Postural stability, falls and fractures in the elderly: results from the Dubbo Osteoporosis Epidemiology Study. *Med J Aust* 160: 684-685, 688-91.
37. Rubenstein LZ, Vivrette R, Harker JO, Stevens JA, Kramer BJ (2011) Validating an evidence-based, self-rated fall risk questionnaire (FRQ) for older adults. *J Safety Res* 42: 493-499.
38. Fransson PA, Gomez S, Patel M, Johansson L (2007) Changes in multi-segmented body movements and EMG activity while standing on firm and foam support surfaces. *Eur J Appl Physiol* 101: 81-89.
39. Clark S, Riley MA (2007) Multisensory information for postural control: sway-referencing gain shapes center of pressure variability and temporal dynamics. *Exp Brain Res* 176: 299-310.
40. Usui N, Maekawa K, Hirasawa Y (1995) Development of the upright postural sway of children. *Dev Med Child Neurol* 37: 985-996.

41. Petrofsky JS, Focil N, Prowse M, Kim Y, Berk L, et al. (2010) Autonomic stress and balance—the impact of age and diabetes. *Diabetes Technol Ther* 12: 475-481.
42. Petrofsky JS, Lohman E, Lohman T (2009) A device to evaluate motor and autonomic impairment. *Med Eng Phys* 31: 705-712.
43. Kouzaki M, Shinohara M (2010) Steadiness in plantar flexor muscles and its relation to postural sway in young and elderly adults. *Muscle Nerve* 42: 78-87.
44. Petrofsky JS, Laymon M (2009) Heat transfer to deep tissue: the effect of body fat and heating modality. *J Med Eng Technol* 33: 337-348.
45. Tse YY, Petrofsky JS, Berk L, Daher N, Lohman E, et al. (2013) Postural sway and rhythmic electroencephalography analysis of cortical activation during eight balance training tasks. *Med Sci Monit*, 19: 175-86.
46. Coulthard JT, Treen TT, Oates AR, Lanovaz JL (2015) Evaluation of an inertial sensor system for analysis of timed-up-and-go under dual-task demands. *Gait Posture* 41: 882-887.
47. Hassani A, Kubicki A, Brost V, Mourey F, Yang F (2015) Kinematic analysis of motor strategies in frail aged adults during the Timed Up and Go: how to spot the motor frailty? *Clin Interv Aging* 10: 505-513.
48. kojima G, Masud T, Kendrick D, Morris R, Gawler S, et al. (2015) Does the timed up and go test predict future falls among British community-dwelling older people? Prospective cohort study nested within a randomised controlled trial. *BMC Geriatr* 15: 38.
49. Davis JC, Best J, Hsu CL, Nagamatsu LS, Dao E, et al. (2015) Examining the effect of the relationship between falls and mild cognitive impairment on mobility and executive functions in community-dwelling older adults. *J Am Geriatr Soc* 63: 590-593.
50. Davis JC, Best JR, Bryan S, Li LC, Hsu CL, et al. (2015) Mobility is a key predictor of changes in wellbeing among older fallers: Evidence from the Vancouver Falls Prevention Cohort. *Arch Phys Med Rehabil* 9: 1634-1640.
51. Fasano A, Plotnik M, Bove F, Berardelli A (2012) The neurobiology of falls. *Neurol Sci* 33: 1215-1223.
52. Lamb SE, Jorstad-Stein EC, Hauer K, Becker C (2005) Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. *J Am Geriatr Soc* 53: 1618-1622.
53. Hausdorff JM, Nelson ME, Kaliton D, Layne JE, Bernstein MJ, et al. (2001) Etiology and modification of gait instability in older adults: a randomized controlled trial of exercise. *J Appl Physiol* (1985) 90: 2117-2129.
54. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, et al. (2009) Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev* 15: CD007146.
55. Robertson MC, Campbell AJ, Gardner MM, Devlin N (2002) Preventing injuries in older people by preventing falls: a meta-analysis of individual-level data. *J Am Geriatr Soc* 50: 905-911.
56. Peel NM (2011) Epidemiology of falls in older age. *Can J Aging* 30: 7-19.
57. Petrofsky J, Bains G, Prowse M, Gunda S, Berk L, et al. (2009) Dry heat, moist heat and body fat: are heating modalities really effective in people who are overweight? *J Med Eng Technol* 33: 361-369.
58. Petrofsky JS, Lohman E, Suh HJ, Garcia J, Anders A, et al. (2006) The effect of aging on conductive heat exchange in the skin at two environmental temperatures. *Med Sci Monit* 12: CR400-408.
59. Petrofsky J, Berk L, Alshammari F, Lee H, Hamdan A, et al. (2012) The effect of moist air on skin blood flow and temperature in subjects with and without diabetes. *Diabetes Technol Ther* 14: 105-116.
60. Mazzuca SA, Page MC, Meldrum RD, Brandt KD, Petty-Saphon S (2004) Pilot study of the effects of a heat-retaining knee sleeve on joint pain, stiffness, and function in patients with knee osteoarthritis. *Arthritis Rheum* 51: 716-721.
61. Khwailed I, Petrofsky JS, Lohman E, Mohamed O, Daher D (2015) Six-Week Habituation to Simulated Barefoot Running Induces Neuromuscular Adaptations and Changes in Foot-Strike Patterns in Female Runners *Med. Sci. Monit* 13: 2021-2030.
62. Braun BL (1998) Knowledge and perception of fall-related risk factors and fall-reduction techniques among community-dwelling elderly individuals. *Phys Ther* 78: 1262-1276.
63. Cumming RG (1998) Epidemiology of medication-related falls and fractures in the elderly. *Drugs Aging* 12: 43-53.
64. Grisso JA, Kelsey JL, Strom BL, Chiu GY, Maislin G, et al. (1991) Risk factors for falls as a cause of hip fracture in women. The Northeast Hip Fracture Study Group. *N Engl J Med* 324: 1326-1331.
65. Lord SR, Lloyd DG, Li SK (1996) Sensori-motor function, gait patterns and falls in community-dwelling women. *Age Ageing* 25: 292-299.