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Jerrold S. Petrofsky
*Touro University Nevada*, jerrold.petrofsky@tun.touro.edu

Michael S. Laymon
*Touro University Nevada*, michael.laymon@tun.touro.edu

Iman Akef Khowailed
*Touro University Nevada*, iman.khowailed@tun.touro.edu



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# The Effect of Continuous Heat Wraps on Balance and Gait in the Elderly

**Jerrold Petrofsky**[1*], **Michael Laymon**[2] **and Iman Akef Khwailed**[2]

[1]*Department of Physical Therapy, Loma Linda University, Loma Linda, California, USA*

[2]*Department of Physical Therapy, Touro University, Henderson Nevada, USA*

[*]**Corresponding author:** Jerrold Petrofsky, Department of Physical Therapy, Loma Linda University, Loma Linda, California 92350, USA, Tel: + 909558 7274; E-mail: jpetrofsky@llu.edu

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## Abstract

**Background:** In an ageing geriatric population, tremor and poor balance become more pronounced and can lead to falls. Falls are the leading cause of mortality in this population. Continuous heat wraps have been shown to increase tissue flexibility. It was the purpose of this study to examine the effects of heat on balance and gait in the elderly with impaired mobility.

**Subjects:** Twenty people with impaired mobility (assessed as a score of more than 4 on the "Stepping On" questionnaire) were tested with a balance platform after using ThermaCare continuous heat wraps on their legs and knees for 6 days. Data was collected at day 0 (before heat) and day 7. The average age was 60.3+/-8.3 years. The loss in mobility could not be due to pain killers or other drugs the person was taking that may reduce mobility. Half of the subjects started with a week of heat treatment and half were no heat controls. At the end of the first arm, there was a one week washout and the groups were reversed.

**Methods:** Balance was assessed on a custom made balance platform during 8 different balance tasks lasting 10 seconds each and presented at random. Tremor was measured during the balance tasks at 8 and 24 Hertz. Gait was assessed by the "timed up and go" test.

**Results:** Muscle tremor was reduced; balance and gait were significantly improved, after 6 sessions of heat application on the legs.

**Conclusion:** As per the literature, this improvement in balance should reduce the chance of falls in this population.

**Keywords:** Falls; Balance; Heat tremor

## 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 [3-5]. The length of hospital stay is about twice that of a younger person after a fall [6]. Falls reduce the quality of life by reducing confidence and independence [7] even if people don't fall since it is a fear [8]. The elderly can present with greater postural sway (poor balance), which is strongly associated with a greater risk of falling [9,10].

Some of the contributing factors to poor balance are muscle strength deficits [11,12], reduction in motor control [13], loss of coordination [14,15], impairments in vision [16] and the vestibular system [16,17], and lack of proprioception in the joints and feet [18]. These contribute to make walking not just difficult, but painful in some cases [19].

One contributing factor may be a reduction in the temperature of peripheral tissues. The arms and legs are shell tissues [20-22]. Whereas the core has its temperature maintained at about 37 degrees C, the shell (arms and legs) is kept at a cooler temperature to provide heat loss from the core [21,22]. Normally for example, the temperature of the deep muscles in the legs is about 32°C [23-25]. In the elderly, metabolism is decreased and thermoregulation is impaired [26-28]. The legs are therefore kept at cooler temperatures [29]. This in turn can have an adverse effect on strength and motor control by slowing nerve conduction velocity [30].

Heat applied to peripheral tissues can be used to increase the laxity in ligaments [31-33]. The application of heat reduces pain [32, 34-39]. Heat can also increase blood flow to tissue [40-45]. 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 [46-48].

And yet while heat is used clinically as a treatment for many disorders, little has been done to examine the effects of heat on gait and balance in the elderly. Recently, heat was applied to the knees of people with nonspecific knee pain. The authors found that heat and exercise showed a large improvement in gait by reducing knee pain and improving physical function [49]. Similar results were seen in another study on arthritic knees [50]. Hot and dry heat was applied for 20 minutes and temporal gait parameters were assessed in another study [51]. Body fat reduces heat transfer even with moist heat and there was probably little heating of deep tissue [52-55]. Heat in all of these studies was applied for very short periods of time. Low level continuous heat wraps penetrates deep into tissue and causes warming in muscle and joints [46,55]. Further, with hours of heat application, there is a carryover effect that keeps blood flow high for as much as 24 hours post application of heat and contributes to self-warming of tissues [34,37,56]. Continuous low level heat wraps have not been studied as to any effects on gait or balance.

In the present investigation we looked at the effect of continuously applied heat on the legs of the elderly with known gait impairments and balance impairments for a 1 week period to see if repeated heat treatments make their balance better.

## Subjects

Twenty healthy subjects 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 [57]. This score indicates a high risk of falls. 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).

| | 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.

## Methods

### "Stepping on" questionnaire [57]

A fall questionnaire was used to screen the subjects. It has been developed and validated in other studies [58]. There are 13 questions. A score of greater than or equal to 4 is considered as an indicator of high risk for falls.

### Gait mobility testing

To test mobility as specified by the National Institutes of Health, the time up and go test was used [59-61]. The stand up and go started with the subject sitting in a chair and on visual command would stand up and walk 20 feet. This was repeated two times. Temporal and pressure characteristics were recorded under the two test conditions. Gait temporal characteristics and pressure was measured on a Zeno walkway (Protokinetics, Havertown, PA).

### Analog visual pain scale for gait

A visual analog gait ability scale that was used in this study was from 0 to 10. Subjects placed a vertical mark across a 10 cm horizontal line such that the closer they marked the mark to the 10 cm point; the greater was their difficulty in gait. The first step in calculating the combined difficulty was to multiply the visual analog score by 10. Thus, the score went from 0 to 100. One hundred on this scale was extremely hard mobility whereas zero showed no impairment.

### Balance testing- 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 [62]. Some studies used coefficient of variation of the weight displacement as measures of the postural sway [63-67]. Petrofsky and collogues [68-70] used the 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.

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 [66]. 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 outputs of the 4 Wheatstone strain gauge bridges were amplified by a Biopac MP35 low-level bio-potential amplifier and were digitized through a 24-bit A/D converter. The sampling rate was 1000 samples per second [66].

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 ÷ Mean × 100%) as a measure of the postural sway [66]. The average CV of each task was determined over a 5 second sample of the data.

### Balance tasks

Eight quiet standing balance tasks, each lasting for 10 seconds, were included in this study. 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 & closed) were used in the balance tasks. To alter the somatosensory input, 2 different surface compliances (firm surface and foam) were used. The Aero mat balance block, a PVC/NBR foam with size 16 × 19 × 2.5 inches and density around 0.04-0.06 g/cm$^3$ (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).

## Application of Heat

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 lower back. It was kept on for 4 hours.

### Procedures

Subjects first entered the laboratory and filled out the IRB documentation and rested for 15 minutes. Next, balance was tested on the balance platform. The analogue visual gait difficulty scale was filled out to see daily leg pain levels during gait. The timed up and go test was also accomplished. These measures were repeated at day 0 (before heat) and at day 7, after 6 days of heat. Heat was used daily for all 6 days and subjects filled out a compliance log and analog visual gait difficulty scales for comfort in gait each evening and morning when they woke. They then wore heat until the morning of testing but not during testing. Half of the subjects used heat first and the other half was just tested 1 week apart. The groups were then reversed with the heat group now being tested 1 week later with no heat application (Table 2).

## Results

### Balance

The results of the balance platform data are shown in (Figures 1, 2 and 3).

| | **Firm Surface** | | **Foam** | |
|---|---|---|---|---|
| **Feet position** | 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 eight balance tasks used in the study were set to challenge balance by removing one, 2 or 3 of the major inputs into balance. The order was at random but the display of the tests in increasing order of difficulty is as shown in a previous publication [33]. The order of the tasks and the result on sway from this publication is shown in (Figure 1) below.

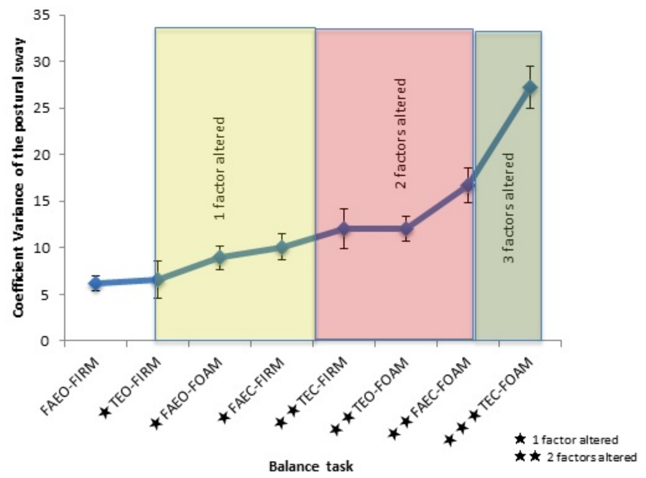


**Figure 1:** The postural sway in the 8 balance task challenge used here by increasing order of difficulty [33].

This figure shows that by altering 1, 2 or all 3 factors that are sensory inputs for balance, the coefficient of variation of platform movement (sway) increased with the increasing difficulty of the task. Interestingly, for the most difficult balance tasks, brain activity over the motor strip also increased in previous studies showing that for the 5 less difficult tasks, peripheral reflexes were able to compensate for postural challenges but for the most difficult challenges, motor control shifted to the brain [33,71].

In the present investigation, the results after heat and no heat application are shown in (Figure 2). As can be seen in Figure 2, the use of heat reduced sway significantly ($p<0.01$) comparing data in the group under control conditions (no heat testing before and 1 week later) to the week after heat for the 6 most difficult balance tasks ($p<0.01$). There was no statistical difference between the groups in the first test and second test (the 2 easiest balance tasks) ($p>0.05$).

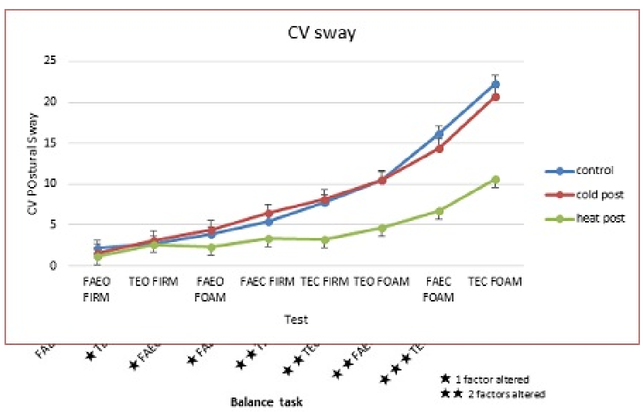


**Figure 2:** The average +/- the standard deviation of the coefficient of variation of postural sway in all of the subjects under 3 conditions; control, after 1 week as a repeated measure and after 1 week of heat.

For the no heat group, when one factor was altered, comparing feet apart eyes open on foam compared to a firm base of support, there was a 3 fold increase in sway. The same two tasks, when compared before and after heat for 1 week showed less than double the sway. When 2 factors were altered, e.g. feet apart eyes closed foam compared to feet apart eyes open firm, in the no heat group showed a 12 fold increase whereas after heat, a similar comparison showed a 4.6 fold increase in sway. Finally, with 3 factors altered, with eyes closed, tandem on foam, the sway in the no heat group increased, compared to the easiest task, and increased 19 fold whereas after heat the increase with 3 factors altered was 7.8 fold higher. Thus for 1, 2 or 3 factors altered, sway was significantly less after a week of heat ($p<0.01$) even though heat was not used during testing.

## Tremor

(Figure 3) 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.

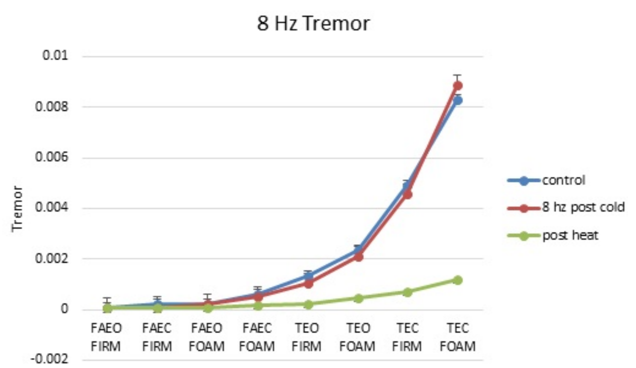


**Figure 3:** The tremor during the 8 balance tasks in all subjects under 3 conditions, control, post no heat use for 1 week and post heat use for 1 week. In all subjects as the mean +/- the SD.

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 ($p<0.01$).

## Time up and go time (TUG)

This 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 [59-61].

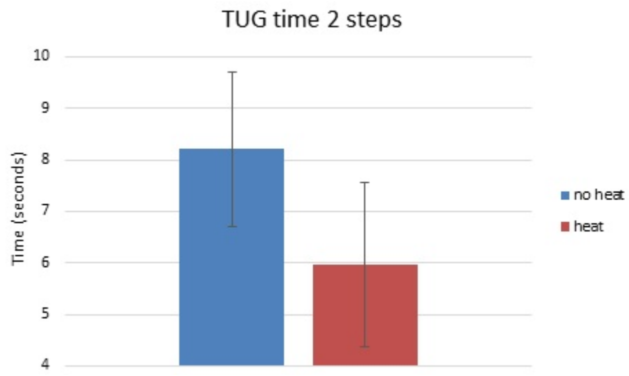


**Figure 4:** The time from standing through the first 2 steps in the 2 groups of subjects as the means +/- the standard deviation.

For the first 2 steps the timing can be measured and are interesting because on standing, there is the greatest instability in balance and the greatest reliance on strength. The time for the first 2 steps is shown in (Figure 4). As shown there was a significant reduction in the time for the first 2 steps from sitting 1 week after the application of heat ($p<0.01$).

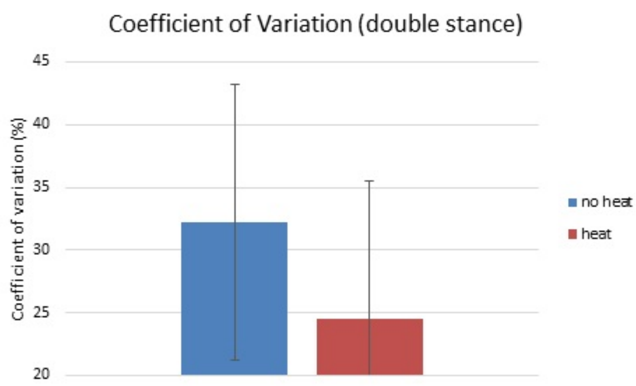


**Figure 5:** The coefficient of variation in the center of gravity during gait in the 2 groups of subjects as the means +/- the standard deviation.

During the walk, the center of gravity was assessed and the coefficient of variation of sway was established. The greater the number, the greater the instability of the subject on walking. As shown in Figure 5, there was a significant reduction in sway during gait in the heat group ($p<0.01$). The Time up and go time is shown in (Figure 6).

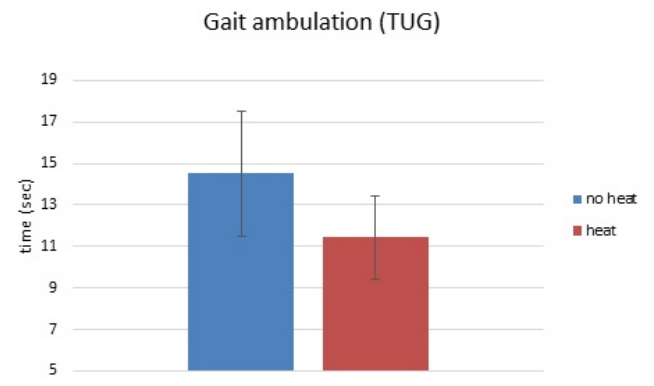


**Figure 6:** The time up and go time (TUG) in the subjects after no heat and after 6 session of heat. Data is the mean +/- the standard deviation of the group.

As shown in (Figure 6), the time to complete the track was significantly faster in the heat group ($p<0.01$).

## Benefit of heat in walking as assessed by the subjects

As shown in (Figure 7), Gait was significantly easier after the application of heat as assessed by the subjects ($p=0.02$) comparing pore and post heat gait averaged over 6 days. Each point is the mean of 6 days on all subjects +/- the standard deviation.

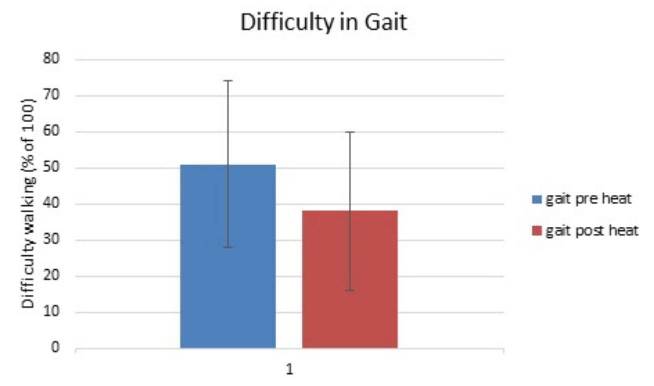


**Figure 7:** The subject's perceived difficulty walking before and after application of heat to their legs bilaterally. 100% is very very difficult and 0 is easy gait. The data is the average of the group +/- the standard deviation.

## Discussion

Falls have been defined as "an unexpected event in which the participant comes to rest on the ground, floor, or lower level" [72]. With an ageing population in the United States, mobility is a major concern in health care [2,73]. Poor mobility and poor balance, leads to unsteady gait and falls [10,74,75]. 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 [7,76]. In the elderly, multifactorial intervention has proved best to reduce fall incidence [74].

Balance involves the integration of the visual, vestibular, and somatosensory systems [69,70,77-79]. Failure of any of these 3 can be compensated for by the other 2, but in ageing, all three systems are impaired, contributing to falls. Balance is not just for standing, but it is an integral part of gait [65]. During gait, the visual fields are continually changing as well as the center of mass of the body relative to the base of support [69,78,80]. As such, impairment of the visual, vestibular, and somatosensory systems can result in increased postural sway and a loss of balance resulting in falls [81-85].

In the present investigation, balance, as reported previously, was impaired in the older individuals examined here. This population was chosen because of gait impairments. When tested before intervention, their balance was still poor compared to younger people. After 1 week of using no heat and the experiments were repeated, there was no difference in sway on the second measurement. This precludes the possibility of training since the study used a cross over design. But when heat was used, even though it was used before and not during the measurements, there was much better balance and gait improved as assessed by the Time up and go test and sway during gait. This is not surprising since heat increases flexibility and elasticity of muscle, tendons and ligaments [30,86,87]. It also increases circulation to reduce inflammation and increase healing [55,56]. The fact that gait and balance improved while heat wasn't being applied shows a carryover effect of using heat. For example, when wounds were warmed for 30 minutes with heat, 24 hours later, circulation and tissue temperature were still elevated [33,56]. A key to the improved balance and better gait may be the reduction in muscle tremor. Tremor indicates motor loop errors. In previous studies, it has been shown that the greater the tremor, the poor the balance [88]. Further, if motor control is poor enough, there is also a corresponding increase in EEG on the motor strip as control shifts from peripheral reflexes to central control. The reduction in tremor may be due to the increased elasticity in the tendons.

The increased elasticity would cause the joints to use more muscle activity to stabilize movement and potentially reduce motor error as is seen in runners as they accommodate to different surfaces [89,90]. Further, the increased temperature increases nerve conduction velocity [30] which may in turn, allow for better motor control. Increased heat also alters the force velocity relationship in muscle, allowing for faster operation [91,92] and increased tissue metabolism [93]. All of these may contribute to fewer tremors but further investigation is needed.

There is other evidence for the benefit of heat. In other studies, heat packs and moist heat packs have been shown to improve gait in the elderly [51]. Heat also reduces pain and increases range of motion [86,87,94]. In women, there are fewer injuries to the knee and ankle when flexibility of tissue is greatest, at ovulation [86,87]. It is not unreasonable in older people that increased flexibility and increased metabolism due to heat will lead to fewer falls and injuries. The use of heat over longer periods of time would be interesting to study.

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