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

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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 ThermaCare 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].

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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 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 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 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 [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 ÷ Mean × 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

Analogue visual scale for difficulty of gait: Participants were asked to mark on a 10 cm AVS to rate the degree of difficulty of 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 (f firm surface & 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/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 revered 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 form 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)
improvement in time (p<0.01). Of interest were the first 2 steps since there was a significant improvement to 11.4 ± 3.5 seconds, a significant ± 3.9 seconds in the control and no heat conditions while after heat, strength. The faster a person can stand up and walk the less chance of In institutes of health. It shows a measure of motor control and muscle and go (TUG) is a standard measure of gait that is used by the National a comfortable speed for the TUG test and walking tests. The Time up motor moving the belt. The Zeno walkway allowed subjects to walk at shown by the p values on Table 4.

Table 3, as control data before heat and Table 4 as the difference between after application of heat for one week, it averaged 63.4 ± 15.1 neutons/kg body mass.

After application of heat for one week, it averaged 72.5 ± 9.6 neutons/kg body mass and force for the 2 conditions where heat was not used (control and with (p<0.01) 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 spacialcial 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 spacialcial 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 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 ± 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.
education has been shown to reduce the risk and fear of falls [54].

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

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].

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.

| Spatial Parameters | PRE | Temporal Parameter | PRE |
|--------------------|-----|--------------------|-----|
| Step Length (cm)   |     | Step Time (seconds) |     |
| Stride length (cm) |     | Stride Time (seconds) |     |
| Step Width (cm)    | 0.47 | Cadence (steps/min) | 5.65 |

| mean | SD | p  |
|------|----|----|
| -2.99 | 4.85 | 0.032 |
| -3.53 | 4.15 | 0 |
| 0.47  | 2.83 | 0.533 |
| -0.03 | 0.05 | 0.022 |
| -0.09 | 0.09 | 0.002 |
| 5.65  | 5.81 | 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.

Figure 4: The gait symmetry in the subjects after no heat and after 6 session of heat. Data is the mean +/- the standard deviation of the group for the single stance phase.

Figure 5: The cadence external rotation of subjects after no heat and after 6 session of heat. Data is the mean +/- the standard deviation of the group.

Figure 6: 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

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 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].

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.

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 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 [17,26,60]. 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.

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].

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Another study found an inverse correlation between falls and gait speed and stance time [65].

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 underestimated, 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. Jargensen 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, Lewellyn 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 39: 91-95.
10. Schalow G (2001) Time axis calibration in human CNS organization for judging dysfunction. Electromyogr Clin Neurophysiol 41: 485-505.
11. Dowiach 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, Sahlmann SA, Schaal 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. Dohm IM, Hagströmer M, Hellenius ML, Stähle 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 RV (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, Khwalled 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, Alshahmri M, 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, Russi 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 39: 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. Sato H, Iida H, Hiasaka 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, Gorakash N, Alshahmri 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, Güleşen B, Bıcklı 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 WE (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: 684-688, 688-91.
51. Fasano A, Plotnik M, Bove F, Berardelli A (2012) The neurobiology of falls. J Safety Res 43: 493-499.

50. Davis JC, Best JR, Bryan S, Li LC, Hsu CL, et al. (2015) Mobility is a key component of the Compendium of falls. J Appl Physiol 101: 81-89.

49. Davis JC, Best JR, Hsu CL, Nagamatsu LS, Dao E, et al. (2015) Examining the factors contributing to falls in older people. J Appl Physiol 101: 337-348.

48. Kojima G, Masud T, Kendrick D, Morris R, Gawler S, et al. (2015) Does the motor system play a role in the etiology of falls in older people? J Appl Physiol (1985) 90: 2117-2129.

47. Hassani A, Kubicki A, Brost V, Mourey F, Yang F (2015) Kinematic analysis of foot-strike patterns in female runners. Med Sci Monit 13: 2021-2030.

46. 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. J Motor Behav 19: 175-186.

45. Petrofsky JS, Laymon M, Khwailed IA, Lee H (2016) The Effect of Thermacare Heat Wraps on Balance and Mobility in Seniors with Impaired Gait - A Cross Over Study. Physiother Rehabil 1: 105. doi:10.4172/jppr.1000105

44. Usui N, Maekawa K, Hirazawa Y (1995) Development of the upright postural sway of children. Dev Med Child Neurol 37: 985-986.

43. 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. J Appl Physiol 91: 705-712.

41. Kouzaki M, Shinohara M (2010) Steadiness in plantar flexor muscles and its relation to postural sway in young and elderly adults. J Appl Physiol 109: 771-787.

40. Petrofsky JS, Laymon M (2009) Heat transfer to deep tissue: the effect of body fat and heating modality. J Appl Physiol 103: 337-348.

39. 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. J Motor Behav 19: 175-186.

38. 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.

37. Hassan 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? J Appl Physiol (1985) 90: 209-211.

36. Kojima G, Masud T, Kendrick D, Morris R, Gawler S, et al. (2015) Does the motor system play a role in the etiology of falls in older people? J Appl Physiol (1985) 90: 2117-2129.

35. 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 93: 1634-1640.

34. Fasano A, Plotnik M, Bove F, Berardelli A (2012) The neurobiology of falls. J Neurosci 33: 1215-1223.

33. 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: 1615-1622.

32. Hausdorff JM, Nelson ME, Kiliston 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.

31. 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.

30. 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.

29. Peel NM (2011) Epidemiology of falls in older age. Can J Aging 30: 7-19.

28. 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.

27. 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: CR400-406.

26. Petrofsky J, Berk L, Alshammari I, 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.

25. Mazzucca SA, Page MC, Mundrum 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.

24. 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.

23. 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.

22. Cumming RG (1998) Epidemiology of medication-related falls and fractures in the elderly. Drugs Aging 12: 43-53.

21. 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.

20. Lord SR, Lloyd DG, Li SK (1996) Sensori-motor function, gait patterns and falls in community-dwelling women. Age Ageing 25: 292-299.