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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, theA 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 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 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.

	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 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

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 × 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) [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 tibialus 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 if 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)

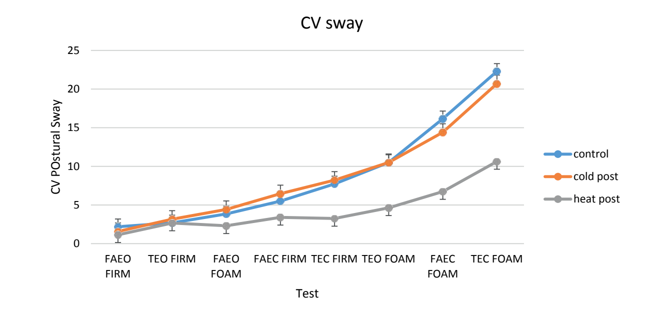

Figure 1: The average +/- the standard deviation of the coefficient of variation of postural sway in all of the subjects under 3 conditions; control, after 1 week as a repeated measure and after 1 week of heat.

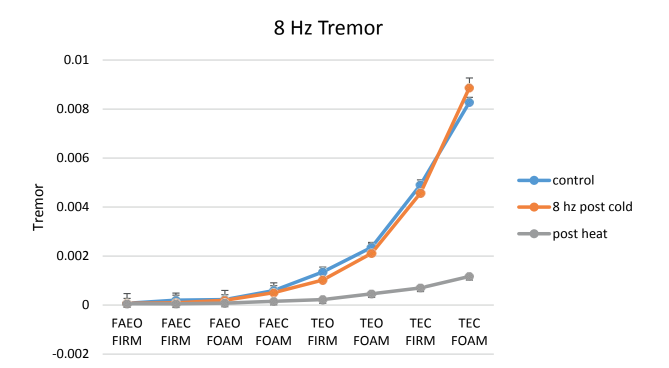

Figure 2: The tremor during the 8 balance tasks in all subjects under 3 conditions, control, post no heat use for 1 week and post heat use for 1 week. In all subjects as the mean +/- the SD.

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.

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 vastis medialus 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 spacialecial 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 spacialecial 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% ($p<0.01$).

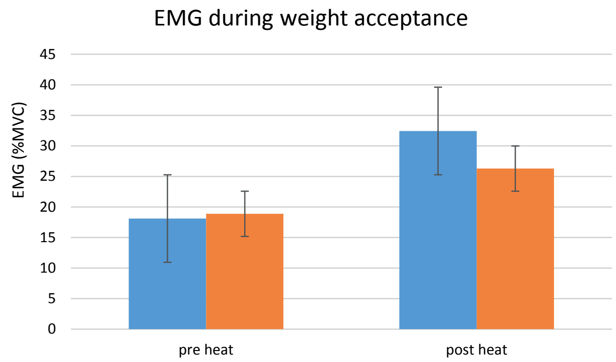

Figure 3: The muscle activity of the knee extensors on the medial and lateral knee in the control period and after 1 week of application of heat.

	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.

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.

	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	-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.

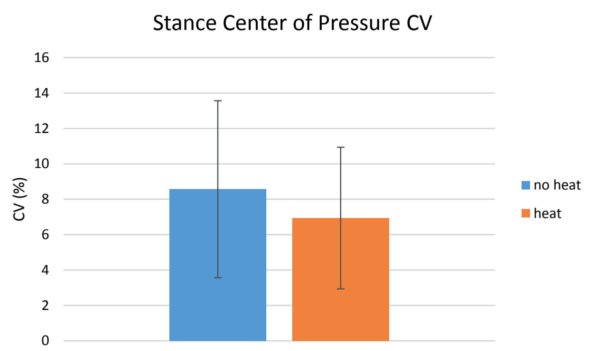

Figure 4: The gait symmetry in the subjects after no heat and after 6 session of heat. Data is the mean +/- the standard deviation of the group for the single stance phase.

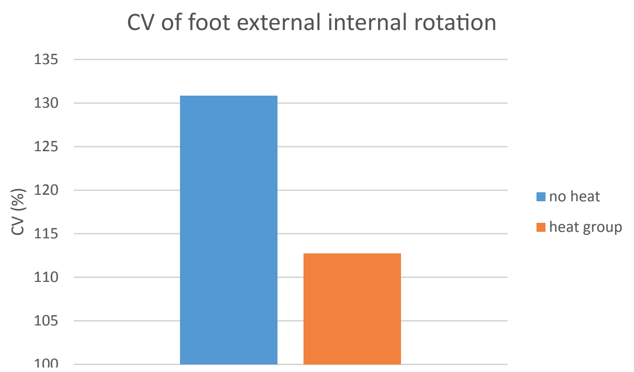

Figure 5: The cadence external rotation of subjects after no heat and after 6 session of heat. Data is the mean +/- the standard deviation of the group.

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 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].

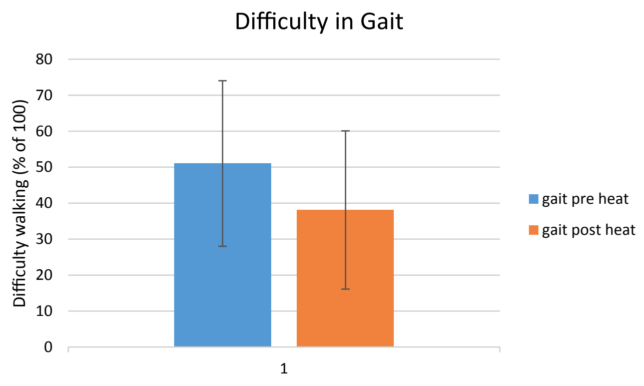

Figure 6: The subject's perceived difficulty walking before and after application of heat to their legs bilaterally. 100% is very very difficult and 0 is easy gait. The data is the average of the group +/- the standard deviation.

Poor gait is related to the incidence of falling. Anything that increases temporal and spacialecial 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]. 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].

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 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.

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