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The Effects of Tai Chi on Balance and Peripheral Somatosensation in Older Adults with Type 2 Diabetes

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THE EFFECTS OF TAI CHI ON BALANCE AND PERIPHERAL SOMATOSENSATION IN OLDER ADULTS WITH TYPE 2 DIABETES

by

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Abstract

The increasing prevalence of type 2 diabetes in older adults is a major health concern, as older adults with diabetes have a two- to threefold risk of injurious falls and physical disability. Although studies on the effects of Tai Chi on balance and fall prevention have increased over the last two decades, the benefits for older adults with diabetes, specifically for those with impaired somatosensation in the lower extremities, are limited. Therefore, the purpose of this study was to investigate the effects of Tai Chi exercise on balance, peripheral somatosensation, and fitness in older adults with type 2 diabetes. The study included eight adults with type 2 diabetes (mean age: 65.5 years) who participated in an 8-week Tai Chi intervention. Pre- and post-intervention assessments included foot tactile sense, ankle proprioception, plantar pressure distribution, balance, and fitness. A convenience sample of healthy older adults was included to establish a normal reference for the assessed variables. Following intervention, the older adults with type 2 diabetes showed significant improvements in ankle proprioception and fitness, and decreased plantar pressure in the forefoot. The Tai Chi intervention did not change balance or tactile sensation. The results of this study suggest that Tai Chi practice may contribute to foot health by distributing the plantar pressure away from the ulcer-prone sites in the forefoot. Tai Chi may also reduce the fall risk in older adults with diabetes by improving the ankle proprioceptive sense, which is thought to be an important factor for automatic balance correcting responses.

Keywords: diabetes, elderly, ankle proprioception, tactile sensation, plantar pressure

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Manuscript

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The Effects of Tai Chi on Balance and Peripheral Somatosensation

in Older Adults with Type 2 Diabetes

According to the most recent estimates from the World Health Organization (WHO), more than 220 million people worldwide have diabetes, and this number will double within the next 20 years (WHO, 2011). By then, most individuals with diabetes in developed countries will be 64 years and older, while those in underdeveloped countries will be between 45 and 64 years of age (Wild, Roglic, Green, Sicree, & King, 2004). Of those with diabetes, approximately 90% have type 2 diabetes in which the body does not produce enough insulin or utilizes the available insulin inefficiently (Acharya et al., 2008).

Type 2 diabetes, also known as non-insulin-dependent diabetes mellitus (NIDDM), is often the result of uncontrolled metabolic syndrome, which is a cluster of interrelated risk factors including elevated blood pressure, high levels of blood lipids, elevated fasting glucose, and obesity (Alberti et al., 2009). The chronically elevated blood glucose level that is characteristic for type 2 diabetes predisposes patients to long-term complications (Lambers, Van Laethem, Van Acker, & Calders, 2008). Moreover, pathophysiological factors can impair lower-extremity functioning of older adults with diabetes. These factors, including uncontrolled hyperglycemia, reduced peripheral blood flow, weakened muscle strength, altered proprioception, and diminished motor coordination, are key contributors to loss of physical independence for older people with diabetes (Gregg et al., 2000; Park, Goodpaster, Strotmeyer, & de Rekeneire et al., 2006).

The reduced blood flow and uncontrolled hyperglycemia can lead to peripheral diabetic neuropathy, which is characterized by a progressive loss of nerve fibers that affects foot sensation, innervations of the small muscles of the foot, and fine vasomotor control of the pedal circulation (Gonzales & Oley, 2000; Jeffcoate & Harding, 2003). While a minority of people with neuropathy experience symptoms that manifest as burning sensation, sharp pain, numbness, and pain to normal touch, the majority have insidious symptoms such as the inability to feel, assess temperature, or sense painful stimuli, particularly in the periphery (e.g., the foot). As a result of the loss of protective sensation, individuals with peripheral neuropathy are at an increased risk for microtrauma and hidden injury to the foot, which can cause infections, calluses, and ultimately foot ulceration (Pinzur, 2002; Vinik, Park, & Stansberry, 2000). Diabetic foot ulcerations are one of the primary reasons for hospitalization among the diabetic population and the leading cause of non-traumatic foot amputations (Jeffcoate & Harding, 2003; Pinzur, 2002; Vinik et al., 2000).

Although not all individuals with type 2 diabetes develop peripheral neuropathy, over time, a chronically elevated blood glucose level can affect the sensorimotor receptors in the lower extremities, thereby compromising an important mechanism for balance control (Gurfinkel, Ivanenko, Levik, & Babakova, 1995). The altered sensorimotor receptors along with diminished peripheral sensation and a greater postural instability (Richerson, Robinson, & Shum, 2005) may explain why older adults with diabetes have a two- to threefold higher risk for falls and physical disability compared to non-diabetic elderly (Park, Goodpaster, Strotmeyer, & Kuller et al., 2007).

To reduce the fall risk of older adults with and without diabetes, exercise intervention programs including resistance, endurance, balance, and flexibility training have been suggested. The benefits of such programs include improved overall health and the preservation of independence (Choi, Moon, & Song, 2005; Mihay, Boggs, Breck, Dokken, & NaThalang, 2006). More recently, Tai Chi has been recognized as an effective alternative to traditional exercise programs for fall prevention among older people in Western societies (Lin, Hwang, Wang, Chang, & Wolf, 2006). Tai Chi, an ancient Chinese martial art, incorporates elements of strength, balance, postural control, and concentration, and is recognized as one of the most effective interventions for reducing falls in the older adult population (Choi et al., 2005; Lin et al., 2006; Mihay et al., 2006). Because its movements are slow, continuous, and low-impact, Tai Chi exercise is particularly suitable to the physical condition of older people. Although it is only since the early 1990s that the effects of Tai Chi on balance have been scientifically investigated in English peer-reviewed literature, there is evidence that this non-traditional form of exercise has beneficial effects on the physical health and well-being of older adults (Yau, 2008).

While interest in Tai Chi's benefits for the elderly is growing in the Western world, the benefits for older adults with diabetes, specifically for those with diminished peripheral somatosensation, are limited. With the growing prevalence of type 2 diabetes among older adults and the associated high fall risk, there is a need for appropriate treatment strategies and therapeutic interventions. Therefore, the purpose of this study was to investigate whether Tai Chi exercise may be an appropriate treatment strategy to improve diminished somatosensation and the subsequent high fall risk in this population. The primary objective was an assessment of balance, foot tactile sense, and ankle proprioception; the secondary objective was an evaluation of overall fitness. In order to understand how the outcome measures of the diabetic older participants differed from non-diabetic adults of similar age, the data were compared to those of healthy older adults.

Methods

Study Design

The study was a single-arm Tai Chi intervention with a pre-posttest within-subjects design. The intervention phase for the older adults with diabetes consisted of eight weeks of Tai Chi training, during which 1-hour sessions were offered three times a week at the Texas School of Tai Chi in El Paso (east side and west side location). Outcome data were collected prior to the start of the intervention and after eight weeks (intervention termination). A convenience sample of healthy older adults was included to establish a normal reference for foot tactile sensation, proprioception, balance, and fitness. The study protocol was approved by the Institutional Review Board of the University of Texas at El Paso (UTEP).

Participants

Eight older adults with type 2 diabetes participated in the Tai Chi intervention. They were recruited by direct contact with attendees of educational classes at the El Paso Diabetes Association (EPDA) and through ambassadors of the UTEP Wellness Program. To be included in the study, the participants had to be between 55 and 80 years of age, diagnosed with type 2 diabetes for more than five years, and live independently within the community. Exclusion criteria included engaging in moderate or strenuous exercise three months prior to the start of this study, inability to walk independently, chronic medical problems (other than diabetes) that limited physical activity participation, a body mass index (BMI) greater than 40 kg/m^2, and cognitive impairments. In addition, participants needed a physician's clearance for participating in low-to-moderate intensity exercise and had to agree to participate three times per week in the 8-week intervention. Eight healthy adults without diabetes but with the same inclusion/exclusion criteria were included in this study to serve as a referent.

Study Protocol

Potential participants (n = 21) were initially screened by telephone for eligibility in this study. Those who met the study criteria and agreed to fully participate (n = 16) were scheduled for an assessment during which the study was explained in further detail. With enrollment in the study, participants signed the university-approved informed consent form and responded to a general health questionnaire. The single assessment of the referent population and the pre- and post-intervention assessments of the diabetic group were made during a prescheduled appointment with each participant. All assessments followed a similar protocol. The participants were first tested on the Tekscan pressure mat, followed by the monofilament, the ankle proprioception, and the fitness test. In addition, a standardized script was used to ensure that all participants received the same instructions and encouragements.

Outcome Measures

The primary outcome measures included assessments of balance, plantar pressure distribution, foot tactile sense, and ankle proprioception. Balance and plantar pressure were determined using the Tekscan pressure mat (Tekscan Inc., Boston, MA). Foot tactile sense was measured with the Semmes-Weinstein Monofilament test, and ankle proprioception was assessed through joint angle reproduction (JAR) using a goniometer. Information gathered from the Tekscan provided insight into how each participant loaded his or her feet and to determine the extent of postural sway; the JAR test measured static proprioception or position sense.

The secondary outcome measure included an assessment of overall fitness. Overall fitness level was assessed with the Senior Fitness Test (SFT), a standard fitness test for older adults (Rikli & Jones, 2001). The SFT included tests such as arm curls, chair stand, back scratch, chair sit-and-reach, 8-foot up-and-go, and 6-minute walk. Data obtained from these tests revealed information about the participants' strength, flexibility, mobility, and cardiorespiratory fitness.

Foot tactile sense (Semmes-Weinstein monofilament test). The Semmes-Weinstein monofilament test measures the sensitivity of nerves and is a common tool to assess the extent of sensory function loss with peripheral neuropathy. The monofilament test is a thin piece of nylon wire that is touched to the skin until it bends. Without looking at the tester or at the wire during testing, the patient is asked to express when he or she feels the touch.

For this study, a 5.07/10g monofilament was used because detection denotes the threshold of “protective sensation” or the amount of sensation necessary to prevent hidden injury (Guyton & Saltzman, 2001). After the procedure was explained, the participants were asked to lay supine on a massage table and close their eyes to begin the testing. Six pedal sites were tested on each foot (Figure 1). Each site was tested three times, with two “active” tests where the monofilament touched the skin and one “sham” where the monofilament did not touch the skin. With each active or sham test, the participants were asked “Do you feel it – yes or no?” Testing stimuli (active touch or sham) were randomly presented three times at each of the six sites. The order of sham and active application and the site order of the monofilament testing were the same for all participants. Participants were classified as having peripheral neuropathy if two of the three applications at a site were answered incorrectly.

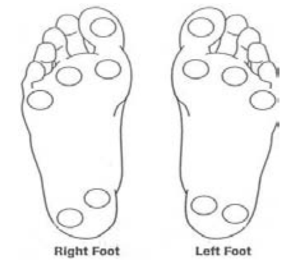

Figure 1: Semmes-Weinstein monofilament test

Ankle proprioception. Proprioceptive measures were evaluated by determining the participants’ ability to reproduce a target joint angle, called joint angle reproduction (JAR). A universal goniometer (Baseline™) was used to measure right and left ankle flexion and extension. The participants were seated on a massage table with both legs hanging freely over the edge. After the procedure was explained, the fulcrum of the goniometer was centered over the lateral aspect of the right lateral malleolus. The proximal or stationary arm of the goniometer was aligned with the midline of the fibula, using the head of the fibula as a reference point. The distal or movable arm of the goniometer was aligned parallel with the fifth metatarsal (Norkin & White, 1985). The participants had one familiarization trial with eyes open and a second trial with eyes closed. For the assessment, the participants were asked to place both hands behind them on the table, close their eyes, and concentrate on the ankle joint movement.

The test started with the ankle resting at each participant's natural angle, from where it was slowly moved either 10° towards the shin (dorsiflexion) or 10° towards the pointed toe (plantarflexion or extension). The participant was instructed to concentrate on the sensation of the joint angle, while the position was held for five seconds. After returning the foot to the starting position, the participant was asked to reproduce the target angle. The difference between the target and actual angle to the nearest ± 0.5 degrees was recorded. There were five trials for each ankle movement for a total of 10 trials per foot. The order of testing for the movements to flexion and extension were predetermined, and each participant underwent the same testing order. The average for the ankle flexion and the extension joint reproduction angle was calculated and presented as absolute error, reflecting the total number of degrees away from the target angle, and as relative error with positive and negative values representing the degrees of overshoot and undershoot, respectively.

Plantar pressure distribution and center of pressure. Using the Tekscan pressure mat, the participants' center of pressure (COP) and loading of the foot (peak pressure points) were determined. The mat was at ground level (0.3 cm in depth) with a solid floor, and the data capture rate was set to 40 Hz. Prior to data collection, the pressure mat was calibrated to each participant's body weight based on the manufacturer's recommendations (Tekscan, 2010).

Plantar pressure was measured on the great toe, 1^{st}, 3^{rd}, and 5^{th} metatarsal head (MTH), and the heel of each foot, while the participants were standing barefoot with both feet weighted on the pressure mat for 30 seconds with eyes open. These sites were chosen because pressure changes from the heel to the forefoot in people with diabetes may present an early marker of peripheral neuropathy (Boulton et al., 1987). The peak plantar pressure for each site was computed by averaging the 1200 movie frames (Tekscan Mat Research, v6.40). Two different measurement units were used to show both the absolute peak pressure to which the tissue in each assessed area was exposed (kPa/cm^2) and the peak pressure after it was normalized to body weight (kPa/kg).

Balance was assessed by determining the center of pressure (COP) displacement in the anterior-posterior (A-P) and medial-lateral (M-L) direction during double-leg stance with eyes closed. The eyes-closed assessment was chosen as a means for eliminating differences in visual acuity between participants. The participants were instructed to stand barefoot and in comfortable stance width with arms across the chest on the pressure mat for 30 seconds. Total sway area (cm^2) and COP displacement in the A-P and M-L direction was computed by using the sway analysis module (SAM) feature included in the clinical Tekscan software (Mat Research, v6.40).

Senior Fitness Test (SFT) (Rikli, & Jones, 2001). Each of the following SFT tests was initially explained and demonstrated, followed by one familiarization trial to ensure the correct form and execution of the exercise. The order of testing was consistent for all participants. In addition, the participants were informed that they are free to stop at any time during each of the tests if needed.

Arm curls. This test was used to assess the participants' upper body strength. The test was performed in a seated position, with the chair firmly placed against the wall. The participants were instructed to start with the right arm and to complete as many arm curls as possible in 30 seconds. After a 1-minute rest period, the test was repeated with the left arm. Men used a 5-pound (2.27 kg) weight, and women used a 3-pound (1.36 kg) weight. The number of full arm curls was recorded and used for the analysis.

Chair test. This test measured the participants' lower body strength and coordination. The participants were seated all the way back in a stable chair of standard height (0.44 m) without armrests placed firmly against the wall. They were instructed to stand up and sit down as many times as possible in 30 seconds with arms folded across their chests. The requirement was to stand up fully between repetitions and to sit down without touching the back of the chair. The numbers of full up-and-down cycles were recorded and used for the analysis.

Back scratch. This assessment was used to determine the participants' shoulder flexibility. The participants were instructed to reach with one hand over the shoulder and with the other hand up the middle of the back from a standing posture (Figure 2). After a warm-up trial for each arm, the participants started with the right arm reaching over the shoulder, followed by the left arm reaching over the shoulder. The distance between the middle fingers was recorded as a negative (-) value if the fingers did not touch and as a positive (+) value if the fingers reached past one another (overlapped). Each side was tested twice, and the average of each side was calculated and used for the analysis.

Figure 2: Back scratch

Chair sit-and-reach. This test assessed the participants' lower body flexibility. The participants were tested in a standard chair (height 0.44 m), with the chair's back placed firmly against the wall. The participants were asked to sit on the edge of the chair, with one leg extended as straight as possible and the other leg bent at 90 degrees, and with both arms stretched out, hands overlapping with middle fingers even (Figure 3). They were instructed to reach for the great toe of their extended leg. After a warm-up trial for each leg, the participants started with the right leg extended, followed by the left leg extended. The distance between the middle fingers and the great toe was recorded as a negative (-) value if the fingers did not touch the toe or as a positive (+) value if the fingers reached beyond the toe. Each participant completed two trials with each leg, and the average of the two trials was calculated and used for the analysis.

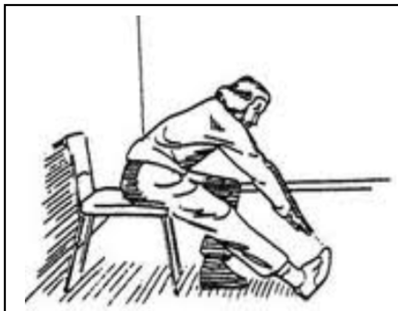

Figure 3: Chair sit-and-reach

8-foot up-and-go. This assessment was used to determine the participants' agility and dynamic balance. The participants were seated all the way back in a stable chair of standard height (0.44 m) without armrests placed firmly against the wall. At the tester's "Go," the participants stood up, walked eight feet (marked by a small orange cone), turned around, and returned to their seated position. The time from the initial seated position to the final seated position was recorded. Each participant completed two trials, and the average of the two trials was calculated and used for the analysis.

6-minute walk test (6MWT). This test assessed the participants' aerobic conditioning. The 6MWT was performed indoors on a long, flat, and straight surface. The walking course was 30 m in length (approximately 100-ft) in a hallway directly outside the Stanley E. Fulton Biomechanics and Motor Behavior Laboratory located in the Durham Center. The length of the walking course was marked every two meters, and the turnaround points on both ends were marked with an orange traffic cone. The participants were instructed to cover as much distance as possible by walking back and forth as fast as possible around the cones. They were allowed to slow down, stop, and rest if needed during the allotted 6 minutes (two chairs were placed in the hallway for this occasion), but encouraged to resume walking as soon as they were able. A research assistant oversaw the 6MWT and tallied each participant's completed laps (from starting cone back to starting cone) on a worksheet. The spot where the participants finished their walk was marked with a bean bag. The total distance walked was calculated by multiplying the number of finished laps by 30 m and adding the distance covered in the final lap.

Intervention

The Tai Chi lessons were taught by an experienced Tai Chi instructor who followed the classic Yang style (long form, first section), which emphasizes multidirectional weight shifting, awareness of body alignment, and coordination of movement. Additionally, guidance in correct breathing techniques was provided and integrated into the Tai Chi routine. Each session began with specific warm-up exercises for approximately 10 minutes, followed by 45 minutes of Tai Chi practice, and ended with approximately five minutes of breathing exercises. During Tai Chi practice, the previously learned forms were repeated prior to adding new forms. Furthermore, the instructor placed great emphasis on the correct execution of the movements, particularly on foot placement, weight shifts, and postural alignment. All participants received a DVD and were encouraged to practice at home, but were not queried regarding their home practice.

Data Analysis

Data analyses were conducted using the statistical software package SPSS v18.0 (SPSS Inc., Chicago, IL). All data were checked for normality using the Shapiro-Wilk's test. For the intervention group, several variables violated the assumption of normality; therefore, a difference score was calculated between pre- and posttest data for each paired variable and normalized through Log transformation. A one-sample *t*-test was used to determine if difference scores were significantly different from zero. Within the referent group, many variables also violated the assumption of normality, but several transformation methods failed to achieve normality; thus, the Mann-Whitney U-test was used to compare the non-transformed pretest data of the diabetic group with the non-transformed referent data. Similarly, the Mann-Whitney U-test was used to compare the non-transformed posttest data of the diabetic group with the non-transformed referent data to check whether significant differences found between the two groups at baseline remained following the 8-week intervention. Statistical significance was set at $p < 0.05$.

Results

Study Adherence

All participants with diabetes completed the Tai Chi intervention as well as the pre- and post assessments. Average study adherence was 94.8%. Two participants attended each of the required 24 training sessions (100%); three participants missed one session (95.8%); two participants missed two sessions (91.7%); and one participant missed three sessions (87.5%). Reasons for the absences were sickness, family obligations, weather, work schedule, and jury duty.

Participant Characteristics

There were no statistically significant differences in height, weight, and BMI between the referent and the diabetic group ($p \geq 0.208$; Table 1). However, the diabetic participants were heavier (+ 6 kg) than their non-diabetic counterparts and classified as obese (BMI > 30 kg/m^2).

Primary Outcome Measures

Foot tactile sense. One participant in the referent group (lateral aspect of the right heel) and one participant in the diabetic group (lateral and medial aspects of both heels) presented with peripheral neuropathy. Following the Tai Chi intervention, there was no change in the diabetic group's peripheral neuropathy scores, as the same individual showed no signs of improvement in

Table 1

Participant Characteristics

	Referent Group	Diabetic Group
Number of women (% women)	6 (75)	6 (75)
Age (yrs)	63.8 ± 5.7	65.5 ± 7.4
Height (cm)	163.4 ± 7.5	162.0 ± 9.8
Body Weight (kg)	76.3 ± 12.0	82.6 ± 13.9
BMI (kg/m^2)	28.6 ± 3.8	31.5 ± 5.2
Diagnosed with diabetes (yrs)	N/A	18.63 ± 9.21

Data are means ± standard deviations (SD) of non-transformed data the neuropathic aspects of the heels. Due to the limited differences between the groups and the lack of change over the course of the intervention, no statistical tests were performed.

Ankle proprioception. Significant differences in proprioception between the referent and the diabetic group were detected for relative right ankle flexion ($p = 0.005$), absolute right ankle flexion ($p = 0.001$), absolute right ankle extension ($p = 0.006$), absolute left ankle flexion ($p = 0.002$), and absolute left ankle extension ($p = 0.028$) (Table 2). Following the intervention, significant improvements in proprioception of the diabetic group were found for relative right ankle flexion ($p = 0.003$) and ankle extension ($p = 0.015$), absolute right ankle flexion ($p = 0.001$) and ankle extension ($p = 0.002$), relative left ankle flexion ($p = 0.022$), and absolute left ankle flexion ($p = 0.001$) and ankle extension ($p = 0.012$). Although an improvement in proprioception was observed for relative extension of the left ankle, the changes failed to achieve statistical significance ($p = 0.075$). Proprioception variables that were significantly different at baseline between the referent and the diabetic group were similar following the 8-week intervention ($p \geq 0.155$).

Table 2

Ankle Proprioception

	Referent Group	Diabetic Group Pre-Intervention	Diabetic Group Post-Intervention
Relative Average RF (°)			
Flexion	0.85 ± 1.36	4.68 ± 2.75†	2.10 ± 1.75*
Extension	1.00 ± 0.98	2.20 ± 1.59	1.08 ± 0.76*
Absolute Average RF (°)			
Flexion	1.80 ± 0.70	4.98 ± 2.41†	2.30 ± 1.64*
Extension	1.45 ± 0.45	2.65 ± 1.24†	1.30 ± 0.76*
Relative Average LF (°)			
Flexion	1.45 ± 0.64	3.95 ± 3.33	1.83 ± 1.78*
Extension	0.58 ± 1.10	2.88 ± 2.25	1.00 ± 0.99
Absolute Average LF (°)			
Flexion	1.60 ± 0.59	4.45 ± 2.85†	1.93 ± 1.74*
Extension	1.63 ± 0.46	3.08 ± 2.13†	1.30 ± 0.83*

Data are means ± SD of non-transformed data; RF = right foot, LF = left foot
*Significant change between pre- and post-intervention for diabetic group ($p \leq 0.022$)
†Significant difference between referent group and diabetic group pre-intervention ($p \leq 0.028$)

Plantar pressure distribution. No significant differences for total peak plantar pressure (TPP; $p \geq 0.074$ RF; $p \geq 0.083$ LF) or peak plantar pressure normalized to body weight (PPN; $p \geq 0.093$ RF; $p \geq 0.054$ LF) were found among the five assessment sites between the referent and the diabetic group during quiet standing with eyes open at baseline (Table 3). Although a reduction in peak pressure at the right and left 1st MTH was observed for the diabetic group following the intervention, the changes for both TPP ($p \geq 0.200$ RF; $p \geq 0.519$ LF) and PPN ($p \geq 0.211$, RF; $p \geq 0.757$ LF) were not statistically significant. A statistical difference was found at the right heel for PPN ($p = 0.027$), but not for TPP ($p = 0.172$), between the referent and the diabetic group at posttest.

Table 3

Plantar Pressure Distribution

Total Peak Plantar Pressure (kPa/cm^2)	Referent Group	Diabetic Group Pre-Intervention	Diabetic Group Post-Intervention
Peak Plantar Pressure RF			
Great toe	26.39 ± 15.86	48.63 ± 39.38	47.84 ± 36.83
1st MTH	61.00 ± 26.26	108.82 ± 56.62	90.38 ± 53.01
3rd MTH	93.00 ± 26.79	96.50 ± 56.42	89.25 ± 36.18
5th MTH	75.00 ± 51.79	68.75 ± 43.31	58.32 ± 36.39
Heel	160.00 ± 51.43	118.88 ± 52.20	117.38 ± 47.94
Peak Plantar Pressure LF			
Great toe	39.00 ± 19.29	47.38 ± 55.71	32.63 ± 31.15
1st MTH	56.00 ± 24.40	112.38 ± 77.77	103.38 ± 89.62
3rd MTH	93.00 ± 33.77	98.00 ± 49.23	89.00 ± 46.13
5th MTH	77.00 ± 42.26	59.13 ± 33.31	57.38 ± 26.48
Heel	157.00 ± 66.52	121.38 ± 48.31	119.75 ± 36.88
Normalized Peak Plantar Pressure (kPa/kg)	**Referent Group**	**Diabetic Group Pre-Intervention**	**Diabetic Group Post-Intervention**
Peak Plantar Pressure RF			
Great toe	0.33 ± 0.21	0.54 ± 0.34	0.57 ± 0.39
1st MTH	0.89 ± 0.38	1.43 ± 1.10	1.28 ± 1.01
3rd MTH	1.13 ± 0.28	1.20 ± 0.78	1.10 ± 0.52
5th MTH	1.00 ± 0.62	0.82 ± 0.49	0.70 ± 0.41
Heel	1.98 ± 0.59	1.39 ± 0.60	1.38 ± 0.61
Peak Plantar Pressure LF			
Great toe	0.47 ± 0.25	0.52 ± 0.55	0.39 ± 0.37
1st MTH	0.76 ± 0.34	1.53 ± 1.52	1.46 ± 1.98
3rd MTH	1.11 ± 0.27	1.17 ± 0.65	1.06 ± 0.62
5th MTH	0.84 ± 0.19	0.68 ± 0.34	0.68 ± 0.26
Heel	2.05 ± 0.82	1.42 ± 0.50	1.42 ± 0.40†

Data are means ± SD of non-transformed data; RF = right foot, LF = left foot; MTH = metatarsal head
Normalized Peak Plantar Pressure = normalized to body weight
†Significant difference between referent group and diabetic group post-intervention ($p = 0.027$)

Center of pressure. No significant differences were found in sway area ($p = 0.529$) or A-P ($p = 0.248$) and M-L ($p = 0.713$) COP displacement between the referent and the diabetic group during quiet standing for 30 seconds with eyes closed at baseline (Table 4). Although a reduction was observed in all three assessed variables for the diabetic group following the intervention, the changes did not reach statistical significance ($p \geq 0.225$).

Secondary Outcome Measure

Senior fitness test (SFT). The referent group demonstrated significantly better left upper body flexibility ($p = 0.046$) and covered significantly more distance ($p = 0.027$) during the 6MWT than their diabetic counterparts during the pretest evaluation (Table 5). No other significant difference in SFT variables were observed between the referent and the diabetic group at baseline. Following the intervention, the diabetic group demonstrated significant improvement for right and left arm curl test ($p = 0.001$ and $p = 0.002$, respectively), the chair stand test ($p = 0.007$), right and left back scratch test ($p = 0.010$ and $p = 0.007$, respectively), and right and left sit-and-reach test ($p = 0.010$ and $p = 0.023$, respectively) compared to the pretest. The diabetic group also significantly decreased the time for the 8-foot up-and-go test ($p = 0.007$) and covered significantly more distance during the 6MWT ($p = 0.003$) at posttest. Initial differences for the left back scratch and 6MWT at baseline between the referent and the diabetic groups were lost following the 8-week Tai Chi intervention ($p > 0.05$).

Table 4

Center of Pressure Displacement

	Referent Group	Diabetic Group Pre-Intervention	Diabetic Group Post-Intervention
Sway area (cm^2)	1.53 ± 1.10	2.10 ± 1.73	1.79 ± 1.22
Anterior-posterior (cm)	2.35 ± 0.79	3.00 ± 0.97	2.94 ± 1.29
Medial-lateral (cm)	1.51 ± 0.77	1.55 ± 0.64	1.31 ± 0.37

Data are means ± SD of non-transformed data

Discussion

The purpose of this study was to evaluate the effects of eight weeks of Tai Chi practice on balance and peripheral somatosensation, including both foot tactile sensation and ankle proprioception, in older adults with type 2 diabetes. The major finding of this study was that Tai Chi improved ankle proprioception in older adults with type 2 diabetes. The results also showed that despite an improvement in ankle proprioception, there was no significant change in balance (i.e., sway area and sway distance). Lastly, the moderate-intensity, low-impact practice of Tai Chi led to an increase in the SFT components (i.e., arm curls, upper and lower body flexibility, mobility, and aerobic endurance). These findings suggest that Tai Chi may be an effective means for enhancing ankle proprioception and fitness in older adults with type 2 diabetes.

Foot Tactile Sense and Ankle Proprioception

This study assessed both foot tactile sense and ankle proprioception to examine the effects on balance and neuropathy, respectively. Because only two participants presented with minor loss

Table 5

Senior Fitness Test

	Referent Group	Diabetic Group Pre-Intervention	Diabetic Group Post-Intervention
Arm Curls (repetitions)			
Right arm	22.50 ± 4.57	21.75 ± 3.73	26.88 ± 4.39*
Left arm	22.38 ± 4.50	22.0 ± 4.54	26.25 ± 4.43*
Chair Test (repetitions)	12.63 ± 2.92	11.75 ± 3.58	14.38 ± 4.81*
Back Scratch (cm)			
Right side	-7.77 ± 16.75	-21.56 ± 14.21	-18.80 ± 12.87*
Left side	-12.33 ± 9.58	-27.48 ± 15.87†	-23.33 ± 14.31*
Chair Sit-and-Reach (cm)			
Right leg extended	1.74 ± 9.92	-6.23 ± 8.34	0.04 ± 5.28*
Left leg extended	2.84 ± 11.27	-6.48 ± 7.98	-0.48 ± 5.00*
8-Foot Up and Go (s)	5.81 ± 0.81	7.78 ± 2.60	6.84 ± 2.22*
6-Minute Walk Test (m)	554.35 ± 93.21	412.77 ± 126.76†	462.61 ± 123.32*

Data are means ± SD of non-transformed data
*Significant change between pre- and post-intervention for diabetic group ($p \leq 0.023$)
†Significant difference between referent group and diabetic group pre-intervention ($p \leq 0.046$)

of tactile sensation, the potential effect of Tai Chi on this variable could not be evaluated. Thus, the focus on Tai Chi's effect on peripheral somatosensation was directed towards ankle proprioception and its effect on balance.

Although scientists have suspected that proprioception is impaired in individuals with diabetes, information concerning the morphological effects of diabetes on proprioceptive receptors is limited. The findings of this study showed that proprioception is impaired in people with diabetes, but can be significantly improved with regular Tai Chi practice. The comparison with the referent group revealed that ankle flexion was to a greater extent affected by loss of proprioceptive sensation than ankle extension. Interestingly, the referent as well as the diabetic participants showed a tendency to overshoot the target angle. After eight weeks of Tai Chi practice, ankle proprioception in the diabetic group was similar to that of the referent group (Table 2).

There are several theories that may explain Tai Chi's positive influence on ankle proprioception. First, the deliberate foot movement patterns of Tai Chi may intensify the sensitivity of the proprioceptors. This theory would be in agreement with the notion that repeated practice of complex movement patterns increases the body's reliance on afferent input, and in doing so, stimulates the re-sensitization of peripheral sensory receptors (Thompson, Mikesky, Bahamonde, & Burr, 2003). Second, the continuous shifting of weight through different postures and steps may enhance the circulation of blood in the lower extremities (Wang, Lan, & Wong, 2001), thereby providing the necessary oxygen and energy to the sensory receptors located in the joint capsules, ligaments, tendons, and muscles. Between both resensitization of the peripheral sensory receptors and the nourishment of the lower extremity tissues, improved ankle proprioception may occur. Although directionally opposite, this view may be supported by findings that prolonged ischemia induced by a tourniquet applied above the ankle reduced passive joint position sense in healthy participants (Konradsen, Ravn, & Sørensen, 1993). Lastly, Tai Chi may lower glycated haemoglobin (HbA1c) levels (Song, Ahn, Roberts, Lee, & Ahn, 2009), which could contribute to increased ankle range of motion and improved proprioception. This theory would be indirectly supported by findings that long-term exposure to high glucose levels can stiffen the ligaments and tendons in the lower extremities through a process known as glycosylation (Acharya et al., 2008), leading to compromised joint mobility and increased ankle stiffness (Rao, Saltzman, Wilken, & Yak, 2006), which is associated with loss of proprioception (Uh, Beynnon, Helie, Alosa, & Renstrom, 2000).

Because it is unknown what mechanisms contribute or how mechanisms combine to improve ankle proprioception, future work should assess both static and dynamic proprioception (kinesthesia) along with serological or other cardiovascular markers to further explore the effects of Tai Chi on proprioception. Moreover, using a flexometer strapped to the participant's ankle may reduce the potential for measurement errors during the joint angle reproduction (JAR) test, and the use of a dynamic ankle proprioception device, such as the Biodex isokinetic dynamometer, may yield a better understanding of the changes that occur in ankle proprioception with Tai Chi. Improvements in ankle proprioception may help balance control of older people with diabetes, which, in turn, may reduce the high fall rate observed in this population.

Plantar Pressure Distribution

Increased plantar pressure, particularly in the great toe and the 1st and 5th MTH is a key factor in the development of ulcers in diabetic patients with neuropathy (Acharya et al., 2008). The cause for the elevated plantar pressure in the forefoot of people with diabetes seems to be a combination of decreased foot and ankle flexibility and altered proprioception. Lack of range of motion in the ankle joint requires a person to put extra force on the forefoot, which causes more pressure in the forefoot than in the heel (Acharya et al., 2008). Impaired proprioception creates an imbalance between the long flexors and extensors of the toes, leading to structural changes that force a person to increase the supination movement of the foot, which, in turn, increases the pressure moments under the 4^{th} and 5^{th} MTH (Stess, Jensen, & Mirmiran, 1997). Foot pressure changes in diabetic patients without any clinical evidence of neuropathy may present an early marker of peripheral neuropathy (Boulton et al., 1987). Similar to the work of Acharya and colleagues (2008), a tendency for anterior plantar pressure displacement in people with diabetes was also observed in this study (Table 3). The diabetic group had a higher peak pressure in the great toes and the 1^{st} MTH than the referent group, whereas the pressure in the heels was lower. Higher pressure in the forefoot and lower pressure in the rearfoot in people with type 2 diabetes without neuropathy was also detected by Pataky, Assal, Conne, Vuagnat, and Golay (2005).

The finding of this study that regular Tai Chi practice may have the potential to distribute the plantar pressure more evenly across a person’s foot suggests implications for the early detection of peripheral neuropathy, as Tai Chi appears to target both factors responsible for the foot pressure abnormalities that precede peripheral neuropathy. However, to truly understand the relationship between proprioception, plantar pressure, and Tai Chi exercise, future work should examine the muscle activation patterns of older adults with and without diabetes for both standing and walking. Evaluating the plantar pressures along with a more in-depth analysis of the kinematic and kinetic adaptations that occur at the foot and ankle may help explain how changes that arise with Tai Chi exercise affect lower extremity functioning. This would include using a motion capture system combined with electromyography (EMG) and plantar pressure assessments during both standing and walking trials to evaluate the functional changes that develop through Tai Chi practice.

Center of Pressure

Although loss of balance in the elderly is more likely to occur during dynamic activities such as walking, maneuvering obstacles, or transitioning from sit to stand, research suggests that older adults with diabetic neuropathy have a poorer postural control during quiet standing with eyes open and eyes closed compared to their non-diabetic counterparts (Corriveau et al., 2000). In this study, there were no significant differences in sway area or COP displacement in the A-P and M-L direction between the referent and the diabetic group both pre- or post-intervention (Table 4). One explanation could be that the double-leg stance was not a sufficient challenge to the postural control system and that single-leg stance measures would have been more sensitive to the proprioceptive sensation involved in the inversion-eversion movements of the foot during single-leg standing. Then again, the 8-week Tai Chi intervention (24 hours of practice) may not have provided sufficient training, as research has shown that improvements in single-leg stance become most evident after more than 40 hours of Tai Chi practice (Wu, 2002).

Future work exploring balance in neuropathic and non-neuropathic diabetic populations may require more difficult balance challenges to tease out differences of balance control strategies. Because Tai Chi involves controlled movements and changes of body position in different directions, a test assessing functional balance, such as stepping over an obstacle, may be a better means to evaluate older adults' balance control and fall risk. These tests would reveal whether improvements in balance can be transferred into activities of daily living.

Senior Fitness Test (SFT)

Although Tai Chi is generally associated with favorable effects on cardiorespiratory fitness, flexibility, and lower extremity strength in older people (Hong, Li, & Robinson, 2000; Li, Devault,

& Van Oteghen, 2007), studies on the effects of Tai Chi on physical fitness in older adults with type 2 diabetes are limited (Maiorana, O'Driscoll, Goodman, Taylor, & Green, 2002). Tai Chi's effectiveness for improving overall fitness appears to be in its slow, purposeful movement patterns emphasizing body and trunk rotation, postural alignment, and coordination of the upper extremities. These movements, executed in a semi-squat position, are thought to help mobilize the whole body, improve flexibility and leg strength, and increase cardiovascular endurance (Lan, Lai, Chen, & Wong, 1998).

In this study, the diabetic participants significantly improved in all measures of fitness (Table 5). Interestingly, the greatest improvement occurred in the 6MWT, which is an assessment of cardiorespiratory fitness. While long-term Tai Chi practitioners have shown increased cardio-respiratory fitness (Hong et al., 2000), the large improvement observed in previously sedentary people following eight weeks of low-to moderate-intensity training seems to be a combination of different factors rather than an increase in cardiovascular endurance alone. It is possible that improved plantar pressure distribution together with enhanced proprioception and ankle flexibility increased the diabetic participants' walking confidence. This amplified confidence, together with improved cardiovascular endurance, may have led to an increase in walking speed, allowing for a greater distance to be covered. The participants' improved ankle flexibility could also have contributed to a more normal heel-to-toe gait pattern, which in turn, could improve gait efficiency. Unfortunately, this study did not evaluate gait patterns or stride length which may have helped to explain these results. Gains in walking, regardless of the mechanism, could have led to increased personal walking activities outside the Tai Chi intervention within the diabetic group. In the future, physical activity levels before and during the Tai Chi intervention should be assessed to determine if participants engage in more regular physical activities, which may help explain some of the gains of the intervention.

The findings of this study suggest that regular Tai Chi training has the potential to maintain and improve older adults' physically fitness, even when they have moderate chronic disorders such as type 2 diabetes. Increased physical fitness can reduce many diabetes-related complications as well as improve balance control and mobility, thereby reducing the risk of falling.

Strengths and Limitations

There are several limitations to this study. First, the study was a quasi-experimental pre-posttest design without a control and/or traditional exercise group. Therefore, the improvements experienced by the older adults with diabetes may be related to increases in physical activity in general, not just to Tai Chi practice. Future work should evaluate the health benefits of various modalities of physical activity in order to determine what activities yield the strongest gains in balance and peripheral somatosensation. Second, the small sample size reduced the statistical power, limiting the generalizability to the broader diabetic population. Lastly, this study only explored the neurologic mechanisms; however, both vascular and neurologic mechanisms are at play in the diabetic foot. While this study did not see a change in neuropathy (only one participant had neuropathy), it could be that Tai Chi also affected the vascular components, such as peripheral artery disease (PAD). Future work should thus investigate if measures of micro- or macrovascular disease change in older adults with type 2 diabetes with Tai Chi practice, which may help elucidate the health benefits of Tai Chi for this population. Despite these limitations, the findings of this study may have important implications for the diabetic population, as the benefits of Tai Chi on ankle proprioception and plantar pressure distribution may help prevent foot ulcers and reduce falls.

Conclusion

With the growing prevalence of type 2 diabetes in older adults, understanding and improving foot health and fall risks is of paramount importance, and Tai Chi may be an effective therapeutic modality for improving foot condition and balance in this population. The results of this study suggest that Tai Chi may contribute to foot health by distributing the plantar pressure away from the ulcer-prone sites of the forefoot and reducing the fall risk of older adults with diabetes by improving the proprioceptive sensation of the ankles, an important factor for automatic balance correcting responses. Furthermore, Tai Chi may be the exercise intervention of choice for maintaining and improving physically fitness of older adults with type 2 diabetes. However, the findings of this study should be interpreted with caution. More controlled and randomized studies with larger sample sizes are required to determine whether the trends shown in this study are truly applicable to this population.

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Chapter 2:

Literature Review

THE EFFECTS OF TAI CHI ON BALANCE AND PERIPHERAL SOMATOSENSATION

IN OLDER ADULTS WITH TYPE 2 DIABETES

The Effects of Tai Chi on Balance and Peripheral Somatosensation

in Older Adults with Type 2 Diabetes

The World Health Organization (WHO) estimates that more than 220 million people worldwide have diabetes, and reports suggest that this number will double in the next 20 years (WHO, 2011). Part of this increase may be due to the aging population. In developed countries, individuals with diabetes will most likely be 65 years and older, while those in underdeveloped countries will be between 45 and 64 years of age (Wild, Roglic, Green, Sicree, & King, 2004).

Approximately 90% of individuals with diabetes have type 2 diabetes in which the body does not produce enough insulin or utilizes the available insulin ineffectively (Acharya et al., 2008). Type 2 diabetes, also known as non-insulin-dependent diabetes mellitus (NIDDM), is often the result of uncontrolled metabolic syndrome. According to Alberti et al. (2009), metabolic syndrome is a cluster of interrelated risk factors including elevated blood pressure, dyslipidemia (high levels of triglycerides and low levels of high-density lipoprotein), elevated fasting glucose, and obesity (particularly central obesity). Type 2 diabetes is characterized by a chronically elevated blood glucose level (hyperglycemia), which predisposes patients to chronic complications, such as cardio-myopathy, and micro- and macro-angiopathies (Lambers, Van Laethem, Van Acker, & Calders, 2008).

Many of the complications of type 2 diabetes can be attributed to changes in vascular structure and function, with consequent end-organ damage and death (Akbari & LoGerfo, 1999). Specifically, two types of vascular disease are seen in people with diabetes: 1) a non-occlusive microcirculatory dysfunction involving the capillaries and arterioles of the kidneys, retina, and peripheral nerves, and 2) a macro-angiopathy characterized by atherosclerotic lesions of the coronary and arterial peripheral circulation (Akbari & LoGerfo, 1999; Cade, 2008). The former dysfunction is fairly distinctive to diabetes, while the latter lesions are morphologically similar in both individuals with and without diabetes. These macro- and microvascular changes can lead to cardiovascular dysfunction and increase the risk for peripheral artery disease (PAD), a disorder characterized by poor blood supply to the lower extremities (Cade, 2008; Jude et al., 2009).

In addition to the arterial damage, diabetic neuropathy is a common ailment in diabetic populations. It is estimated that approximately 50% of people with diabetes have some form of neuropathy, although not all people may be symptomatic (Acharya et al., 2008; Cade, 2008; Duby, Cambell, Setter, White, & Rasmussen, 2004). Diabetic neuropathy is defined as "the presence of symptoms and/or signs of peripheral nerve dysfunction in people with diabetes after the exclusion of other causes" (Boulton & Malik, 1998, p. 508). The disorder is characterized by a progressive loss of nerve fibers and sensation (Boulton & Malik, 1998) and affects sensory, autonomic, and motor neurons of the peripheral nervous system, with sensory symptoms most apparent (Acharya et al., 2008; Vinik, Park, & Stansberry, 2000). The loss of sensation and the deinnervation of nerves along with reduced blood flow can lead to severe diabetic complications in the lower extremities, particularly in the foot (Acharya et al., 2008).

Over time, peripheral neuropathy and macro- and microvascular damage can lead to foot ulceration with subsequent lower extremity amputation in people with diabetes (Cade, 2008). Each year, 2-3% of people with diabetes develop a foot ulcer, and 15% will develop one during the course of their diabetes (Reiber, Boyko, & Smith, 1995). Foot ulcers increase the likelihood of non-traumatic foot amputations, with 85% of these amputations preceded by a foot ulcer (Pecoraro, Reiber, & Buress, 1990). Because of the high incidence of foot ailments in the diabetic population, the term "diabetic foot" was coined. Diabetic foot is defined as "the foot of a patient with diabetes, which has the potential risk of pathologic consequences, including infection, ulceration, and/or destruction of deep tissue associated with neurologic abnormalities, various degrees of peripheral vascular disease and/or metabolic complications in the lower extremities (Frykberg et at., 2006, p. 52).

The Diabetic Foot

Peripheral Artery Disease

Similar to peripheral neuropathy, peripheral artery disease (PAD) is a known risk factor for foot ulcers. It is estimated that more than 3.5 million people with diabetes have PAD (Cade, 2008), and 40-60% of all diabetic patients with foot ulcers have PAD (Jude, Eleftheriadou, & Tentolouris, 2009). PAD is characterized by narrowing or occlusion of the arteries in the lower extremities, which leads to a gradual reduction of blood supply to the limbs. People with PAD may be asymptomatic or show symptoms of intermittent claudication or pain during activities (Cade, 2008; Jude et al., 2009). Because the detection of PAD is often delayed due to diminished pain perception caused by peripheral neuropathy, infections and foot ulcerations are common in individuals with diabetes and PAD. Given the impaired circulation in the foot, the end stage manifestation of PAD is often dry gangrene, which makes amputation almost unavoidable (Jude et al., 2009).

Peripheral Neuropathy

Peripheral neuropathy is a common complication of diabetes, with substantial impact on morbidity and mortality (Duby et al., 2004). The pathology of peripheral or diabetic neuropathy includes oxidative stress, polyol pathway flux, advanced glycation end products, and protein kinase C activation, which all contribute to the microvascular disease and nerve dysfunction that is typical for diabetic peripheral neuropathy (Cade, 2008; Duby et al., 2004). The nerve damage affects foot sensation, innervations of the small muscles of the foot, and fine vasomotor control of the pedal circulation (Jeffcoate & Harding, 2003). Typically, the damage is unnoticed by the patient, as it is a gradual painless loss or change. It is usually detected and verified by clinical tests (Vinik et al., 2000).

Peripheral (sensorimotor) neuropathy has a variable effect on large and small afferent nerve fibers, which results in mixed symptoms and loss of sensation (Vinik et al., 2000). While a minority of people with neuropathy experience symptoms that manifest as burning sensation, sharp pain, numbness, and pain to normal touch, the majority have insidious symptoms such as the inability to feel, assess temperature, or sense painful stimuli, particularly in the periphery (e.g., the foot). As a result of the loss of protective sensation, individuals with neuropathy are at an increased risk for microtrauma and hidden injury to the foot (Pinzur, 2002; Vinik et al., 2000). Likewise, motor neuron damage affects the muscles required for normal foot movement, causing changes in the distribution of forces during walking and reactive thickening of the skin at the sites of increased pressure. Lastly, the dysfunction of the micro-circulation due to vasomotor neuropathy results in reduced blood flow to the areas of need (Jeffcoate & Harding, 2003). Consequently, delayed healing due to ischemia, continuing microtrauma because of lack of sensation, and atrophy secondary to loss of innervations of the foot muscles predispose people with diabetes to infections, calluses, and ultimately foot ulcerations (Duby et al., 2004; Jeffcoate & Harding, 2003).

Diabetic Foot Ulcers

Neuropathic foot ulcerations are most often the result of impaired somatosensation in the lower extremities, as decreased pain sensation along with impaired proprioception requires a person to shift weight-bearing to atypical sites on the foot (Greene, 1986). The moderate repetitive stress of ordinary walking can also cause pre-ulcer hemorrhage or sterile inflammatory autolysis in the subcutaneous tissue of individuals with intact sensation; however, sensory feedback will cause a healthy person to alter his or her gait in response to the discomfort, protecting the foot before an ulcer can develop. Because impaired proprioception and diminished pain sensation affect the afferent feedback mechanism, the ability of the diabetic patient to alter his or her gait to protect the foot in response to painful, injurious, or inflammatory stimuli is reduced (Roberts, 2004).

Abnormal plantar pressure distribution resulting from weight-bearing shifts to atypical sites on the foot appears to be a key factor in the pathology of neuropathic ulcers of the diabetic foot. Pataky, Assal, Conne, Vuagnat, and Golay (2005) noted increased plantar pressure under the great toes and 5th metatarsal heads in type-2 diabetic patients without signs of micro- and macrovascular complications, whereas the pressure in their heels was significantly lower than that in the non-diabetic patients. Because the patients with diabetes also had prolonged plantar pressure in the same areas with foot-floor contact during walking, the researchers concluded that elevated plantar pressure along with extended foot-floor contact time could be an early indicator of neuropathy.

The elevated forefoot pressure may be the result of impaired ankle function. In patients with poorly controlled glucose, glycosylation or “sticking” of the glucose to the proteins in the body can harden tendons and ligaments, a condition referred to as equinus (Acharya et al., 2008). If glycosylation occurs in the Achilles tendon, it can result in a shortening of the tendon, thereby limiting foot and ankle joint mobility. The lack of range of motion in the ankle joint requires a person to put extra force on the forefoot, which causes more pressure in the forefoot than in the heel. Along with inadequate foot sensation and blood supply, the high pressure may lead to calluses and ulcers in the foot (Acharya et al., 2008).

Diabetic foot ulcerations are a major public health concern, because they are one of the primary reasons for hospitalization among the diabetic population and the leading cause of non-traumatic foot amputations (Pinzur, 2002; Vinik et al., 2000). While 15-27% of all diabetic foot ulcers (rates vary between countries) entail the surgical removal of bone (Jeffcoate & Harding, 2003), the majority of ulcers requires amputation of the affected lower extremity (Duby et al., 2004). Diabetic foot ulceration and amputation have a poor prognosis. Results of cross-sectional surveys in Europe showed an immediate postoperative mortality of 10-15%, while survival rates after three years were between 50 and 59% (Jeffcoate & Harding, 2003).

While PAD, peripheral neuropathy, and foot ulcers are fundamental keys to understanding the diabetic foot, there are other complications that arise with type 2 diabetes, such as retinopathy, visual impairments from either progressing diabetic retinopathy or poor glycemic control, and orthostatic hypotension caused by autonomic neuropathy. Each one of these complications poses a serious health threat, and taken together, they contribute through multiple mechanisms to the increased fall risk experienced by older adults with diabetes (Maurer, Burcham, & Cheng, 2005).

Falls among Older Adults with Diabetes

Given the often devastating and disabling consequences of fall-related injuries, balance control is a major concern among the aging population. Age-related structural and functional decline of the somatosensory system accompanied by a variety of complications that can affect balance potentially contribute to the increased postural instability in older adults (Shaffer & Harrison, 2007). Compared to non-diabetic individuals, older adults with diabetes have a two- to threefold higher risk for falls and physical disability (Park, Goodpaster, Strotmeyer, & Kuller et al., 2007) due to diminished peripheral sensation and a greater postural instability (Richerson, Robinson, & Shum, 2005). Moreover, older adults with diabetes and peripheral neuropathy are 15 times more likely to suffer fall-related injuries than their non-diabetic counterparts (Cavanagh, Derr, Ulbrecht, Maser, & Orchard, 1992).

Older adults with diabetes typically demonstrate greater amplitude of sway, sway area, mean velocity of sway, and frequency of sway (Richerson & Rosendale, 2007). Furthermore, diminished perception of ankle inversion/eversion and reduced whole body movement in the anterior-posterior and medial-lateral planes have been reported in this population. These physical measures are not only evidence for the increased instability, but also the rationale why older adults with diabetes feel less safe when compared to healthy older adults during standing and walking (Richerson & Rosendale, 2007).

One factor that seems to play a role in the fall risk in older adults with diabetes is the presence of a previous foot ulcer combined with one or more co-morbid conditions. Wallace et al. (2002) investigated 400 older individuals with type 2 diabetes over a two-year period and concluded that a prior foot ulcer alone did not increase the fall risk. However, if combined with co-morbid conditions such as stroke, cardiovascular bypass surgery, chronic respiratory disease, heart failure, cancer, or depression, the incidence for one or multiple falls greatly increased. In addition, pathophysiological factors that impair lower-extremity functioning of older people with diabetes, such as diminished peripheral blood flow, uncontrolled hyperglycemia, weakened muscle strength, altered proprioception, and diminished motor coordination are key contributors to loss of physical independence (Gregg et al., 2000; Park, Goodpaster, Strotmeyer, & de Rekeneire et al., 2006).

Balance Control and Balance Strategy

The maintenance of balance is dependent on sensory afferent information from the somatosensory, visual, and vestibular systems (Horak, 2006; McKeon & Hertel, 2007). Although input from all three systems is required to generate appropriate balance responses, the somatosensory system appears to be the biggest contributor of feedback for postural control in healthy people under most environmental conditions (Horak, 2006). A diminished somatosensory system seems to intensify the postural sway of upright standing to a greater extent than an impaired visual or vestibular system (Simoneau, Ulbrecht, Derr, & Cavanagh, 1995). The somatosensory system includes both the tactile and the proprioceptive system (McKeon & Hertel, 2007). The receptors of the tactile system (Pacinian corpuscles, Meissner's corpuscles, Merkel's cells, and Ruffini endings) provide the central nervous system with sensations of touch and pressure and more complex sensations like vibration (Riemann & Guskiewicz, 2000). The cutaneous receptors located on the plantar surface of the feet are thought to play an essential role in balance control and upright posture (Kavounoudias, Roll, & Roll, 1998). The proprioceptive system contributes to the sense of joint position and joint motion or kinesthesia. Muscle spindles, joint afferents, and Golgi tendon organs supply the central nervous system with information concerning muscle length and tension, joint angles, and changes in these angles (Riemann & Guskiewicz, 2000). The proprioceptive feedback in the lower extremities is considered essential for automatic balance correcting responses in humans (Kavounoudias et al., 1998).

When both tactile and proprioceptive information is lacking or reduced because of injury or neuropathy, attenuation of balance control is likely (van Deursen & Simoneau, 1999). However, quantifying the loss of somatosensation in the lower extremities cannot fully predict the dysfunction of the balance system, because its function also depends on compensatory strategies that people develop to achieve stability (Horak, 2006). Loss of proprioception and a decline in the ability to generate ankle torques can lead to changes in the motor strategy used for standing balance by switching to movement patterns that rely less heavily on proprioceptive feedback (Kokmen, Bossemeyer, & Williams, 1978). Research has shown that in older people with diminished proprioception, the compensatory mechanism for postural and balance control includes co-contraction of the plantar flexors and dorsiflexors (Benjuya, Melzer, & Kaplanski, 2004; Madhavan & Shields, 2005), whereas excessive hip and trunk movements may be used as a method to maintain postural equilibrium when stabilizing ankle torques are diminished (Horak, Nashner, & Diener, 1990).

Although it has become apparent that diabetes has a damaging effect on the cutaneous receptors in the feet, it is currently not clear which component of the somatosensory system (tactile or proprioceptive) is most responsible for the balance deficits in patients with diabetic peripheral neuropathy (van Deursen & Simoneau, 1999). After a review of the effects of impaired somatosensation in the lower extremities on standing balance, Kars, Hijmans, Geertzen, and Zijlstra (2009) concluded that proprioception in patients with peripheral nervous system disorders was not as thoroughly investigated as tactile sensation. This view is supported by an earlier finding of van Deursen, Sanchez, Ulbrecht and Cavanagh (1998) who stated that the morphological effects of diabetes on muscle spindles and other proprioceptive receptors have not been studied. It can be expected, however, that the chronically elevated blood glucose level ultimately affects most of the receptors in the lower extremities, thereby compromising an important mechanism for postural stability (Gurfinkel, Ivanenko, Levik, & Babakova, 1995).

While aging naturally slows reflexes and increases the time to react to different stimuli, the effect of type 2 diabetes on these same reaction times may be another factor for the increased falls observed among older adults with diabetes. Richerson et al. (2005) found that older adults with diabetes had a significantly higher reaction time to movement (plantar surface touch) compared to older adults without diabetes. While older adults with diabetes showed increased reaction times to plantar surface touch, indicating that peripheral neuropathy was present, the researchers concluded that this marked increase in movement reaction time cannot solely be linked to peripheral neuropathy. In their opinion, there must be an additional slowing in the processing of the signals by the central nervous system. Thus, in addition to decreased foot sensation, the decreased nerve conduction velocity or loss of signaling further complicates the diagnosis and treatment of diabetic foot ailments and the associated high fall risk.

The treatment goal of diabetic foot complications is to prevent further tissue damage and relieve discomfort. Although the first step is to control blood glucose levels through a healthy diet and medication, a critical part of the treatment involves taking care of the feet by wearing appropriate shoes and checking the feet for cuts and infections on a regular basis (National Institutes of Health [NIH], 2008). To further improve health outcomes and quality of life as well as to counter the fall risks, research suggests that older people should be strongly encouraged to adhere to a regular exercise regimen (Cress et al., 2006).

Exercise Interventions for Older Adults with Diabetes

Traditional Exercise Programs

Intervention programs including resistance, endurance, balance, and flexibility training have traditionally been used for decreasing the fall risk of older adults with and without diabetes. The benefits of such programs encompass improved overall health and the preservation of the highest possible level of independence (Choi, Moon, & Song, 2005; Mihay et al., 2006). Regular exercise is particularly important for older adults with diabetes, as it can counteract strength loss, improve mobility (Brandon, Gaasch, Boyette, & Lloyd, 2003), and modify the natural history of peripheral neuropathy (Balducci, Jacobellis, Parisi, et al., 2006). Balducci and colleagues (2006) suggested that long-term moderate-intensity aerobic exercise has the potential to delay the onset of diabetic peripheral neuropathy by positively influencing both motor and neuro-muscular parameters. Because moderately intense physical activity, such as brisk walking, can improve glycemic control (Boulé, Haddad, Kenny, Wells, & Sigal, 2001), the American Diabetes Association (ADA) recommends at least 30 minutes of daily moderate-intensity exercise. At the same time, the

ADA suggests that people with peripheral neuropathy should limit their weight-bearing activities because it could add to the risk for foot ulceration (Sigal, Kenny, Wasserman, & Castaneda-Sceppa, 2004). Although some studies suggest that modest daily weight-bearing activity does not increase the risk for developing foot ulcers in people with diabetic neuropathy (LeMaster, Reiber, Smith, Heagerty, & Wallace, 2003; LeMaster, Mueller, & Reiber et al., 2008), non-weight-bearing activities such as swimming, bicycling, or arm exercises are encouraged for patients with severe peripheral neuropathy as there may be an increased risk for skin breakdown and infection due to decreased pain sensation in the lower extremities (Sigal et al., 2004).

Tai Chi Training for Older Adults

Over the last two decades, Tai Chi has been recognized as an effective alternative to traditional exercise programs for fall prevention among older people in Western societies (Lin, Hwang, Wang, Chang, & Wolf, 2006). Tai Chi, an ancient Chinese martial art, incorporates elements of strengthening, balance, postural control, and concentration. This combination of activities led some researchers to suggest that it is the most effective interventions for reducing falls in the older population (Choi et al., 2005; Lin et al., 2006). Because its movements are slow, continuous, and low-impact, Tai Chi exercise is particularly suitable to the physical condition of older people (Choi et al., 2005; Mihay et al., 2006). The exercise intensity does not exceed 55% of maximum oxygen intake and 60% of the individual’s maximum heart rate (Hong, Li, & Robinson, 2000; Lan, Lai, Chen, & Wong, 1998). Although it is only since the early 1990s that the effects of Tai Chi on balance have been scientifically investigated in English peer-reviewed literature, there is evidence that this non-traditional form of exercise has beneficial effects on the physical health and well-being of older adults (Yau, 2008).

Choi et al. (2005) studied the effects of a Tai Chi exercise program on physical fitness, fall avoidance efficacy, and fall episodes among institutionalized older adults. After 12 weeks of training, the Tai Chi group demonstrated significant improved muscle strength with increased flexibility and mobility compared to the non-exercising control group. The positive effect of Tai Chi on physical fitness, balance and fall reduction in older people has also been demonstrated by Li, Devault, and Oteghen (2007), Mihay et al. (2006), Tsang and Hui-Chan (2004), and Voukelatos, Cumming, Lord, and Rissel (2007). In these studies, Tai Chi practitioners showed improved strength and flexibility, increased motor function, more confidence in fall avoidance, and better balance control during functional tasks. The latter is particularly important for older people, as it indicates incorporation of fall prevention strategies into activities of daily living. Tai Chi also seems to have a positive effect on cardiorespiratory fitness. Hong et al. (2000) found that long-term Tai Chi practitioners achieved significantly higher scores for heart rate both at rest and after a three-minute step test than their sedentary counterparts.

Tai Chi Training for Older Adults with Diabetes

Although Tai Chi has been successfully used for several years to improve balance, lower extremity muscle strength, aerobic capacity, and mobility in older adults without diabetes, limited data is available as to whether these benefits extend to the older diabetic population as well. The results of the available literature are inconsistent in regard to insulin sensitivity, glucose control, and fall reduction (Lam, Dennis, & Diamond, 2008; Shen et al., 2007; Song, Ahn, Roberts, Lee, & Ahn, 2009; Tsang, Orr, Lam, Camino, & Fiatarone Singh, 2008). While most of these researchers found no improvements in fasting blood sugar levels, they agreed that regular Tai Chi training can reduce glycosylated hemoglobin (HbA1c) levels. The latter finding may be significant, given that

HbA1c plays a crucial role in the development of increased plantar pressure and the associated risk for diabetic foot ulcers (Acharya et al., 2008).

Richerson and Rosendale (2007) demonstrated that Tai Chi training can be an effective method to improve plantar sensation and balance in older adults with diabetes. The researchers speculated that this improvement may be the result of an increase in peripheral blood microcirculation, which was first discovered by Wang, Lan, and Wong (2001). In their experiment, experienced Tai Chi practitioners demonstrated that regular moderate-intensity exercise at 55% VO_2 max can increase plasma nitric oxide metabolite levels, which are linked to a decrease in cutaneous vascular resistance, thereby increasing skin blood flow and vascular conductance. Tai Chi's secret for improving balance in older adults with diabetes may thus be an increase in plantar sensitivity and the reduction of plantar pressure by ways of increased vascular circulation, which may ultimately reduce the risk for foot ulcerations and lower limb amputations in this population.

Conclusion

In summary, older people with diabetes are at a higher risk for falls and disability than their non-diabetic counterparts. In addition to the fall risks comprised by the normal process of aging, older people with diabetes also have to deal with various diabetes-related complications including micro- and macrovascular diseases, peripheral neuropathy, orthostatic hypotension caused by autonomic neuropathy, retinopathy, and decreased nerve conduction velocity. Among the most debilitating complications are peripheral neuropathy, peripheral artery disease, and foot ulceration, with the latter being the major cause for non-traumatic lower limb amputations.

Regular exercise is particularly important for older adults with diabetes, as it can counteract strength loss, improve mobility, and modify the natural history of peripheral neuropathy. Exercise programs including resistance, endurance, balance, and flexibility training have traditionally been used for decreasing the fall risk associated with diabetic lower extremity complications. One promising exercise for preventing falls and addressing foot health is Tai Chi. Because its movements are slow, continuous, and low-impact, Tai Chi exercise may be particularly suitable to the physical condition of older people with diabetic foot ailments. Although the available data on its benefits for the diabetic population are limited, Tai Chi exercise may have the potential to improve plantar sensation and decrease plantar pressure, thereby ultimately reducing the risk for foot ulcers and falls. However, further research is needed to validate Tai Chi as an alternative method to reduce falls among older adults with type 2 diabetes.

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Appendix:

Working Material

ASSESSMENT SHEETS

Name: Date of Birth:

Gender: Race:

Height (cm): Weight (kg):

PRIMARY OUTCOME MEASURES (Balance and Proprioception)

TEKSCAN	Right Foot	Left Foot	Both Feet
Pressure (kg)			
Time (sec)			

MONOFILAMENT	Right Foot			Left Foot			
	Toe	Ball	Heel	Toe	Ball	Heel	
Trial 1							
Trial 2							
Trial 3							
Sum per Point							
Sum per Foot							

ANKLE JAR TEST	Right Foot		Left Foot	
	Degree Flexion	Degree Extension	Degree Flexion	Degree Extension
Trial 1				
Trial 2				
Trial 3				
Trial 4				
Trial 5				
Relative Average				
Absolute Average				
Motion per Leg				

SECONDARY OUTCOME MEASURES (Senior Fitness Test)

ARM CURLS (Time: 30 seconds – Number completed) Dominant Arm:	Right Arm:	Left Arm:
BACK SCRATCH (Distance between middle fingers in cm) Dominant Arm:	Right Arm:	Left Arm:
Average per Arm		
CHAIR TEST (Time: 30 seconds)	Number of Completed Stand-Sit Cycles:	
CHAIR SIT-AND-REACH (Distance between middle finger and great toe in cm) Dominant Side:	Right Side:	Left Side:
Average per Side		
8-FOOT UP AND GO (Time from initial seated position to final seated position in seconds)		
Average Time		
6-MINUTE WALK TEST	Number of completed laps (60 m)	Unfinished Lap (m)
Total distance walked		

SCRIPT FOR SENIOR FITNESS TEST

Arm Curl (Upper Body Strength)

Explain to the participant what you are testing and demonstrate the movement. Men will use an 8-pound (3.63 kg) weight; women will use a 5-pound (2.27 kg) weight. Explain that he/she is free to stop at any time during the test if needed. The test will be performed in a seated position, with the chair firmly placed against a wall.

Ask: ***"Which arm do you consider to be your dominant arm?"*** Write down response.

Say: ***"Sit comfortably on this chair and start with the weight in your right hand. Please do one trial arm curl, so I can check your form."***
Watch participant and check form – give feedback as necessary. "***Okay, that looks good! Your goal is now to do as many curls as possible until I tell you to stop. Let me know when you are ready to start the curls."***

Make sure the weight starts at the down (arm fully extended) position. Start the timer when the participant indicates that he/she is ready and count the number of curls the participant is doing in 30 seconds. Record the number, and have the participant switch arms.

Say: ***"We'll rest for a minute."*** Chat with the participant for approximately one minute, and when time is up say: ***"Now you'll do the same thing with the weight in your left hand. Please do one trial, so I can check your form."***
Watch participant and check form – give feedback as necessary. ***"Okay, let's test the left arm. Do as many curls as possible until I tell you to stop. Let me know when you are ready to start."***

Make sure the weight start at the down (arm fully extended) position. Start the timer when the participant indicates that he/she is ready and count the number of curls the participant is doing in 30 seconds. Record the number, and compliment the participant.

Say: ***"Good job!"***

Back Scratch (Upper Body Flexibility)

Explain to the participant what you are testing and demonstrate the movement. Don't show them how easy it is for you – show it with space between the hands (make it look like a struggle even if it isn't) – the goal is to make the participants feel at ease. This test will be performed standing.
Ask: ***"Which arm do you consider to be your dominant arm?"*** Write down response.

Say: ***"Start with your right hand over your shoulder and with your left hand up the middle of your back. Try to touch your fingers."***

Give the participant two warm-up trials to stretch out a bit. Measure and record the total distance between the middle fingers in trials three and four, rounding each measurement to the nearest tenth of a centimeter. Record a negative (-) value if the fingers DO NOT touch, and a positive (+) value if the fingers DO touch.

Say: ***"Great! Now do the same movement with your left hand over your shoulder and with your right hand up the middle of your back. Again, try to touch your fingers."***

Give the participant two warm-up trials to stretch out a bit. Measure and record the total distance between the middle fingers in trial three and four, rounding each measurement to the nearest tenth of a centimeter. Record a minus (-) score if the fingers DO NOT touch and a positive score (+) if the fingers DO touch.

Say: ***"That was excellent!"***

Chair Test (Lower Body Strength)

Explain to the participant what you are testing and demonstrate the movement. Demonstrate the test with slow form, and then speed up your form to show that the goal is to do as many as possible. Explain that he/she is free to stop at any time during the test if needed. Make sure that chair is firmly put against the wall and the participant sits all the way back in the chair with the arms folded across his/her chest. Explain that he/she has to stand up fully between repetitions and sit down without touching the back of the chair. Before testing, have the participant do 1 trial sit-to-stand to watch form and safety.

Say: ***"Stand up and sit down as many times as possible until I tell you to stop. Let me know when you are ready to start."***

The participant will start in the seated position for the 30-second trial. Start the timer when the participant indicates that he/she is ready and count the number of full up-and-down cycles the participant is doing in 30 seconds. Record the number and compliment the participant.

Say: ***"Great job!"***

Carefully watch the participant to make sure he/she is moving safely (not leaning or tilting to the side). Be prepared to provide assistance as necessary.

Chair Sit-and Reach (Lower Body Flexibility)

Make sure that chair is firmly put against the wall. Explain to the participant what you are testing and demonstrate the movement. In the demonstration, make sure to sit on the edge of the chair, with one leg straight as possible and the other leg bent at 90 degrees. Both arms should be stretched out, hands overlapping, and middle fingers even.

Ask: ***"Which side do you consider to be your dominant side?"*** Write down response.

Say: ***"Sit on the edge of the chair and stretch out your right leg. Do two practice trials to stretch out a little, and then do two trials during which I'll take the measurements. When you're ready, touch your toes."***

After the two practice trials, measure and record the distance between the middle finger and the middle of the great toe in trials three and four, rounding each measurement to nearest tenth of a centimeter. Record a negative (-) value if the participant does NOT reach his/her feet, and a positive (+) value if he/she reaches past the toes.

Say: ***"Take a break if necessary and then stretch out your left leg and try to touch your toes with your left hand."***

After the two practice trials, measure and record the distance between the middle finger and the middle of the great toe in trials three and four, rounding each measurement to nearest tenth of a centimeter. Record a negative (-) value if the participant does NOT reach his/her feet, and a positive (+) value if he/she reaches past the toes. Compliment the participant.

Say: ***"Excellent job!"***

8-Foot Up and Go (Agility and Dynamic Balance)

Make sure that chair is firmly put against the wall and the participant sits all the way back in the chair. A cone should be placed at exactly 8 feet from the edge of the chair, centered from left to right. Explain to the participant what you are testing and demonstrate if necessary. Explain that he/she is free to stop at any time during the test if needed. Have the participant do one practice trial prior to starting (not timed) to make sure he/she understand the test.

Say: ***"When you are ready, stand up and walk to the orange cone, turn around and return to your seated position in the chair. Let me know when you are ready to start."***

Start the timer when the participant indicates that he/she is ready and record the time it takes from the initial seated position to the final seated position to nearest tenth of second. Have the participant rest for 1 minute and repeat the test. Then compliment the participant.

Say: ***"That was great!"***
Carefully watch the participant to make sure he/she is moving safely (not leaning or tilting to the side). Be prepared to provide assistance as necessary, especially as s/he rounds the cone and when starting to stand and sit.

6-Minute Walk Test (Aerobic Fitness)

Make sure the 30-meter course in the hallway has taped markers every 3 meters and cones placed at the start and end. Make sure there is a chair in the hallway in case a participant would like to sit and rest. Explain to the participant what you are testing and demonstrate if necessary. Explain that he/she is should walk as briskly as possible but may slow down, or stop and rest at any time during the test if needed. Encourage the participant to resume walking in case of a stop. If he/she needs to sit, help the participant to the chair.

Say: ***"When you are ready, walk back and forth around the cones as fast as possible until I tell you to stop. If you need to slow down or rest, you may do so, but start again as soon as you are able to. If you get tired before the time is up, just stop and indicate at what point you finished your walk."***

Encouragements:
At minutes 1, 2, and 4 say: ***"Great job; keep it up!"***
At minute 3 say: ***"You are halfway there; don't give up yet!"***
At minute 5 say: **"*Only one minute left; you can do it!"***
At minute 6 say: ***"Stop! You you're done. You just did a great workout!***
If a participant has to quit earlier, give a compliment: ***"This was a good walk!"***

With each lap finished, place a tick mark on the page. At the six-minute mark (end of the test) mark with tape where the participant ended and help the participant to the chair to rest if necessary. Measure the distance of the final lap.

TAI CHI/EXERCISE ANALYSIS HEALTH STATUS QUESTIONNAIRE

Name: ______________________________________ Date: ______________________

Primary Phone Number: ____

Person to Contact in Case of Emergency: ____

Emergency Contact Phone Number: ____

Gender: _____________________________________ Age _________________ (years)

Ethnicity/Race: ☐ Asian ☐ African-American ☐ Hispanic ☐ White ☐ Other

A. GENERAL QUESTIONS (✓Check "yes" or "no" and fill in the blanks if appropriate)

When were you first diagnosed with diabetes by your doctor? ______________________

Have you been exercising on a regular basis within the last 3 months? ☐Yes ☐No
If yes, what kind of exercise have you be doing? ________________________________

Do you need an assistive device, such as a cane, for walking? ☐Yes ☐No

Do you have high blood pressure (>140/90 mmHg)? ☐Yes ☐No
If yes, are you taking blood pressure medication? _______________________________

Are you currently taking medication against anxiety or depression? ☐Yes ☐No

B. GENERAL HEALTH STATUS (✓Check if you currently have any of the following conditions)

Do you have any of the following medical conditions:

( ) Heart Disease or Dysfunction ( ) Severe Arthritis
( ) Unstable Heart Conditions ( ) Hearing Conditions
( ) Neurological Disorders ( ) Acute Infection

( ) Other ailments you feel we should know for your safety (describe):

____

( ) Allegeric reactions to medication (describe):

____

( ) Allegeric reactions to other substances (describe):

____

Decision Making Criteria Set

TAI CHI/EXERCISE ANALYSIS HEALTH STATUS QUESTIONNAIRE

Name: ______________________________________ Date: ______________________

Primary Phone Number: ____

Person to Contact in Case of Emergency: ____

Emergency Contact Phone Number: ____

Gender: _____________________________________ Age _________________ (years)

Ethnicity/Race: ☐ Asian ☐ African-American ☐ Hispanic ☐ White ☐ Other

***Decision Making Criteria*: If not within the age range of 55-80 years old, the subject will not be invited to participate in the study.**

A. General Questions (✓Check "yes" or "no" and fill in the blanks if appropriate)

When were you first diagnosed with diabetes by your doctor? ______________________

Have you been exercising on a regular basis within the last 3 months? ☐ Yes ☐ No

If yes, what kind of exercise have you be doing? ________________________________

Do you need an assistive device, such as a cane, for walking? ☐ Yes ☐ No

Do you have high blood pressure (>140/90 mmHg)? ☐ Yes ☐ No

If yes, are you taking blood pressure medication? ______________________________

***Decision Making Criteria*: If the subject has been diagnosed with diabetes less than 5 years ago, has been exercising regularly at a high intensity within the last 3 months, and is using an assistive device for walking, he or she will not be invited to participate in the study.**

Although taking blood pressure medication is not an exclusion criterion, we are asking for it as these medications lower heart rate, which is an important indicator of exercise intensity. If a participant is taking blood pressure medication, other means of assessing exercise intensity, such as the rate of perceived exertion (RPE,) must be used if needed.

B. GENERAL HEALTH STATUS (✓Check if you currently have any of the following conditions)

Do you have any of the following medical conditions:

( ) Heart Disease or Dysfunction
( ) Unstable Heart Conditions
( ) Neurological Disorders
( ) Severe Arthritis
( ) Hearing Conditions
( ) Acute Infection

( ) Other ailments you feel we should know for your safety (describe):

____

( ) Allegeric reactions to medication (describe):

____

( ) Allegeric reactions to other substances (describe):

____

***<u>Decision Making Criteria</u>*: The subject will not be included and invited to participate if he or she checks one or more of the boxes of:**

Heart Disease or Dysfunction	*Severe Arthritis*
Unstable Heart Conditions	*Hearing Conditions*
Neurological Disorders	*Acute Infection*

The question relating to allergic reactions to medication is to provide to medical personnel should an emergency occur.

The question relating to allergic reactions to other substances is to ensure the subject's safety around latex gloves that will be used for the Weinstein Monofilament and JAR test. If the subject is allergic to latex, non-latex gloves will be used.

C. WE WILL COLLECT INFORMATION ON:

Height: ______ (cm) Weight: ______ (kg)

***<u>Decision Making Criteria</u>*: This data will be collected to calculate the subject's body mass index (BMI). If the subject's BMI is ≥ 40 kg/m^2 (severely obese), he or she will not be included and invited to participate in this study.**

University of Texas at El Paso (UTEP) Institutional Review Board
Informed Consent Form for Research Involving Human Subjects

Protocol Title: The Effect of Tai Chi on Balance, Tactile Foot Sense, and Overall Fitness in Older Adults with Type II Diabetes
Principal Investigator: Elisabeth Cavegn, BS; Jody Riskowski, PhD, CSCS
UTEP: Kinesiology

Authorization Statement

I have read each page of this paper about the study (or it was read to me). I know that being in this study is voluntary and I choose to be in this study. I know I can stop being in this study without penalty. I will get a copy of this consent form now and can get information on results of the study later if I wish.

Participant Name: ______________________________ Date: ____________

Participant Signature: ______________________________ Time: ____________

Consent form explained/witnessed by: ________________________

Signature

Printed name: ______________________________

Date: ____________ Time: ____________

University of Texas at El Paso

Volunteers Wanted for Research Study

The Effects of Tai Chi on Balance, Tactile Foot Sense, and Overall Fitness in Older Adults with Type 2 Diabetes

- The purpose of this research study is to look at the effects of Tai Chi exercise in older adults with type 2 diabetes. We will be testing balance, sensitivity of the nerves in the feet, and overall fitness including muscle strength, flexibility, mobility, and aerobic capacity. The length of the study will be approximately 10 weeks, which includes the 8-week Tai Chi intervention.

- You are eligible to participate in this study if you:
  - *are between 55 and 80 years old*
  - *have been diagnosed with type 2 diabetes for at least 5 years*
  - *are not exercising on a regular basis*
  - *are able to walk independently*
  - *do not have other chronic medical problems that limit participation*
  - *are not severely obese (your body mass index must be ≤ 40 kg/m*^{2}*)*
  - *do not have cognitive impairments*

- Benefits from participating in this research include:
  - *Information for all participants regarding their risk for falling and foot ulcerations*
  - *Information for all participants about their current strength, flexibility, and mobility, which are important factors for carrying out the daily activities of living*
  - *Free assessments and free Tai Chi exercise*

- To learn more about this research contact:
  - *Elisabeth Cavegn, BS, PTA (915-491-3729 or eicavegn@miners.utep.edu)*
  - *Jody Riskowski, PhD (915-747-6012 or jlriskowski@miners.utep.edu)*

UTEP IRB Approval Number 145925-1

La Universidad de Texas en El Paso

Se Buscan Voluntarios para Estudio de Investigación

Efectos del Tai Chi en Balance, Sentido Táctil del Pies, y Condición Física General en Adultos Mayores con Diabetes Tipo 2

- El propósito de este estudio es observar los efectos del Tai Chi en adultos mayores con diabetes tipo 2. Se examinaran el balance, la sensibilidad de los nervios de los pies, y la condición física general, incluyendo la fuerza muscular, flexibilidad, movilidad, y la capacidad aeróbica. La duración del estudio será aproximadamente de 10 semanas las cuales incluyen 8 de Tai Chi.

- Usted podrá participar en esta investigación si usted:
  - *tiene entre 55 y 80 anos*
  - *ha sido diagnosticado/a con diabetes tipo 2 por lo menos hace 5 anos*
  - *no hace ejercicio regularmente*
  - *puede caminar sin ayuda*
  - *no tiene algún otro problema médico crónico que limite su participación*
  - *no es severamente obeso/a (su índice de masa corporal tendrá que ser* $\leq$ *40 kg/*m^2*)*
  - *no tiene impedimentos cognitivos*

- Los beneficios por participar en esta investigación incluyen:
  - *Información a todos los participantes sobre el riesgo de caídas y ulceraciones en los pies*
  - *Información a todos los participantes sobre su estado actual de fuerza, flexibilidad, y movilidad; los cuales son factores importantes para llevar a cabo actividades de la vida diaria*
  - *Evaluaciones gratuitas y ejercicio de Tai Chi gratis*

- Si desea mas información acerca de este estudio por favor comuníquese con:
  - *Elisabeth Cavegn, BS, PTA (915-491-3729 o eicavegn@miners.utep.edu)*
  - *Jody Riskowski, PhD (915-747-6012 o jlriskowski@miners.utep.edu)*

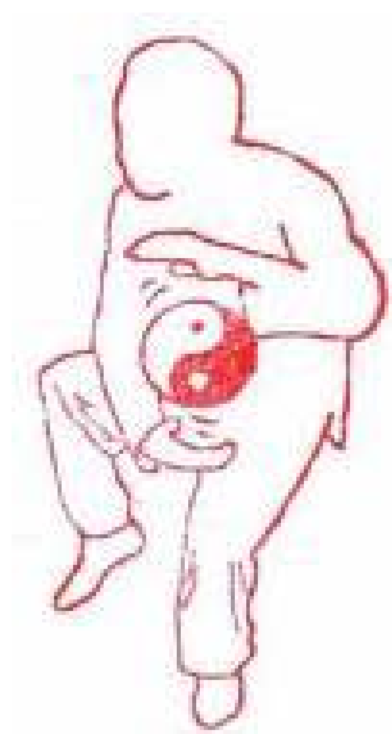
Numero de aprobación del IRB de UTEP 145925-1

Thesis Defense Announcement

Elisabeth Cavegn

Master’s Program in Kinesiology

The Effects of Tai Chi on Balance and Peripheral Somatosensation in Older Adults with Type 2 Diabetes



Tuesday, May 10, 2011

College of Health Sciences

Room 105, 3:00 PM

Curriculum Vita

Elisabeth Cavegn was born and raised in Zurich, Switzerland. After graduating from high school, she worked part time as an au pair in Neuchâtel (Western Switzerland), while attending art classes at the local community college. In the spring of 1974, she entered the School of Art and Design Zurich (now the Zurich University of the Arts) and completed her degree in graphic design in 1978. After working for many years on advertising campaigns for clients including Swissair, Adidas, Audi, and Volkswagen, she accepted the position as representative art director for a woman's magazine. During that time, she obtained her certification as an aerobics/fitness instructor and conducted classes at a local fitness center. In 1999, she came to El Paso and received her associate degree in applied science from El Paso Community College in the spring of 2004. In August 2004, she received her license as a physical therapist assistant from the Texas Board of Physical Therapy Examiners. In the spring 2007, she received her bachelor's of science degree with a minor in biology from The University of Texas at El Paso. In the summer of 2008, she entered the Graduate School at The University of Texas at El Paso.

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