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Effect of tai chi on the glucose and functional fitness level among elderly men with hyperglycemia

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A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background & Study Aim: The results of epidemiological studies suggest that diabetes is significantly more frequent amongst physically inactive individuals and rarely develops in active subjects. We analyzed the effect of *tai chi* on individuals with elevated level of glucose.

Material & Methods: The participants (25 men aged 61 to 79 years) were randomly assigned to the experimental – "E" (n = 10 with hyperglycemia) or control – "C" group (n = 15 right level of blood glucose). Men from "E" group had reported hyperglycemia and "C" group had normal level of glucose. Every subjects participated in an 18-week exercise class held twice a week. The level of glucose was measured using Cormay tests. Lower body strength, aerobic endurance and dynamic balance was measured on the basis of tests from the Senior Fitness Test.

Results: The reduction in the level of glucose (from 159.0 mg/dl to 133.4 mg/dl) observed in group "E" was likely a consequence of increased uptake of this sugar by skeletal muscles. Also the results of all three tests of functional fitness (chair stand, 2-Min Step and 8 foot up and go) markedly improved in both groups (main effect from F = 21.0 to F=66.6; $p \leq 0.01$).

Conclusions: The proposed training regimen met our expectations and, therefore, we can conclude that *tai chi* can improve the components of health and physical function in men with hyperglycemia. In patients with hyperglycemia, glucose was decreased (among healthy subjects did not change) and muscle strength, endurance, and dynamic balance increased as in healthy after training.

Key words: balance • endurance • Senior Fitness Test • strength

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Tai chi – a traditional form of Chinese fitness exercise characterized by smooth, or even dancing movements of a relatively low intensity. *Tai chi* developed in China in the 11th century and has a positive influence on the recovery and maintaining of physical and psychic health [6].

Functional fitness – physical abilities to perform normal everyday activities safely and without excessive fatigue [17].

Hyperglycemia – blood glucose level above 125 mg/dl.

Qigong – literally: "Life Energy Cultivation") is a holistic system of coordinated body posture and movement, breathing, and meditation used for health, spirituality, and martial arts training [36].

Xinghi – one of the so-called external styles of Chinese therapeutic exercises.

INTRODUCTION

Increasingly, the professional activity of an individual is related to a low level of physical effort. Similarly, household chores are associated with minimal physical activity. Moreover, the older is the individual; the lower is his/her activity. Older age and progressive reduction of physical activity level are associated with metabolic disorders, including diabetes, obesity, and coronary artery disease. The results of epidemiological studies suggest that diabetes is significantly more frequent amongst physically inactive individuals and rarely develops in active subjects [1]. In the case of type 2 diabetes patients, physical exercise is reflected by higher sensitivity to insulin, better compensation of glycemia, and favorable modification of lipid profile. Due to the frequent incidence of severe consequences of diabetes [2], maintaining physical fitness is vitally important for the affected patients.

Gregg et al. [3] observed that 15% of elderly men with diabetes reported an inability to walk one-fourth of a mile, climb stairs, or do housework compared with 8% of men without diabetes. Moreover among approximately 5 million U.S. elderly people with diabetes, 1.2 million are unable to perform major physical tasks.

Studies of the motor capacities of diabetic patients revealed that impaired lower-extremity function is a long-term diabetic complication in older patients [4]. The observed reduction of muscle mass in diabetic patients may constitute one of the reasons behind their lower fitness. Consequently, the authors of this study suggested that comprehensive assessment of older diabetic patients should include a standardized evaluation of lower-extremity performance.

The conclusions of previous studies point to the necessity of developing forms of physical activity that would prevent the decrease in functional fitness of hyperglycemic individuals.

Properly designed regimen of physical training for individuals with hyperglycemia should be adjusted in terms of both the type and intensity of the exercise, as well as with paying attention to the duration and frequency of the training sessions. In the case of diabetic patients, it should be based on dynamic aerobic exercise with moderate intensity. These requirements are satisfied by *tai chi*, which is characterized by flowing and dynamic sequences of movements. Wide possibility of individualizing the exercises and individual selection of exercise load facilitate the aerobic character of *tai chi* training.

Previous studies documented the positive influence of this form of movement in healthy individuals, as well as in patients with osteoporosis [5], degenerative joint disease [6], functional disorders of the heart [7], excessive adiposity, Parkinson's disease [8], and many other conditions. *Tai chi* has been practiced for centuries in China, where its positive influence on mood and overall health status of older people has been appreciated [9, 10]. During the last several years, researchers have focused on the effects of *tai chi* on individuals with hyperglycemia or confirmed diabetes; however, the results of these studies are inconclusive.

Song et al. [11] determined that 6 months of consistent *tai chi* practice improve the overall health of type 2 diabetics. Out of a group of 62 patients, those who participated in a twice-weekly course showed significant declines in fasting glucose and A1c (a measure of long-term blood glucose levels). Moreover, the subjects from *tai chi* group demonstrated improvements in diabetic self-care, mental health, social function, and vitality, which may have additionally promoted the improvement in the results of medical tests.

Another study, 14 weeks long and involving one hour of *tai chi* exercises per day practiced for 5 days a week, examined 20 middle-aged females with type 2 diabetes, who participated in this program [12]. Authors observed improvements in glycemic control and a reduction in triglyceride levels and concluded that *tai chi* could be used as an interventional tool to improve glycemic control and serum TG level in the elderly people. Despite short, 14-week, duration of the experiment, it unambiguously revealed positive effect of this form of physical activity on blood parameters. Richerson and Rosendale [13] reported similar findings after conducting analysis of the impact of *tai chi* on reducing the number of falls among elderly patients with type 2 diabetes. In addition to improving sensory perception (of the feet) and overall balance, a beneficial decline in their A1C level (a minor component of hemoglobin to which glucose is bound) was also noted in all the *tai chi* participants.

Yeh et al. [14] studied the effect of a 12-week course of *tai chi* exercise on T cell helper reaction in patients with type 2 diabetes. In addition, a combination of *tai chi* and selected medication may provide an even better improvement in both the metabolism and immunity of patients with type 2 diabetes. Wang [15] revealed that even an 8-week intervention may be sufficient to observe the effect of *tai chi*. By the 8th

week of exercise, blood glucose decreased, while the number of high- and low-affinity insulin receptors and the binding capacity of low-affinity insulin receptor increased. Serum insulin increased but was still within the normal range. After a single bout of *tai chi* exercise, blood glucose, number of high- and low-affinity insulin receptors, and their binding capacity increased, while serum insulin did not change. Even very short *tai chi* intervention showed beneficial effects on the health status of patients with type 2 diabetes.

Nevertheless, the results of the most recent study conducted by Lam et al. [16] question the efficacy of tai chi training. In this study, researchers assessed a total of 53 patients who were recruited to *tai chi* and control group. Authors observed improvements in A1c, 6-minute walk test, and total cholesterol upon comparing baseline and follow up results. However, the difference between the two treatment groups was not statistically significant. In the case of *tai chi* group, health status results showed improvements in three domains; however, there was no significant improvement in metabolic control or cardiovascular risk at follow up compared to the control group. Interestingly, subjects in *tai chi* group showed improvements in physical and social functioning. The question whether *tai chi* modulates the level of glucose and functional capacity of hyperglycemic individuals still remains unanswered. Consequently, we assumed that an appropriate level of physical activity constitutes the first line of hyperglycemia treatment. Since *tai chi* is a form of exercise recommended irrespective of patients' age, we analyzed the effect of 18-week *tai chi* training on individuals with elevated level of glucose.

MATERIAL AND METHODS

Participants

The study included 25 men aged 61 to 79 years. The subjects were recruited from the community using direct mailings and community efforts aimed at encouraging study participation. None of the participants used social assistance or nursing care. The subjects had not previously participated in *tai chi* or other forms of sport or exercise for health or recreational purposes for at least the last 5 years.

Men with history of significant cardiovascular, pulmonary, or musculoskeletal disease (e.g. joint fracture, artificial joint replacement) or neurological diseases (e.g. stroke, Parkinson's disease, poor vision) were excluded. The participants were randomly assigned to the experimental – "E" (n = 10 with hyperglycemia – blood glucose level above 125 mg/dl) or control group – "C" (n = 15 – blood glucose level 70 -100 mg/dl).

Participation in the study was voluntary and every subject expressed in writing their consent to take part in the experiment after receiving written information about the process of examination and participation in an exercise group, which had the approval of the Local Committee of Ethics in Research.

Procedure

Every men participated in an 18-week exercise class held twice a week. Exercise sessions took 45 minutes and were led by a certified *tai chi* instructor. The sessions included 10 minutes of warm up exercise (involving stretching and balance exercise), 30 minutes of *tai chi* practice, and 5 minutes of cool down exercise.

The main part of the course consisted of learning and improving forms of Tai Chi. We used 5 sequences of movement chosen from the simplified 24 form *tai chi*: 1) the wild horse parts its mane, 2) brush knee and step forward, 3) reverse reeling forearm, 4) left/right sparrows tail, 5) wave hands like clouds [17]. The subjects performed techniques of *Qigong*, including the circular motion of individual parts of the body (hips, trunk), stretching the spine, slopes and half-squats. Each exercise was repeated nine times [18].

Each participant had to adequately control the body in order to perform the task. Exercises consisted of free movement or whole body in space. This forced practitioners to appropriately moving the center of gravity through a precise balance and differentiated charging lower limbs. Subjects mirrored the motions and postures of the instructor at the same speed and with the same technique. During the sessions, the instructor continuously monitored the subjects and corrected the body position, joint angles, and form-to-form transition. The attention was paid to the smoothness of motions and the monitoring of correct breathing at the same time. The intensity of the classes allowed to maintain the heart beat at the level of approx. 110-120 beats per minute.

Tai chi meditation posture – elements *xinghi* – was also important for the effectiveness of the training. It helped not only strengthen the muscle strength of the lower limbs and shoulder, but learned concentration

and improve the feeling of the body. The last part – the cool-down is 5 minutes relaxation exercises.

Tai chi forms part of the movement with low intensity. The intensity was controlled with the use of sport-testers. General assumptions program of activities has been prepared in accordance with the recommendations of the American College of Sports Medicine [19]. The final part of the training was varied relaxing music.

Measurements

All measurements were taken one week before the intervention and again after 18 weeks. The level of glucose in the venous blood serum was measured using Cormay tests. Lower body strength ("chair stand"), aerobic endurance ("2-Min Step") and dynamic balance ("8 foot up and go") was measured on the basis of tests from the Fullerton Functional Fitness Test [20]. Each test component of the SFT has been selected for its high content validity, criterion validity, construct validity, and reliability [21, 22]. The ICCs were quite good (0.79 to 0.97) on all components of the SFT for the three environments [23]. Those tests assist health practitioners and different specialists in identifying weaknesses that cause mobility problems and developing exercise programs that improve functional fitness. Tests can be conducted with minimal space, equipment, and technical requirements, making it easy to administer in most community settings or in the home. There is only needed a chair and a stopwatch to perform these tests.

Statistical analysis

Statistical analyses were performed using Statistica 10 software (StatSoft Inc, OK, U.S.) and statistical significance was defined as $p \leq 0.05$. ANOVA (analysis of variance) was used to determine the significance of differences between experimental and control groups and for the analysis of variation of pre-test and post-test results. The analysis with two levels of the first factor (within-subject factor: "training" – pretest, posttest) and two levels of second factor (between-subject factor: "group" – lower and higher level of blood glucose) was used. For interaction effects, the eta-squared ($\eta 2$) effect size was calculated. The effect size indicates the percent of variance explained by the particular effects of the dependent variable. It was also used to calculate the power of significant effects. To compare the average values of all parameters (both pre-test–post-test within session and between sessions for pre-test and post-test) Bonferroni detailed post hoc comparisons were conducted.

RESULTS

A decrease in the level of glucose, from 159.0 mg/dl to 133.4 mg/dl was documented in men from hyperglycemic group "E", who took part in *tai chi* training for a period of 18 weeks (Figure 1a); this change proved statistically significant ($p \leq 0.01$). During the same period, unchanging right level of glucose (89.8 mg/dl pre and 90.2 mg/dl post) was observed in group "C". Differences were statistically significant (interaction effect between-subject factor: "group" – lower and higher level of blood glucose $F = 22.1$; $p < 0.01$, $\eta 2 = 0.50$) between groups "E" and "C".

Tai chi training proved equally effective with regards to the functional fitness of men from "E" and "C" groups. All three examined components of functional fitness: lower body strength (Figure 1b), aerobic endurance (Figure 1c, and dynamic balance (Figure 1d) improved statistically significantly (main effect within-subject factor: "training" – pretest, posttest from $F = 21.0$ to $F = 66.6$; $p \leq 0.01$).

DISCUSSION

Physical exercise is the simplest and the cheapest non-pharmacological modality of reducing resistance to insulin and the level of glucose in venous blood. The reduction in the level of glucose observed among men with hyperglycemia after *tai chi* training was likely a consequence of increased uptake of this sugar by skeletal muscles. Physical exercise improved uptake of glucose and synthesis of glycogen. Additionally, physical training improves metabolism of glucose in the liver and other tissues [24]. Positive effect of *tai chi* with regards to glucose level are the result of increased sensitivity to insulin associated with the proposed training regimen, comprising 45-minute sessions of exercise, continued two times a week for an 18-week period. Each such training session is associated with decreased blood concentration of glucose. The results of previous studies suggest that such moderate exercise increased sensitivity to insulin irrespective of changes in body weight – in contrast to dietary regimen, which improves insulin sensitivity of tissues through the reduction of body mass [25].

It is possible that *tai chi* can prompt a decline in blood glucose levels; perhaps, by improving blood glucose metabolism. The alternative explanation proposes that exercise may boost levels of fitness along with a feeling of wellbeing and this, in turn, may boost the health of the whole body.

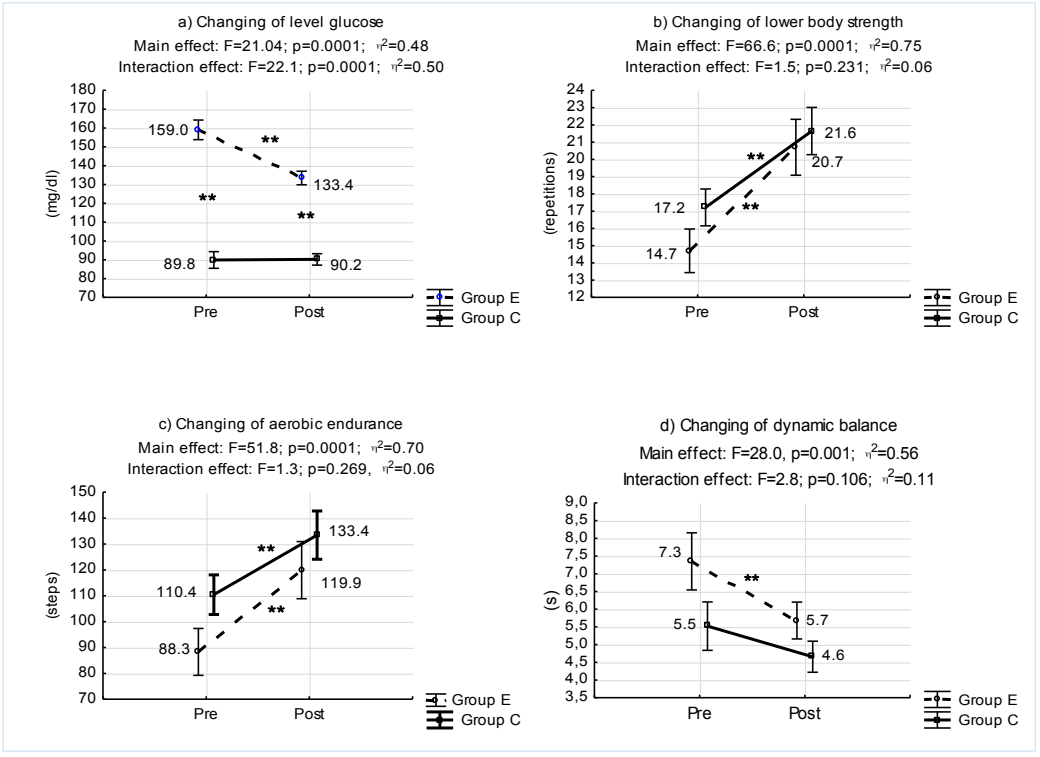

Figure 1. Differences in the changes: a) glucose, b) lower body strength, c) aerobic endurance, d) dynamic balance in group "E" and "C" after the training program.

**p<0.01 (Bonferroni post-hoc test)

The changes in glucose level observed in hyperglycemic patients may be considered clearly positive and convincing. Ta chi training can significantly facilitate the process of regulating the level of sugar. In addition the results of three tests of functional fitness [chair stand, 2-Min Step and 8 foot up and go] markedly improved in both groups (with hyperglycemic and with right level of glucose). It is the second positive effect of *tai chi* training.

Orr et al. [26] randomly allocated type 2 diabetic patients to *tai chi* group and control group, which performed sham exercises (e.g., seated calisthenics, stretching). After 5 months, *tai chi* provided moderately significant improvements in mobility, although not different from sham exercise. The dose and/or movements of *tai chi* may not have been sufficient to elicit robust adaptations.

Observed in this study improvement in the parameters of functional fitness resulting from relatively small load of *tai chi* (45 minutes twice a week) is not surprising. Even minimal level of physical activity can be reflected by positive changes in physical fitness. In contrast, the extent of improvement in muscular strength, aerobic capacity, and dynamic balance in our study should be considered surprising (p<0.01). Positive response to training is important due to the role of proper muscular strength and cardiovascular capacity in the maintenance of the overall health in older individuals with hyperglycemia. Specific adaptive changes of the neuromuscular system can be observed as early as during the first phase of systematic physical training [27]; they usually lead to the improvement in strength abilities resulting mostly from the improved control of muscle groups involved in the exercise, as confirmed by the studies conducted by Rutherford and Jones [28]. Bean et al. [29] recognized the strength and power of lower limb muscles as the main determinants of functional fitness and motor independence.

The results of studies dealing with the efficacy of rehabilitation programs for people of various ages suggest that during the senior years each method of rehabilitation brings expected results with regards to improved fitness. Additionally, due to various contraindications associated with this period of life, many methods of rehabilitation (otherwise highly effective in younger individuals) have to be discarded.

For example, Carter et al. [30] implemented elastic tapes and small dumbbells (1-2 kg) into a comprehensive, 20-week training program aimed at the improvement of muscular strength. This experiment showed only a slight (non-significant) improvement in the strength of knee joint extensors, being a principal target of stimulation. Consequently, the improvement in the results of tests for muscular strength, observed in many participants of *tai chi* training, should be emphasized as a positive effect. The efficacy of this type of training with regards to muscular strength was reported in previous studies. Wolfson et al. [31] revealed that three months of *tai chi* training can be reflected by an improvement in the strength of older healthy subjects. Due to the specific forms of movement included in *tai chi* training, it can be expected that the post-training increase in muscular strength of lower limbs will be more pronounced than in the case of other regions, e.g. upper part of the body; this was confirmed in our male participants with hyperglycemia. However, Jacobson et al. [32] observed a relatively weak positive effect of *tai chi* on the muscular strength of knee joint muscles of older individuals no earlier than after 12 months of the training program. Furthermore, these authors concluded that *tai chi* has an insubstantial influence on muscular strength, postural stability, and kinesthetic perception. In contrast, in the study of Lan et al. [33], a 6-month *tai chi* training of men and women (mean age 61 years) was reflected by a marked increase in the strength of knee joint extensors. According to Wolfson et al. [31], the improvement in muscular strength can result even from three months of *tai chi* trainings conducted three times per week. In another study of older individuals, 12-week *tai chi* training was reflected by an improvement in muscular strength of both knee joint extensors and flexors [34].

The papers documenting the effects of *tai chi* training upon the cardiorespiratory capacity of older males are sparse. Moreover, Orr et al. [26] suggest that the benefits of *tai chi* are likely based on the provoked mental and physiological changes. Nevertheless, our study documented a marked improvement in the results of test, which determine aerobic endurance. As a result of *tai chi* training, the average number of steps taken during 2-minute period by our male participants increased from almost 95 to more than 120, which corresponds to more than 25% improvement. Less pronounced improvement in aerobic endurance (9%) was observed as a result of training regimen proposed by researchers from Portland, comprised of ten exercises based on strictly determined motor tasks (standing, sitting, item transfer, sit-to-stand, dressing up, vacuum cleaning, etc.) performed twice a week [35]. The level of dynamic balance, determined on the basis of "stand and walk" test in an experiment involving older men with hyperglycemia is considered a significant indicator of motor independence.

CONCLUSIONS

The proposed training regimen met our expectations and, therefore, we can conclude that *tai chi* can improve the components of health and physical function in men with hyperglycemia. In patients with hyperglycemia, glucose was decreased (among healthy subjects did not change) and muscle strength, endurance, and dynamic balance increased as in healthy after training.

COMPETING INTERESTS

Authors have declared that no competing interest exists.

REFERENCES

1. Hu FB, Sigal RJ, Rich-Edwards JW et al. Walking compared with vigorous physical activity and risk of type 2 diabetes in women: a prospective study. JAMA 1999; 282 (15): 1433-1439
2. Dziemidok P, Szcześniak G, Kostrzewa-Zabłocka E et al. Is the advancement of diabetic angiopathy evaluated as ankle-brachial index directly associated with current glycaemic control? Ann Agric Environ Med 2012; 19 (3): 563-566
3. Gregg EW, Beckles GL, Williamson DF et al. Diabetes and physical disability among older U.S. adults. Diabetes Care 2000; 23 (9): 1272-1277
4. Volpato S, Ferrucci L, Blaum C et al. Progression of lower-extremity disability in older women with diabetes: the Women's Health and Aging Study. Diabetes Care 2003; 26(1): 70-75
5. Maciaszek J, Osiński W, Szeklicki R et al. Effect of Tai Chi on body balance: randomised controlled trial in men with osteopenia or osteoporosis. Am J Chin Med 2007; 35(1): 1-9
6. Tomaszewski W, Mańko G, Pachalska M et al. Improvement of the Quality of Life of persons with degenerative joint disease in the process of a comprehensive rehabilitation program enhanced by Tai Chi: the perspective of increasing therapeutic and rehabilitative effects through the applying of eastern techniques combining health-enhancing exercises and martial arts. Arch Budo 2012; 8(3): 169-177

7. Liu J, Li B, Lee AN. The effects of Tai Chi training on improving physical functions in patients with coronary heart diseases. Res Q Exerc Sport 2007; 78(1): 1-9
8. Kluding P, Quinn McGinnis P. Multidimensional exercise for people with Parkinson's disease: A case report. Physiother Theor Pract 2006; 22(3): 153-162
9. Taylor-Piliae RE. Tai Chi as an adjunct to cardiac rehabilitation exercise training. J Cardiopulm Rehabil 2003; 23(2): 90-96
10. Chi JCh, Huang ChF, Kernozek T et al. Counter movement jump performance between older adults with and without regular Tai Chi exercise training. Arch Budo 2013; 9(4): 249-254
11. Song RS, Ahn BL, Roberts EO et al. Adhering to a T'ai Chi Program to Improve Glucose Control and Quality of Life for Individuals with Type 2 Diabetes. J Alternative Compl Med 2009; 15(6): 627-632
12. Zhang Y, Fu FH. Effects of 14-week Tai Ji Quan exercise on metabolic control in women with type 2 diabetes. Am J Chin Med 2008; 36(4): 647-54
13. Richerson S, Rosendale K. Does Tai Chi Improve Plantar Sensory Ability? A Pilot Study. Diabetes Tech Therapeut 2007; 9(3): 276-286
14. Yeh SH, Chuang H, Lin LW et al. Regular Tai Chi Chuan exercise improves T cell helper function of patients with type 2 diabetes mellitus with an increase in T-bet transcription factor and IL-12 production. Br J Sports Med 2009; 43(11): 845-50
15. Wang Ch, Collet JP, Lau J. The effect of Tai Chi on health outcomes in patients with chronic conditions: a systematic review. Arch Inter Med 2004; 164(5): 493 – 501
16. Lam P, Dennis S,. Diamond TH et al. Improving glycaemic and BP control in type 2 diabetes - The effectiveness of Tai Chi. Aust Fam Physician 2010; 37: 884-887
17. Liang Soun-Yu, Wu Wen-Ching. Simplified Tai Chi Chuan: 24 Postures with applications and standard 48 postures. IMAA Publication Center, Wolfeboro 1995
18. Maciaszek J. The effect of Tai Chi training on postural stability and its determinants in men over 60. Wydawnictwo AWF Poznań; 2009
19. American College of Sport Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility of healthy adults. Med Sci Sport Exerc 1998; 30 (6): 975-91
20. Rikli RE, Jones CJ. Senior fitness test manual. California State University. Fullerton: Human Kinetics; 2001
21. Rikli RE, Jones CJ. Assessing physical performance in independent older adults: issues and guidelines. JAPA 1997; 5: 244-261
22. Rikli RE, Jones CJ. The reliability and validity of a 6-minute walk test as a measure of physical endurance in older adults. JAPA 1998; 6: 363-375
23. Brooke Van Gundy T. Reliability of the senior fitness test in a modified environment by. Iowa State University Ames: Tiffany Brooke VanGundy; 2006
24. Segal KR, Edano A, Abalos A et al. Effect of exercise training on insulin sensitivity and glucose metabolism in lean, obese, and diabetic men. J Appl Physiol 1991; 71(6): 2402-2411
25. Seibaek M, Vestergaard H, Burchardt H et al. Insulin Resistance and Maximal Oxygen Uptake. Clin Cardiol 2003; 26(11): 515-516
26. Orr R, Tsang T, Lam P et al. Mobility Impairment in Type 2 Diabetes: Association with muscle power and effect of Tai Chi intervention. Diabetes Care 2006; 29(9): 2120-2122
27. Gandevia SC. Spinal and supraspinal factors in human muscle fatigue. Physiol Rev 2001; 81: 1725–1789
28. Rutherford OM, Jones DA. The role of learning and coordination in strength training. Eur J Appl Physiol Occup Physiol 1986; 55(1): 100-105
29. Bean JF, Kiely DK, Herman S et al. The Relationship Between Leg Power and Physical Performance in Mobility-Limited Older People. J Am Geriatr Soc 2002; 50(3): 461-467
30. Carter ND, Khan KM, McKay HA et al. Community-based exercise program reduces risk factors for falls in 65- to 75-year-old women with osteoporosis: randomized controlled trial. CMAJ 2002; 167(9): 997-1004
31. Wolfson L, Whipple R, Derby C et al. Balance and strength training in older adults: intervention gains and Tai Chi maintenance. J Am Geriatr Soc 1996; 44: 498-506
32. Jacobson BH, Chen HC, Cashel C. The effect of Tai Chi Chuan training on balance, kinesthetic sense, and strength. Percept Mot Skills 1997; 84: 27-33
33. Lan C, Lai J, Chen S et al. Tai Chi Chuan to Improve Muscular Strength and Endurance in Elderly Individuals: a Pilot Study. Arch Phys Med Rehabil 2000. 81(5): 604-607
34. Choi JH, Moon JS, Song R. Effects of Sun-styl Tai Chi exercise on physical fitness and fall prevention in fall-prone older adults. J Adv Nurs 2005; 51(2): 150-157
35. Dobek JC, White KN, Gunter KB. The effect of a Novel ADL-Based Training Program on performance of activities of daily living and physical fitness. J Aging Phys Act 2006; 15: 13-25
36. Cohen KS. The Way of Qigong: The Art and Science of Chinese Energy Healing. Random House of Canada; 1999

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