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Effects of square stepping exercises on physiological cost index in elderly population

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Abstract
Aim: The aging process might increase the energy expenditure of an individual to perform any task, including alteration in balance which can increase the risk of falls among the elderly people. The purpose of this study was to find out the effects of square stepping exercise (SSE) sequences on the physiological cost index in the elderly population.
Methods: A total of 30 elder individuals were included for the study (>65 years). They had to practice square stepping exercise elementary 1 and elementary 2 patterns for four weeks with three times a week. Pre and post intervention, the individuals had to perform the 6 minute walk test to calculate the physiological cost index and berg balance scale's components to check their balance score.
Results: Every individual performed the square stepping exercise protocol and had a significant effect on their physiological cost index by reducing their energy expenditure while walking. It also showed significant improvement in the balance of the individuals.
Conclusion: The square stepping exercise practiced showed a significant effect to lower the energy expenditure on physiological cost index and it also improves the balance. It also showed significant correlation coefficient between balance and physiological cost index or energy expenditure.

Keywords: square stepping exercise, elders, physiological cost index, balance, energy expenditure

Introduction
According to the U.S. Centers for disease control and prevention, falls lead to more than 2.8 million injuries in elderly people that are treated in the emergency department annually, which include over 800,000 hospitalizations and over 27,000 deaths. Also the World Confederation for Physical Therapy (WCPT) estimates that one out of Three people above 65 years of age will fall each year [1, 2]. Age related changes in the skeletal muscles affect both the muscle structure and function. Age related reductions in the mass of a muscle are a direct cause of the reduction in muscle strength seen with ageing. Further, this reduction in the strength of the muscle is a major cause of disability in the older adult since strength and power are the major components of balance, gait and the ability to complete their daily activities [3].
Balance can be Static and Dynamic. Dynamic balance is the result of interactions between the participant, the task which the participant is performing and the environment in which the task is being performed. In static balance, the Base of Support (BOS) remains stationary and only the Center of Mass (COM) moves. In dynamic balance, the BOS and COM both are moving. The COM is never kept within the BOS. [18-22]Balance is a complex process that includes reception and integration of sensory inputs; planning and executing a movement that requires upright posture [18, 19].
Oxygen consumption and energy cost of walking (ECW) have been widely used in the literature investigating the efficacy of interventions for improvement of walking capability. Another method used to assess gait demand is the Physiological Cost Index (PCI), proposed by MacGregor [11] PCI is calculated as follows: (heart rate during steady state exercise minus heart rate at rest) divided by walking speed.
PCI is expressed in beats/meter and indicates the increased heart rate (HR) necessary for exercise (walking). PCI theory has been based on the fact that, for submaximal effort, a correlation exists between HR and VO2. Fredrickson *et al.* reported that the PCI can be used as a proxy index for the oxygen cost of walking in subjects after stroke [26]. in a more recent work It has to be considered that heart rate measurement could be affected by altered vagal or sympathetic regulation, secondary to brain injury [10].
Walking is known to improve the oxygen consumption in the body which helps in lowering the energy expenditure spent on doing any particular task. Our study shows the evidences that square stepping exercises are very effective exercise protocol in improving the VO2 max of the body. As the body of the participant gets used to perform tasks and activity with minimum use of oxygen so less energy is spent and more activity can be performed. Many studies on the efficacy of interventions for improvement of walking have used an oxygen uptake (VO2) recording in their measurement procedures [6, 7]. Heart rate (HR) measurement is considered to be a low technology and is proposed to assess the energy expenditure during different tasks. The use of heart rate

monitoring to assess energy cost during walking probably originates from MacGregor, who introduced the Physiological Cost Index (PCI) [11].

Shigematsu *et al.* developed a Square Stepping Exercise (SSE) in 2006 which composed of movements that are similar [6] to walking and can easily be performed indoors. Unlike walking, Square Stepping Exercise involves varied movements in multiple directions. It is performed on a thin mat (100x250 cm) partitioned into 40 squares of 25cm each. The Square Stepping Exercise seems to be a great method for preventing risk of fall and improving balance. This may be because the Square Stepping Exercise involves sensorimotor stimulation [12].

The Square Stepping Exercise consists of walking from one side of the mat to the other according to the pattern of the protocol called the elementary patterns. The participants can only see the sequence which is made by the professional supervisor and then, the participant must reproduce it. Many sequences are possible and the level of difficulty increases as the participant has accomplished the initial sequence [12-15]. Square Stepping Exercise is fairly new intervention protocol and thus has limited research in the same field. That is one of the prime reasons of importance and effectiveness must be carefully studied and examined to understand all the benefits and shortcomings of the protocol.

The berg balance scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research [29].

There is a need of this study as Physical exercises are an effective strategy used to improve functional fitness indexes. Researches demonstrate that strength and balance training and aerobic work-out helps to increase the functional capacity of an participant which can reduce the energy expenditure of a body to perform any task [2, 3, 4]. Correlations between PCI and VO2 have been investigated in amputees (children and adults) [22, 23], children with cerebral palsy [23], adults with spinal cord injuries, and healthy adults. Also PCI has been reported as outcome measure, in several studies, after interventions in persons with cerebral palsy, spinal cord injury, rheumatoid arthritis, stroke, and acquired brain injury [26]. Square stepping exercises have been proven to have positive effects on improvement of balance and coordination in elderly people [12-19].

Materials and Methodology

Study Design – experimental study
Target Population – elderly people
Sampling Method – convenient
Sample Size – 30
Study Setup – old age homes in Pune city
Outcome Measures – Berg balance sale and Physiological cost index

Materials

- Square stepping exercise – mats, chalk, stopwatch.
- Berg balance scale – 2 chairs, stopwatch, foot stool or stepper, scale or measuring tape.
- Physiological cost index – chalks, 30mt yard, stopwatch, device to measure HR, chairs.

Inclusion Criteria

- Elderly people above 65 years of age, walking independently and without support of walking aid
- Participant which fall under low to moderate risk of fall category in berg balance scale
- Post THR and TKR of minimum of 3 years and can walk independently.

Exclusion Criteria

- People not willing to participate
- People having serious cardiovascular and neurological involvement and who cannot walk independently.
- Bony deformities in lower limbs.
- Recent fracture or any surgery cases.

Procedure

Initially the synopsis was submitted to the institute and was approved by the ethical committee. It was an experimental study in which 30 sample size constituted of elderly people aged 65 and above were examined. The participants were selected according to the inclusion and exclusion criteria. The people were examined with their prior permission after explaining the need of study. All the components of the outcome measures were explained and performed under supervision. Pre & post berg balance score and physiological cost index value was noted with the reference of square stepping exercise.

Berg Balance Scale

Baseline data was recorded and the participants were explained regarding the components which they had to perform. All the equipments were arranged according and pre berg balance scale was performed under the supervision. Readings and participant scorings were recorded. Same procedure was done post intervention and the scorings were recorded to analyze the data.

Physiological Cost Index

It is a measuring index used to measure the energy expenditure of the body.

Formula

PCI (beats/meter) = HR after 6MWT – resting HR / walking speed
SPEED (meter/min) = distance (meter) / time (min)

Square Stepping Exercise

The participants then underwent the intervention of the square stepping exercise: elementary patterns 1 and 2,(19) over a period of four weeks, three sessions weekly, for duration of 30mins per session. The 30mins of session was divided as 5mins of warm up, 20mins of intervention followed by 5mins of cool down. Warm up and cool down exercises included deep breathing exercises along with upper and lower extremity range of motion exercises. Elementary pattern one extended over two weeks and elementary pattern two extended for the third and fourth weeks.

Results

Table 1: Shows the Age wise distribution of the participants

Age	Young old (65-74 years)	Middle old (75-84)	Old old (>85 years)
No. of participants	26	4	0

Table 2: States the Comparison of Pre and Post physiological cost index (PCI) value with intervention of SSE.

PCI (beats/mts)	Mean	Standard deviation (SD)
Pre PCI	0.2082	0.2151
Post PCI	0.1566	0.1602

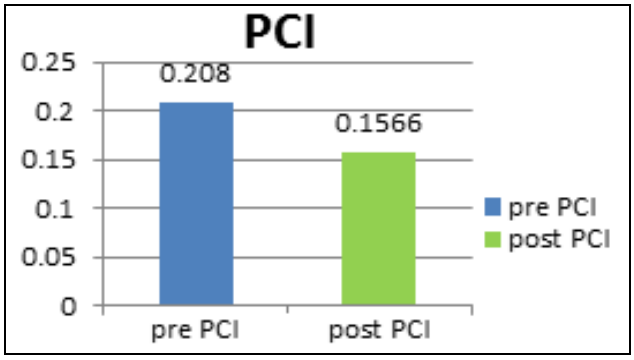

Fig 1

Table 3: Shows the comparison of pre and post Berg Balance scale score with p value <0.0001

Berg balance scale	Mean	Standard deviation
Pre BBS	46.2	5.792
Post BBS	51	5.038

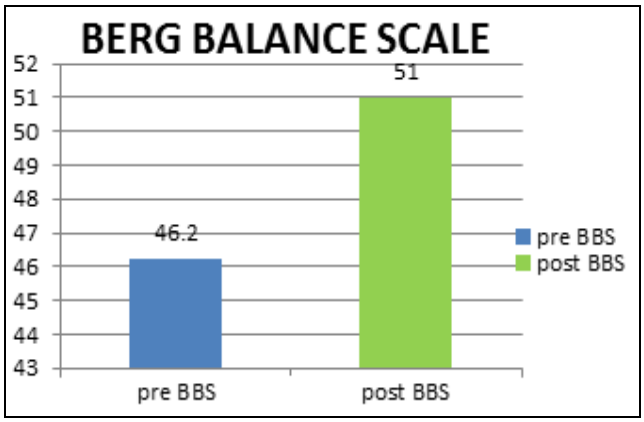

Fig 2

Graph 3.0 shows the Correlation coefficient of berg balance score with physiological cost index score.

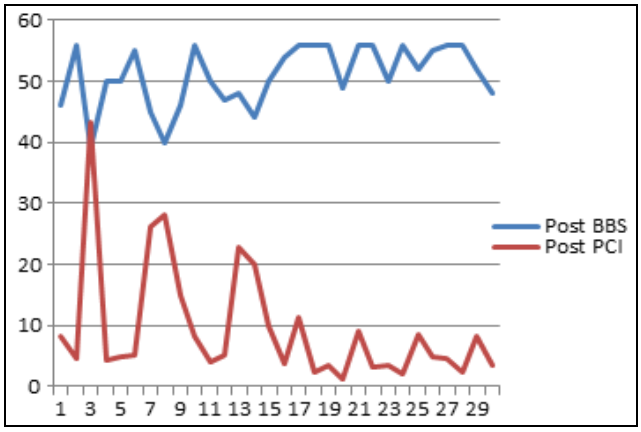

Fig 3: [Spearman's r = -0.5352, Two tailed p Value is 0.0023, considered very significant]

Discussion

The purpose of the study was to check the effects of square stepping exercise on the physiological cost index in elderly. This study showed the effectiveness of square stepping exercise on physiological cost index to check the energy expenditure of the participant and also the effects of square stepping exercise on balance.

Total 30 participants were included with an age 65 and above. The study included both males and females. Out of the 30 participant 26 of them were in category of young old (65-75), 4 participants from middle old (75-85) while there was no one from the old old group. As shown in graph 2 among the 30 participants, 7 participants were normal according to BMI classification, 1 was underweight (<17.99), 13 were obese (>29.99) whereas 9 were overweight (25-29.99). The SSE intervention protocol was carried for 4 weeks. Elementary 1 and 2 patterns were carried out each continuing for 2 weeks.

The physiological cost index (PCI) is a clinical tool thought to indicate the energy expenditure, physiological cost or effort of walking [11]. The use of heart rate monitoring to assess energy cost during walking probably originates from Dr. MacGregor J, who introduced the Physiological Cost Index (PCI) [11].

Physiological cost index was calculated to check the energy expenditure of the participants and to test the effectiveness of square stepping exercise on the PCI. Six minute walk test was carried out and the resting HR and the post six minute walk test HR of every participant were noted to calculate the PCI value. In the present study the mean pre PCI value was 0.2080 and after intervention the post PCI was 0.1566b. The mean difference was 0.0514 which is a significant improvement in the PCI value as P value is 0.0014, which is significant. This study shows that there is reduction in the energy expenditure after performing square stepping exercise. This indicates that walking exercise improves the oxygen consumption in the body which further reduces the energy expenditure to perform an activity. The study also indicated that the PCI value varies

with the walking speed such that a subject's energy expenditure increases when they are walking above or below their preferred speed. More the walking speed, more distance can be covered in the six minute walk test. The PCI value varies with the distance covered while walking. Rana BS *et al.* (2015) did a study on 'estimation of physiological cost index as an energy expenditure index using Macgregor equation'. The PCI value for walking at slow and faster speed was noted along with the preferred speed.

Walking is a widely accepted exercise and is used to develop functional fitness in fall prevention. SSE also composed of similar movements as that of walking, the difference being that SSE consists of multidirectional steps- forward, backward, lateral and oblique movements. These multidirectional movements lead to better activation of the synergist and agonist lower limb muscles [12-14] Jessica *et al*. in their study discussed that the activation of synergists and agonists of muscles of locomotion seems to improve specific components of functional mobility which in turn have an effect on mobility improvement. They also suggest that SSE is a low intensity exercise that targets functional mobility and so reduce the risk of fall. This makes SSE a more feasible alternative for older people mainly for the ones having a fragile health condition

In our study when we assessed balance of the participants and performed square stepping exercise on them, it showed significant improvement in balance of the participants calculated with an outcome measure of berg balance scale. Mean score of berg balance scale pre-intervention was 46.2 and the mean score of the post intervention was 51. Mean difference of the pre and post berg balance score was 4.80.There was an improvement in the balance of the participants according to the berg balance score after square stepping exercise. A change of 4 points is needed to be 95% confident that true change has occurred if the patient scores within 45-56 initially. 7 points if they score between 25-34 and finally 5 points if their initial change is within 0-24 on BBS. Ryosuke Shigematsu *et al.* (2008) 'Square-stepping exercise versus strength and balance training for fall risk factors' which concluded that SSE training is appropriate to achieve the desired results in static balance, agility and walking speed. It was hypothesized that this particular exercise would significantly affect these fitness categories, because SSE consists of quick, multi-directed movements, heel lifts and smooth transfers of weight, which all contribute to improving balance, agility and walking speed [12-18].

In the present study when Correlation Coefficient (Spearman's r value) of berg balance score and the physiological cost index was also taken into consideration. Results proved that r = -0.5352 and the two tailed p value was 0.0023 considering as extremely significant. The results can hence state that there is a positive correlation between balance and the energy expenditure of the participant. It could be said that the balance of body is proportional to the energy expenditure and oxygen consumption of the body where if balance is altered then person requires more energy to perform his activity for eg- during walking if balance is altered then the participant needs more concentration and more energy is required to maintain his static and dynamic balance to walk which ultimately leads to increase in energy expenditure of the body.

Improving the VO2 max further helping in oxygen consumption in the body, and as there is improvement in oxygen consumption in the body it further reports in improving the PCI value of the participant by reducing the energy expenditure. This can be a reason of the significant improvement in the balance and physiological cost index of the participants in the present study. Positive factor of the study was there were no drop outs from any participants during the intervention. Every participant was able to perform and complete the intervention program within required duration. Square stepping exercises can be used to check its effectiveness on abnormal gait patterns. The study can be done to check its effectiveness in various age groups of elderly people and can be compared within it. The PCI rates can also be checked with varying the speed of walking using treadmills. This study can be done with correlation of obesity.

Conclusion

From the present study we can conclude that there is a significant effect of square stepping exercises to lower the energy expenditure on physiological cost index in elderly people and it also improves the balance. In the present study it is proved that there is a significant correlation coefficient between balance and physiological cost index or the energy expenditure.

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