



Effect of Fatigue on Balance and Dual Task Performance in Elderly

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Abstract

Background--fatigue induced by fast walking had an initial negative impact on the control of balance in young healthy adults. However greater proportion of cognitive resources be allocated to the active control of balance. Gait changes following physical fatigue in older person suggest that fatigue may be risk factor for fall in elderly. fatigue induced change, in the excitation of pre motor area force production, places stronger demand on the attentional. system and there by induce a decline in the attentional capacity remaining available for a concurrently performed (cognitive task) in healthy adults.

Aim: To find the effect of fatigue due to physical activity on the balance and dual task performance in elderly.

Method: Whole process was divided in three protocol 1. Pre Fatigue stage, 2. Fatigue protocol, 3 Post. Fatigue protocol. 31 subjects were allocated in study. Variables are B.B.S score, are checked calculation error, and gait speed. In pre fatigue stage B.B.S score, gait speed and calculation error was checked in fatigue protocol fatigue was developed by sit up exercise again post fatigue B.B.S Score, calculation error, Gait speed and then pre and post fatigue data were calculated.

Result: SPSS of version 11.5 was used for data analysis. Significant reduction in post B.B.S score were seen [$p < 0.05$] significant increase in calculation error and significant increase in gait speed.

Conclusion: Conclusion of our study reveals that fatigues alter the balance in elderly and also have effect on cognition so, it may be one of the causes of risk of falls in elderly. Further fatigue also, places higher demand of attention during performance of dual task in normal elderly.

Clinical relevance: As per study reveal fatigue have effect on balance, this observation can contribute to the development of occupational interventions aimed for mitigating the effect of fatigue on balance control and also endurance exercise can be incorporated for prevention of fatigue

Keywords—B.B.S. Scale, Balance, Dual Task Performance, Fatigue

I. INTRODUCTION

Fatigue is defined as time related phenomenon of decline in the maximal force generating capacity of muscle. It is overwhelming sense of tiredness, lack of energy and feeling of exhaustion. Fatigue as a concept is determined by two dimension psychological and physiological (i.e. bodily phenomenon contributing to the perception of fatigue).

Thus psychological factor like wellbeing, concentration problem attention social function also play a role in fatigue production. In physiology fatigue is usually defined as the loss of voluntary force producing capacity during exercise. The losses of force producing capacity can both (and simultaneously) have a peripheral and central origin. This decline in force or force generating capacity may originate from various levels of neuronal axis from motor cortex and spinal cord, to neuromuscular junction, muscle membrane and metabolism. Peripheral fatigue refers to fatigue at the peripheral level i.e. in the muscle tissue. Declining force during contraction is attributed to changing intracellular ion level, accumulation of lactate and extracellular K^+ together with lowering of the Ph which affects membrane excitability. Central fatigue is the decrease of voluntary activation of muscle by the nervous system. A muscle receiving suboptimal input from the central nervous system will not be able to develop its maximal force capacity. In case of submaximal central activation; central activation failure (CAF) is said to be present and any increase in CAF during exercise is called central fatigue¹.

Part of central fatigue is “supraspinal fatigue” because motor cortical output becomes less than optimal; eventually this is task failure when exercise can no longer be continued this point is often termed exhaustion. At spinal level relevant factors include the intrinsic behavior of the motor neuron, recurrent inhibition, reflex inputs reaching α and γ -motoneurons and their presynaptic modulation, as well as other neuromodulatory influences acting on motoneurons and spinal circuitry. At a supraspinal level, the output of descending (including corticospinal) paths to motoneurons and the factors that control this output are likely to be important. The contribution of these various factor will be varying during the course of fatiguing exercise². During sustained maximal contraction the discharge of motor neuron declines, commonly below the level required to produce maximal force from the muscle whose contraction speed is usually slowed. Thus, some central fatigue develops. Recent findings using transcranial stimulation have revealed that the motor cortex is one site at which suboptimal output develops during human muscle fatigue³.

Mammalian skeletal motor units have differing properties including their different susceptibility to fatigue.

Two feedback pathways are of concern here: one via the related muscle unit and muscle spindle afferents (proprioceptive path), and one via recurrent motor axon collaterals and Renshaw cells (recurrent inhibitory path). These two mechanisms contribute to shape the firing patterns of motor units so as to optimize the force output of large fatiguing motor units during long activation, during which their activation rates normally decrease (adapt) over time⁴. The discharge rate of most motor units declined despite an increase in the excitatory drive to the motor neuron pool during the fatigue task⁵.

Postural control involves controlling the body position in space for the dual purpose of stability and orientation. Postural stability or balance is the ability to maintain the body in equilibrium. A body is in equilibrium either when it is at rest (static equilibrium) or when it is in steady state motion (dynamic equilibrium). Postural control requires complex interaction of the musculoskeletal and neural system. Musculoskeletal system includes range of motion, spinal flexibility, muscle properties and biomechanical relationship. Neural component essential to postural control encompasses: motor process including neuromuscular response synergy, sensory process including (visual, vestibular, somatosensory system) and higher level integrative process essential for mapping sensation to action and ensuring anticipatory and adaptive aspect of postural control. Higher level neural process can be reformed as cognitive influences on postural control. There are many aspects of cognition such as attention, and motivation. During ageing changes in these systems contribute to increased likelihood of fall. Statics in the injury and accident in the older adults indicate that fall is the seventh leading cause of death in people over 75 year of age. In addition fall rates in persons 65 year of age and older are at least 33 percent per year in community dwelling older adults with women being more prone to fall than male⁶.

Maintenance of posture is reliant on input from the visual, vestibular and somatosensory system. Sensory motor system receives input from articular cutaneous, musculotendinous receptor including muscle spindle, Golgi tendon organ that sends afferent signal regarding change in length and tension. Muscle fatigue may impair the proprioceptive and kinesthetic properties of joint by increasing threshold of muscle spindle discharge, disrupting afferent feedback and subsequently conscious joint awareness. Therefore altered somato sensory input due to fatigue could result deficit in neuromuscular control as represented through deficit in postural control in young healthy volunteers⁷.

Sharpe M H et al found proprioceptive signal from receptor in and around muscle changes during muscle fatigue⁸. The acuity of position sense at the ankle was reduced subsequent to a fatigue protocol in young adult male⁹.

Fatigue placed higher demand on the postural control system by increasing the frequency of action needed to regulate the upright stance in young healthy male subject¹⁰. Muscle spindle discharge does decline during sustain contraction, and suggest that fusimotor mediated spindle support to alpha motor neuron decline as muscle fatigue¹¹. Martine Simoneu et al found that fatigue induced by fast walking had an initial negative impact on the control of balance in young healthy adults. However greater proportion of cognitive resources be allocated to the active control of balance task¹². According to above such studies it is clear that fatigue, affects the balance in young adults but there is dearth of literature regarding the effect on elderly.

Gait changes following physical fatigue in older person suggest that fatigue may be risk factor for fall in elderly¹³. With aging, attentional demand for postural control increases as sensory information decreases; in addition the inability to allocate sufficient attention to postural control under multiple condition may be a contributing factor to imbalance and fall in older adults¹⁴. Age related changes in sensory and motor function appear to increase the requirement of cognition regulation of sensorimotor process¹⁵. For the elderly person, postural control regulating a reweighting of sensory inputs could lead to increased risk for loss of balance and fall if insufficient attentional resources are allocated with postural task¹⁶. So it is evident that aging needs more attentional demand for postural control and any loss of allocation of more attention leads to risk of fall in elderly.

During many activities of daily living people need to perform more than one activity at a time. Dual task performance is index of attentional demand. Here attention can be defined as information processing capacity of an individual. An assumption regarding this information processing capacity is that it is limited for any individual and that performing any task requires a given portion of capacity. Thus, if two task are performed together and they require more than the total capacity, the performance on either or both deteriorates¹⁷. Dual task performance is highly advantageous during walking because it allows for communication between people. Transportation of object from one location to another and monitoring of environment so that threat to balance can be avoided. Dual task performance is also known as "concurrent performance" and involve the execution of a primary task, which is a major force of attention, and secondary task performed at the same time¹⁸.

Priest Aw et al found that decrease in gait speed and increment in stride variability were greater in the older subject than younger subject during dual task walking. This indicate that cognitively demanding task (counting backward) during walking have a destabilizing effect on gait that may place the older person at greater risk of fall.



Thus older person needs more attention demand than younger in dual task paradigm¹⁹.

Monicque M.Lorist et al found in healthy adult subject in dual task paradigm that performing a motor task for longer period of time induces motor fatigue. In this state CNS may elicit a constant force for some time by activating progressively greater number of neuron and or increasing their discharge rate. Thus fatiguing muscle place increasing demand on central mechanism during motor behavior and is known as central fatigue. Such central fatigue may be associated with a considerable deterioration of cognition function. Thus fatigue affects cognitive function in young healthy subject²⁰. Monicque M lorist et al in 2006 found that because of fatigue induced change, in the excitation of pre motor area force production, places stronger demand on the attentional system and there by induces a decline in the attentional capacity remaining available for a concurrently performed (cognitive task) in healthy adults²¹. So from previous study it is clear that dual task is attentional demanding task and fatigue induces more demand on attention in healthy adult. But it is not very clear that how fatigue affect the cognitive task in normal elderly.

While there is a lot of literature regarding the effect of fatigue on balance and cognition on young adults at the same time there is dearth of literature regarding the same on elderly. Therefore, our study was designed to find the effect of fatigue on balance and cognition in elderly.

Need of study:

In my knowledge there is no study on the effect of fatigue on balance and dual task performance in normal elderly.

There is dearth of literature which measure quantitatively the effect of fatigue on cognitive aspect in elderly.

Purpose of study:

To find the effect of fatigue due to physical activity on the balance and dual task performance in elderly.

Hypothesis:

Fatigue produced due to physical activity may alter balance control and have effect on cognition. SAMPLE

A total of 31 subjects with 24 male and 7 female participated in the study based on inclusion, exclusion criteria. Subjects were recruited from general community dwelling people in a single group by convenient sampling.

Inclusion Criteria

1. Age: 60-76 yrs
2. Both genders.
3. Ability to walk 10 meters independently.
4. Able to do simple calculation

Exclusion Criteria

1. History of cardiopulmonary disease.
2. History of neurological impairment.
3. M.M.S.E below 23.
4. Musculoskeletal surgery of lower limb during last 2 year
5. Terminally ill.
6. History of postural hypotension.
7. Fracture of lower limb during last two years
8. History of osteoarthritis of knee.

II. STUDY DESIGN

Experimental study.

Instrumentation

Berg Balance Scale

- Chair with armrest and without armrest.
- Foot step.
- Stop watch.
- Measuring tape.

Outcome Measures

- Berg Balance Scale.
- Gait speed.
- Calculation error.

III. PROCEDURE

Before starting, subjects were instructed about the whole procedure and after that consent form was taken from the each subject. The experiment was divided in three stages.

- 1) Pre fatigue stage
- 2) Fatigue protocol
- 3) Post fatigue stage

Pre fatigue stage: -

In this stage balance of subject was examined by Berg balance scale (B.B.S). During whole procedure they were properly instructed regarding each component of B.B.S. Demonstration of item was done where ever required for the explanation. Examiner was remained close with the subject to avoid fall during the test

Dual task performance:- 10 meter walking at self selected speed by the subject and simultaneously counting backward in 3 digit gap was taken as dual task performance. Digit selected for counting backward was in between 20 and 100 and randomly selected by the subject. Subjects were instructed to count loudly so, that counting was audible to the examiner.

During performance subjects were instructed to concentrate on both the gait and calculation simultaneously. They were closely followed by the examiner during the performance for the prevention of fall and making notice gait speed and error done in calculation. During the procedure subjects were not given any feedback regarding the performance.

Fatigue protocol: -

Sit-up exercise was taken as a protocol for the production of fatigue. Subjects were instructed to sit on a chair without armrest, cross their arm and repeatedly rise to an erect position and sit down again at fast speed throughout the procedure. Participants were verbally encouraged by the examiner to continue until they get exhausted to do any more repetition.

Post fatigue state: -

After fatigue protocol dual task performance and balance by the BBS was checked to Immediately prevent any recovery from the fatigue.

IV. DATA ANALYSIS

SPSS version 11.5 was used for data analysis. The statistical significance was set at 0.05 at 95% confidence interval and p value < 0.05 was considered significant.

- Paired t-test were used for the analysis of the data comparison within the group.

V. RESULTS

The data was analysed for 31 subjects (24 male and 7 female) with mean age 65.22±4.08. Results were analysed for B.B.S, Gait speed and Calculation error in pre and post fatigue conditions.

Table no: - 5.1 Descriptive of age, sex, and M.M.S.E

n	age (mean± SD)	sex	MMSE (mean± SD)
31	65.22±4.08	24male, 7female	28.28±1.54

Result obtained in a group between different variable.

Table no: -5.2 Descriptive data (mean and SD) for pre fatigue and post fatigue BBS for 31 subjects. There is significant reduction in post fatigue B.B.S value (p ≤ 0.05)

variable	Mean ±SD	t-value	p-value
Pre fatigue B.B.S	51.38±2.12		
		13.771	.001
Post fatigue B.B.S	47.48±2.66		

By the comparison between pre and post fatigue B.B.S, it can be seen that there is significant reduction in B.B.S after the fatigue protocol.

Table no:-5.3 for descriptive data (mean and SD) for pre and post fatigue calculation error. There is significant increase in post fatigue error (p ≤ 0.05).

variable	Mean ± SD	t-value	p-value
Pre fatigue error	1.93 ± 1.03		-5.10.001
Post fatigue error	2.70 ± 1.10		

By the comparison between pre fatigue and post fatigue calculation error it can be seen that there is significant increase in post fatigue (2.7) from pre fatigue (1.93) value.

Table no:-5.4 for descriptive data (mean and SD) pre fatigue gait speed and post fatigue gait speed in (m/s). There is significant increase in post fatigue gait speed (p ≤ 0.05).

Variable	Mean(m/s)±SD	t-value	p-value
Pre fatigue gait speed	.387±.143		-3.384 .002
Post fatigue gait speed	.423±.127		

By the comparison between pre fatigue gait speed and post fatigue gait speed it can be seen that there is significant increase in gait speed from pre fatigue value (.387)m/s to post fatigue value (.423) m/s.

VI. DISCUSSION

The purpose of the present study was to find the effect of fatigue on balance and dual task performance in elderly. We hypothesized that fatigue may alter the balance and may have effect on cognition.

It was found that there was significant reduction in Berg Balance Scale score in post fatigue condition compared with pre fatigue condition that is balance was decreased in elderly after fatigue. Muscle fatigue may impair the proprioceptive and kinesthetic properties of joints by increasing the threshold of muscle spindle discharge, disrupting afferent feedback, and subsequently altering joint awareness. Therefore altered somatosensory input due to fatigue could result in deficit in neuromuscular control as represented through deficit in postural control^{7, 34}. Neurophysiological changes produced during fatigue may be certain other causes. Fatigue produces change in proprioceptive signal from receptor in and around muscle during muscle fatigue⁸.

Finding of Philip corbill suggest that localized muscular fatigue of the ankle planter flexor seems to affect more the motor output of postural control system than the sensory system i.e. fatigue tend to decrease the rate of force development by skeletal muscle.

Sensory system affected mainly at the peripheral level through change in the spindle threshold of the fatigued muscle but other receptor could compensate for this increased threshold¹⁰. With fatigue, muscle spindle tends to decrease their firing rate and the discharge of motoneuron (from cortex one possible site) declines below the level required to produce the maximum force³. Furthermore, fatigue induces greater variability in afferent signal².

Compared with no fatigue conditions, fatigue places higher demand on the postural control system. The factors that could potentially cause a decrease in balance performance after fatigue focus on both central and local means of fatigue. Central or whole-body fatigue refers to decrease in the central nervous system output to the muscles and likely has a component that includes factors responsible for the sense of effort in addition to the alterations in motor pathways. Localized muscle fatigue is induced by a decrease in the metabolic substrates available for muscle contraction, such as adenosine triphosphate, creatine phosphate, and glycogen, as well as an increase in metabolites, including lactic acid, in the muscle, resulting in an inability to maintain a desired muscular force output, this accumulation of metabolites and/or inflammatory substances within the muscle during fatigue activity (i.e. lactic acid or bradykinin), have been shown to elicit increased muscle spindle static and/or dynamic sensitivity via reflex-mediated pathways from chemo sensitive group III and IV afferents onto motor neurons that would affect one's ability to maintain equilibrium due to an incomplete afferent information³⁵.

This decline in balance seems to be in accordance with the finding of Simonue et al who found that fatigue induced by fast walking having initial negative impact on the balance control in healthy young adults but later participant compensate the negative impact of fatigue on balance control by the allocation of greater number of cognitive resources to the postural control¹².

Effect of fatigue on cognition

We also examined the effect of fatigue on cognitive task through dual task performance. It was found that after fatigue participants required more cognitive resources for the dual task performance. After the fatigue protocol they showed more errors in the subtraction and also gait speed was increased. There are various reasons that may accounts for the observed fatigue-induced increase in gait speed in elderly. Physiologic rationale may comprise motor unit remodeling in old age resulting in larger proportions of type I fibers and thus higher fatigue-resistance and it was reported that muscle fatigue has an impact on muscle spindle function in terms of an increase in sensitivity of the mechanoreceptor Increased muscle spindle sensitivity may represent a fatigue-induced compensatory mechanism to maintain function and force output²⁸.

Secondly the age-related loss of ankle plantar flexor strength resulted in lower ankle plantar flexor power during the late stance phase of the gait and older adults learned to compensate for this muscular deficit by increasing hip flexor power^{28, 36}.

Walking faster also could represent a strategy of the older adults to overcome the short walking distance (10 m) and thus the feeling of physical discomfort due to muscle fatigue as quickly as possible. Therefore, it is suggested that future studies investigate the effects of muscle fatigue on gait characteristics by incorporating longer walking distances. In fact, longer distances may prevent older subjects from initially increasing their walking speed to levels higher than their preferred non-fatigued walking speed because they might not be able to keep up this walking speed for the entire distance²⁸.

Further, Simoneau et al investigated the effect of moderate fatigue induced by fast walking on a treadmill on dynamic balance control in young healthy adults. Initially fatigue induced negative impact on balance control which way followed by a subsequent improvement in the performance of the balance task. Subjects achieved this performance enhancement by allocating a greater portion of the cognitive resources to the balance control task^{12, 28}. In general, this finding seems to be in accordance with the results of the present study regarding increase in the performance of gait speed on the cost of error in subtraction.

Faster walking require greater balance control because of the rapidly changing acceleration of the center of mass and the reduction of double support time, in fact slow walking speed also can increase balance demands because greater time must be devoted to balancing the head, arm and trunk over the stance leg but increase in double support time is thought to negate this effect during slow walking¹⁸. Reduced gait speed may represent a compensatory strategy to enhance dynamic stability during walking in order to keep from falling²⁸. So, due to increased gait speed fatigue predisposed elderly more prone to fall during the dual task paradigm.

Fatigue associated deterioration in the performance of subtraction (secondary task) can be in accordance with the study of Nicolas Vuillermer who found that after fatigue protocol attentional demand for postural control is increased because reaction time (secondary task) is increased after fatigue and that was based on the assumption that the performance of secondary task is inversely proportional to the attentional demand of the primary task³⁷.

Further this result can be supported with the assumption regarding attention (information processing capacity) that, it is limited for any individual and that performing any task requires a given portion of capacity. Thus, if two tasks are performed together and they require more than the total capacity, the performance on either or both deteriorates^{17, 37}.

Decreased performance in calculation can be favored by the study of Monicque M Lorist et al who found that fatigue associated deterioration in the secondary task performance might have been related to available resources investment more, into the primary task, thereby producing a reduction in the resources available for adequate performance in secondary task. Prolonged investment of attentional resource is in itself fatiguing. Therefore it seems reasonable to assume that subject seek to perform a task in a way that conserve resources at acceptable performance level. This might be done by using heuristics which are mental shortcuts that provide reasonable performance without investment of too much effort. The increased in incorrect response with time on task indicate that subjects used a more inappropriate strategies at the end of fatiguing dual task conditions. Subject might have done fast guess; the nature of the fast guess is that of the most probable response. Their data showed the most incorrect response involve pressing the frequent button instead of infrequent one²⁰. So, might be in the present study participants used guesses for the calculation that resulted in more error.

Thus based on the above discussion it can be inferred that neurophysiological changes produced during fatigue may be one of the cause of effect of fatigue on balance and also it can be interpreted that fatigue have effect on cognition in elderly, and along with that need more attentional resources in case of dual task paradigm

VII. CONCLUSION

Conclusion of our study reveals that fatigues alter the balance in elderly and also have effect on cognition so, it may be one of the causes of risk of falls in elderly. Further fatigue also, places higher demand of attention during performance of dual task in normal elderly.

Clinical Relevance: As per study reveal fatigue have effect on balance, this observation can contribute to the development of occupational interventions aimed for mitigating the effect of fatigue on balance control and also endurance exercise can be incorporated for prevention of fatigue. Study will be clinically relevant to train people to improve their cognition ability in order to handle better variety of dual tasking situation that are common in daily life and in designing therapies for cognition and motor rehabilitation.

VIII. RESULTS TABLES

TABLE I. Descriptive Data for Age, Sex, and MMSE

n	Age (Mean ± SD)	Sex	MMSE (Mean ± SD)
31	65.22 ± 4.08	24 male, 7 female	28.28 ± 1.54

TABLE II. Descriptive Data for Pre-Fatigue and Post-Fatigue BBS

Variable	Mean ± SD	t-value	p-value
Pre-fatigue BBS	51.38 ± 2.12	13.771	.001
Post-fatigue BBS	47.48 ± 2.66		

TABLE III. Descriptive Data for Pre-Fatigue and Post-Fatigue Calculation Error

Variable	Mean ± SD	t-value	p-value
Pre-fatigue error	1.93 ± 1.03	-5.10	.001
Post-fatigue error	2.70 ± 1.10		

TABLE IV. Descriptive Data for Pre-Fatigue and Post-Fatigue Gait Speed

Variable	Mean (m/s) ± SD	t-value	p-value
Pre-fatigue gait speed	.387 ± .143	-3.384	.002
Post-fatigue gait speed	.423 ± .127		

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