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Research Article

Effect of Car Driving on Postural Balance Control

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Abstract

Upright standing and walking tasks require postural balance control. Human balance is produced by complex neuromuscular processes. Any limitation of these neuromuscular components can be viewed as balance impairments that may increase the probabilities of balance loss. Prolonged sitting, whole-body vibration, physical and psychological fatigues were found to be the main risk factors that are related to the occupational health problems of drivers. Balance control appears to be influenced by all of these risk factors but has not previously been systematically considered as a hazard for car driving. The purpose of this study was to determine the influence of driving on postural balance performance and control. Thirty-five students from physical therapy department, Umm Al Qura University aged 21 to 23 years old were included in this study. They were divided into four groups according to two main variables; the first was the possession of a car either with manual or automatic gearbox and the second was the long distance from where they reside to the faculty place. Biodex Balance System was used to test balance performance and control. Limit of stability test was evaluated at different levels of platform perturbations for the four groups. The results of this study showed that balance performance and reaction control were affected by driving for long distance and for long duration. This study concluded that car drivers being more subjected for short period balance loss and increasing of postural sway following descending from their cars after long distance of driving.

Keywords: Balance Control; Postural Sway; Car Driving; Fatigue

Abbreviations

COG: Center of Gravity; CP: Center of Pressure; ADL: Activities of Daily Living; MDS: Musculoskeletal Disorders; BBS: Balance Berg Scale; LOST: Limits of Stability Test; ODC: Overall Directional Control; SD: Standard Deviation; LOS: Limits of Stability; LOG: Line of Gravity; COM: Center of Motion

Introduction

Postural control is both functional and performance based. Postural control or balance is defined as a function requiring the coordinated activation of joint, muscle, visual, and vestibular receptors to maintain the body's center of mass [1].

Balance is the ability to control the center of gravity (COG) over the base of support in a given sensory environment [2].

Human balance is produced by complex neuromuscular processes involving; sensory detection of body motions, integration of sensorimotor information within the central nervous system and programming, and execution of the appropriate neuromuscular responses [3].

The dynamic systems model for dynamic equilibrium recognizes that balance is the result of interactions among the individual, the task which the individual is performing and the environment in which the task must be performed [4,5].

Environmental conditions include base of support, COG, stability and instability of surface and visual conditions. Individual conditions include Individual's intentions, integrity and interaction of postural control mechanisms, sensory system (peripheral and central), integrity of cognitive system and integrity of musculoskeletal system [6].

Sensory inputs from several sources, including the skin, joint capsule, ligaments, and muscle spindles contribute to the maintenance of postural control. If the muscle spindle plays a significant role in the maintenance of stability, there should be a deficit in postural control after muscular fatigue. For this reason, several researchers have focused on the effects of fatigue on postural control [7].

Fatigue alters the force capacity of muscles. It is a complex and diverse phenomenon involving neural and muscular mechanisms [8]. At the ankle, it decreases the sense of position and the control of balance [9]. For example, Lundin., *et al*. 1993 have examined how plantar flexor and dorsiflexor fatigue induced through an isokinetic protocol affected the control of balance. They reported a significant increase in medio-lateral (M-L) body sway oscillations amplitude compared with a no fatigued state [10]. Similar observations have been reported by others [11].

More global fatigue protocols where fatigue is induced by treadmill walking or skiing, running or cycling also have been used [12]. For example, Nardone., *et al*. 1993 using a treadmill aerobic fatigue protocol, have reported increases of the sway path of the center of pressure (CP) and median frequency of the CP velocity after the fatigue protocol [13]. The latter effect suggested that fatigue induces an increased frequency of actions needed to regulate body sway oscillations [14].

Fatigue also alters central processing of proprioception. With fatigue, cortico-motor neuronal cells firing rates decrease and motor-evoked potentials increase suggesting inadequate cortical output. Moderate fatigue has an effect on dynamic balance control and attentional demands [15].

Balance deficits can be viewed as impairments, functional limitations, or both. Balance can itself be considered as an impairment in that when a person has balance deficits and functional limitation when functional activities such as ambulation, or activities of daily living (ADL) are affected [16].

Movement is accomplished through joints and muscles. Orthopedic problems, deficits in strength, range of motion (ROM) limitation, and endurance defects in addition to fatigue have a great impact on balance abilities. Execution of the full range of normal balance movements require the presence of normal ROM, strength, and endurance of the feet, ankles, knees, hips, back and neck. The eyes must be present for the execution of the full range of normal balance movements [4].

Some of the occupational hazards impact a driver's health negatively. An extended driving period increases the risk for fatigue and the time a driver spends on the road represents another risk factor as well. Prolonged sitting, which exposes the driver to vibrations, can have a negative impact on spinal and organ health. Other physical hazards also include exposure to emissions, chronic fatigue, and persistent sleep deprivation [17,18].

Backman, 1983 and Hedberg, 1988 pointed out the high prevalence of musculoskeletal disorders (MSD) among professional drivers [19,20]. Driver fatigue has been recognized as a probable cause and corresponding risk factor of crashes involving heavy trucks [21].

Fatigue causes the loss of alertness of a driver, which is accompanied by poor judgment, slower reaction time, and decreased skill levels. Therefore, a driver's ability to concentrate and make critical decisions is reduced, and it takes longer to interpret and understand a traffic situation. Fatigue is a significant problem in the road transport sector in terms of the health and quality of life of drivers, as well as in the potential for accidents [22].

In addition, when switching from a monotonous to a complex road environment, drivers' performance in visual distance estimation and arithmetic tasks improved though their driving behavior deteriorated, revealing that the fatigue effect upon drivers might be explained to some extent by their alertness and arousal levels [23].

The purpose of this study was to examine the effect of car driving on postural balance performance and control following descending from their cars after long distance of driving.

Materials and Methods

Subjects

Sixty male students were recruited to participate in this study. They were selected from faculty of applied medical sciences – physical therapy department specially from the third and fourth levels, their age ranged from 21 to 23 years old, table 1 illustrates the demographic characteristics of Participants. Twenty-five students did not meet the inclusion criteria and so they did not participate in this study. Thirty-five students met the inclusion criteria and all of them engaged and completed the study without any refusal and execution. Written consents and agreements were obtained from all participants for their participation in this study.

Variables	G1 Mean	G2 Mean	G3 Mean	G4 Mean
Age (year)	22 .17	22.56	22.43	22.32
Height (centimeter)	173.45	175.13	171.35	172.12
Weight (kilogram)	83.12	81,22	84.5	79,81
The distance (in kilogram) from the place of residence to the place of the department lab	115.22	273.54	118,31	268.40

Table 1: Characteristics of Participants in different groups.

G1: Group one that included participants who owned manual gearbox care which run for a distance less than 200 kilometers to reach the faculty place from the place where they resided.

G2: Group two that included participants who owned manual gearbox care which run for a distance more than 200 kilometers to reach the faculty place from the place where they resided.

G3: Group three that included participants who owned automatic gearbox care which run for a distance less than 200 kilometers to reach the faculty place from the place where they resided.

G4: Group four that included participants who owned automatic gearbox care which run for a distance more than 200 kilometers to reach the faculty place from the place where they resided.

The inclusion criteria were as follow; all participants were medically normal subjects without any associated orthopedic, neurological, cognitive or lower limb vascular disease. They had the ability to ambulate for 50 feet without the assistance of another person. They were able for cooperation with the researchers and dealing with the Biodex balance test equipment. They had a balance scores felt within normal score limit according to the Berg Balance Scale [24].

The thirty-five male participants were divided into four groups according to two main variables, the first is the possession of a car either with manual or automatic gearbox and the second is the long distance from where they reside to the faculty place. The first group (G1) included 10 participants, they had their own manual gearbox car, resided and lived on less than 200 kilometers from the faculty building place and they spent not more than 2 hours for reaching to the college site as the limit speed on the road to the faculty site varied from 80 to120 kilometers/hours. The second group (G2) included 8 participants, they had their own manual gearbox car, resided and lived on more than 200 kilometers from the faculty building place and they spent about 2 to 4 hours for reaching to the college site as the limit speed on all roads available to the faculty site varied from 80 to120 kilometers/hours. The third group (G3) included 10 participants similar to G1 with the only difference was that they had automatic gearbox car. Finally, the fourth group included 7 participants similar to G2 with the only difference was that they had automatic gearbox car.

Exclusion Criteria were as follow; Subjects with evidence of cardiovascular disease, respiratory problems, hepatic or renal diseases, diabetes, sensory or motor problems, cognitive or too aphasic problems, psychological disturbance, lower and upper limb orthopedic problem, and subjects who use drugs or medicine that might interfere with balance (nicotine, alcohol, sedative, tranquilizers) and cigarette smokers.

Materials

Biodex Balance System SD (#950-302) (BBS; Biodex Inc., Shirley, NY) will be used as a valid and reliable measure to test the limit of stability [25,28]. It consists of support handle, platform, display and printer. It has 13 levels of platform. The stability of the platform can be varied by adjusting the level of resistance given by the springs under the platform. The platform stability ranges from static whereas there was no platform motion to dynamic mode whereas the platform was moved throughout 12 levels of difficulties. Level (12) is the most stable, while level (1) representing the greatest instability.

The BBS uses a circular platform that is free to move in the anterior–posterior and medial - lateral axes simultaneously. The BBS allows up to 20° of foot platform tilt which permits the ankle joint mechanoreceptors to be stimulated maximally. In this study BBS used to evaluate the Limits of Stability Test (LOST) and measured overall directional control (ODC) at both static mode and dynamic modes (level 12 and 10).

Overall directional control: this value indicates of motor control skills. It represents as a percentage of theoretical excursion value, 100% equals perfect control. More than 65% according to BBS represent the predicted value for this test. Values less than this value represent subject had poor balance control.

Procedures for evaluation.

Pre-study evaluation procedures

Introductory session about the BBS and its usage was introduced to each participant to make him familiar with the equipment and adapted to BBS operation procedures.

All participants in each group were tested at static mode for limit of stability test. This examination was performed few days before the study hypothesis test. During that day of examination, the students were asked to not drive their cars and came to the lab in their colleague's cars. We recorded the data in these various tests. Then these data were statically analyzed to provide a comparison between groups (1 and 2) and groups (3 and 4) in both tests. The results as showed in table (2) revealed no significant difference between them.

The study evaluation procedures

Once the participant arrived from his trip by his car, regardless the distance he crossed, he went directly to the balance evaluation lab accompanied with one of the researchers.

Before balance testing by BBS the following measures should be checked before starting the test; heart rate, respiratory rate blood pressure and body temperature should be within normal values. The participants in the days of evaluation was asked to eat light breakfast before driving, to sleep at least 6 hours, to never stop in the road for any reason except for traffic sign, to not accompany any one with him in his care, to not listen to the radio or recorded during driving, and to not use a mobile during the driving period.

Also, we should check that the trip was comfortable and not disturbed by road accidents or emergencies.

If the mentioned requested and precautionary measures were not fulfilled in the evaluation day the tests were cancelled and postponed to another day. Also, test was cancelled if any participant received annoying or bad news affecting his psychological status and morality and retest was again run after discarding of these circumstances.

To begin evaluation, participants will stand bare feet on the BBS's locked platform. To assess the foot position and establish the subjects' ideal foot positioning for testing, the stability platform will be unlocked to allow motion. Participants will be instructed to adjust the position of the foot until they find a position at which they could maintain platform stability. The platform will be then locked. Foot position will be constant throughout the test session.

Each participant was subjected to balance evaluations sessions for measuring LOST according to the following protocol.

The researchers tested limit of stability at static mode and the recorded value (ODC) was obtained, the participant took a 15 minutes rest, the former test repeated but at the instability level 12, then the participant took a 15 minutes rest then limit of stability test was run again but at the instability level 10 and the measured value was also obtained.

Each test was repeated three times and the mean score of the measured variables that had been achieved were automatically calculated and introduced by the BBS.

Statistical analysis

Results were expressed as mean ± standard deviation (SD). Comparison between (G1) and (G2) and (G3) and (G4) for different variables was performed using un-paired t- test. While comparison between variables within the same group was performed using one way ANOVA test. The significant difference among various variables in the same group was performed using least significant difference test. SPSS computer program (version 16 windows) was used for data analysis. P value less or equal to 0.05 was considered significant and less than 0.01 was considered highly significant.

Results and Discussion

The results of this study showed no significant difference between groups (1 and 2) and (3 and 4) in static modes for limit of stability tests measured before starting the study evaluation table 2.

Overall directional Control (ODC) at Static mode	**G1**	**G2**	**G3**	**G4**
	57.7 ± 15.63	59.45 ± 18.7	61.4 ± 7.34	59.35 ± 9.7
	P-value = 0.362 Non sig		P-value = 0.235 Non sig	

Table 2: The difference among different groups pre study.

G1:Group 1; G2:Group2; G3:Group3; G4:Group4.

The results of this study for the limit of stability test for groups (1 and 2), in which manual gearbox cars were used, are illustrated in tables (3,4 and 5) and figures (1 and 2) showed that:

- No significance difference between groups (1 and 2) in the overall directional control in various modes with best mean values for group 1 than that for group (2). These mean values were respectively (47.7 ± 13.63 and 42.25 ± 15.7) for static mode, (35.9 ± 9.73 and 31.5 ± 8.63) for dynamic mode-level (12) and (34.7 ± 10.29 and 33 ± 7.11) for dynamic mode-level (10).
- Significant difference in the mean values of overall directional control in various stability modes in group (1). The difference was significance in favor of static modes in comparison with dynamic mode-level 12 and significance difference in favor of static modes in comparison with dynamic mode-level (10) but no significance difference was recorded between dynamic mode-level (12 and 10). The mean values were respectively (47.7 ± 13.63, 35.9 ± 9.73 and 34.7 ± 10.29).
- No significance difference in the mean values of overall directional control in various stability modes in group (2). The mean values were respectively (42.25 ± 15.7, 31.5 ± 8.63 and 33 ± 7.11).

Overall directional Control (ODC)	**G1**	**G2**	**P- value**	**Significance Difference**
Static mode	47.7 ± 13.63	42.25 ± 15.7	0.442	Non sig
Level 12	35.9 ± 9.73	31.5 ± 8.63	0.332	Non sig
Level 10	34.7 ± 10.29	33 ± 7.11	0.697	Non sig

Table 3: The overall directional Control mean values (ODC) recorded in the static mode and at dynamic mode (levels 12 and 10) for Groups (1) and (2).

Data are expressed as mean ± SD. G1:Group1; G2:Group2; G3:Group3; G4:Group4; sig: significance

ODC: over all directional control. P < 0.05 = significant.

Groups	**Degree of freedom**	**Sum Square**	**Mean Square**	**F:Ratio**	**P-value**	**Significance**
Group 1	2	1032.267	516.133	4.003	0.03	Sig
Group 2	2	542.333	271.167	2.187	0.137	Non Sig

Table 4: Analysis of variance for Group (1) and Group (2) among different modes used in the evaluation of the limit of stability test.

Sig: significance. P < 0.05 = Significant.

Groups	Mode Stat variable	Static mode and Dynamic mode (L12)	Static mode and Dynamic mode (L10)	Dynamic mode (L12) and Dynamic mode (L10)
Group 1	Mean Difference	11.8	13	1.2
	Significance	P = 0.028 Sig	P = 0.016 Sig	P = 0.815 Non Sig
Group 2	Mean Difference	10.75	19.25	1.5
	Significance	P = 0.067 Non Sig	P = 0.111 Non Sig	P = 0.790 Non Sig

Table 5: The least significant difference among different modes used in the evaluation of the limit of stability test for Groups (1)&(2).

Sig: significance. P < 0.05 = significant.

Figure 1: Comparison between groups (1) and (2) for the overall directional Control mean values (ODC) recorded in the static mode and at dynamic mode (levels 12 and 10).

Figure 2: Comparison within groups (1) and (2) for the overall directional Control mean values (ODC) recorded in the static mode and at dynamic mode (levels 12 and 10).

The results of this study for the limit of stability test for groups 3 and 4, in which automatic gearbox cars were used, are illustrated in tables (6,7 and 8) and figures (3 and 4) showed that:

- No significance difference between groups (3 and 4) in the overall directional control in static mode with better mean value for group (3) than that for group 4, these mean values were respectively (47.6 ± 15.01 and 46.43 ± 16.28). For dynamic mode-level (12), there was significance difference between both group with better mean value for group (4), these mean values were respectively (20.6 ± 9.9 and 34.57 ± 14.84). For dynamic mode-level (10), there was no significance difference between both group with better mean value for group (4), these mean values were respectively (21.3 ± 12.63 and 24.42 ± 11.02).
- Significant difference in the mean values of overall directional control in various stability modes in group (3). The difference was significance in favor of static modes in comparison with dynamic mode-level (12) and significance difference in favor of static modes in comparison with dynamic mode-level (10) but no significance difference was recorded between dynamic mode-level 12 and 10. The mean values were respectively (47.6 ± 15.01, 20.6 ± 9.9 and 21.3 ± 12.63).
- Significant difference in the mean values of overall directional control in various stability modes in group (3). The difference was significance in favor of static modes in comparison with dynamic mode-level (10), but no significance difference was recorded between static mode and dynamic mode-level 12 and dynamic mode-level (12 and 10). The mean values were respectively (46.43 ± 16.28, 34.57 ± 14.84 and 24.42 ± 11.02).

Limit of stability Test (ODC)	G3	G4	P- value	Significance difference
Static mode	47.6 ± 15.01	46.43 ± 16.28	0.88	Non Sig.
Level 12	20.6 ± 9.9	34.57 ± 14.84	0.034	Sig.
Level 10	21.3 ± 12.63	24.42 ± 11.02	0.605	Non Sig.

Table 6: The overall directional Control mean values (ODC) recorded in the static mode and at dynamic mode (levels 12 and 10) for Groups (3) and (4).

Data are expressed as mean ± SD. G1:Group1 G2:Group2 G3:Group3 G4:Group4 sig: Significance.

ODI: Over All Directional Control. P < 0.05 = Significant.

Groups	Degree of freedom	Sum Square	Mean Square	F:Ratio	P-value	Significance
Group 3	2	4737.267	2368.633	14.672	0.0001	Highly Sig.
Group 4	2	1697.429	848.714	4.196	0.032	Sig.

Table 7: Analysis of variance for Group (3) and Group (4) among different modes used in the evaluation of the limit of stability test.

Sig: Significance. P < 0.05 = Significant.

Groups	Mode Stat variable	Static mode and Dynamic mode (L12)	Static mode and Dynamic mode (L10)	Dynamic mode (L12) and Dynamic mode (L10)
Group 3	Mean Difference	27	26	7
	Significance	P = 0.000 highly Sig	P = 0.000 highly Sig	P = 0.903 Non Sig
Group 4	Mean Difference	11.86	22	10.14
	Significance	P = 0.136 Non Sig	P = 0.01 Sig	P = 0.199 Non Sig

Table 8: The least significant difference among different modes used in the evaluation of the limit of stability test for Group (3) and Group (4).

Sig: Significance. P < 0.05 = Significant.

Figure 3: Comparison between groups (3) and (4) for the overall directional Control mean values (ODC) recorded in the static mode and at dynamic mode (levels 12 and 10).

Figure 4: Comparison within groups (1) and (2) for the overall directional Control mean values (ODC) recorded in the static mode and at dynamic mode (levels 12 and 10).

Discussion

The better overall directional control mean value in group (1) than that for group (2) might be attributed to fatigue either (physically or mentally) and the effect of exposure to body vibration as a result of long distance of driving that participants in group (2) spent to reach the lab place.

Also within the same groups (1 and 2) the better overall directional control mean values for static modes than dynamic modes (12 and 10) might be attributed to raising the test difficulty by increasing the level of instability from static mode to dynamic level (12) then dynamic level (10).

The better overall directional control mean value in group (4) than that for group (3) might be explained by the 1st Newton's law of motion which stated that "Every object in a state of uniform motion tends to remain in the state of motion unless an external force is applied to it ". So, with long distance driving, the driver's body gain more "speed and motion" that allow him to achieve better balance performance with increased level of instability than that with lower levels of stability.

Also, within the same groups (3 and 4), the better overall directional control means values for static modes than dynamic modes (12 and 10) might be attributed to raising the difficulty of the test by increasing the level of instability from static mode to dynamic level (12) then dynamic level (10).

Many factors during driving for long distance accelerate the process of fatigue either physically or mentally such as sitting on driving seat for long time and for long distance, continuous concentration for road observation and the different body muscles contraction required for the process of driving itself.

Many muscles in this sitting position are continuously statically and dynamically act including muscle of back, upper limbs and lower limbs specially muscles of the lower legs and foot. When driving, the feet are being used actively, moving from the fuel pedal to the brake, and in a stick-shift vehicle (in manual gearbox cars), the left foot does additional work for managing the clutch. When the feet are active, they cannot be used to support and stabilize the lower body as normally happens when they are placed on the floor during normal sitting in a chair. To maintain this steady driving posture, internally the back, neck, shoulder arm and leg muscles maintain a static muscle tension over a prolonged period of time. Static muscular work requires muscle tension to be maintained continuously, without intermittent muscle relaxation.

This type of steady low level muscle contraction and the accompanied ischemia and accumulation of lactic acid accelerate the process of fatigue. So, these muscles fatigue (involved in regaining of balance) definitely affect postural balance control and their efficacy to regain postural balance following perturbations.

Also, the more usage of certain muscles than the others subject them to be become less efficient. This might be explained why in certain groups of this study (G1 and G2) the better ODC values were achieved at a more difficult level of instability level (10) than that of level (12). This because when disturbance of balance is small the ankle strategy and its muscles emerge as the principal strategy for balance regaining and the decrement of its efficiency due to fatigue specially in manual gearbox or stick-shift vehicle would adversely affect its important role in balance control.

Also, while a vehicle is in motion the body is subjected to different forces of acceleration and deceleration, lateral swaying from side to side, and whole-body up and down vibrations. All of these earlier mentioned factors in additional to mental fatigue considered as predisposing factors for balance threatening.

There is a relation between fatigue and body vibration with postural balance control. The ability to generate force or strength is essential to developing the appropriate balance strategies. Adequate strength (to control body weight and any additional loads) through normal postural sway ranges is needed to permit dynamic balance activities such as reaching, leaning, and lifting.

Shumway-Cook and Woollacott., 2011 stated that at least fair to good muscle strength is necessary in the ankle dorsiflexors and plantarflexors, and in the hip flexors and extensors. Strength deficits and fatigue are a primary cause of movement abnormalities in both central and peripheral nervous system disorders. In addition, weakness may be the result of force modulation deficits or disuse. Adequate toe clearance may diminish with fatigue [1].

They added that during standing in ideal alignment, one is actually constantly sway forward and back and from side to side, covering an area known as the sway envelope or limit of stability. This motion is called postural sway. The amplitude of postural sway can be up to 12 degrees in the sagittal plane, and up to 16 degrees in the frontal plane in an adult standing with their feet 4 inches apart.

Hamman., *et al*. 1995 described the normal limits of stability as a theoretical cone extending around a person's feet. They defined the LOS, as the maximum angle from vertical can be tolerated without a loss of balance, with a maximal displacement angle equal 6 to 8 degree anteriorly, 4 degrees posteriorly, and 8 degrees laterally to each side. So, loss of balance occurs when the LOS has been exceeded [29].

Postural sway causes the line of gravity (LOG) to move. If the center of motion (COM) moves outside the base of support, stability is reduced. These results in the individual having a greater likelihood of falling. Basmajian and De Luca., 1985 found that many muscles in the body are tonically active during quiet stance. Some of these muscles include the soleus and gastrocnemius when the line of gravity falls slightly in front of the knee and ankle, the tibialis anterior when the body sways backward, the gluteus medius and tensor fasciae latae, the iliopsoas which prevents hyper extension of the hips but not the hamstrings and quadriceps; and the thoracic erector spinae in the trunk (along with intermittent activation of the abdominals) because the line of gravity falls in front of the spinal column [30].

These studies suggested that muscles throughout the body, not just those of the trunk, are tonically active to maintain the body in a narrowly confined vertical position during quiet stance. Once the center of mass moves outside the narrow range defined by the ideal alignment, more muscular effort is required to recover a stable position. In this situation, compensatory automatic postural strategies are used to return the center of gravity to a stable position within the base of support.

Automatic postural strategies or response are a set of functionally organized, long-loop responses that act to keep the body in a state of equilibrium. There are four commonly identified automatic postural responses, or strategies (A. Ankle Strategy, B. Hip Strategy, C. Suspensory Strategy, D. Stepping Strategy).

Ankle strategy describes postural sway control from the ankles and feet. Muscle contractile patterns are from distal to proximal (i.e., gastrocnemius, hamstrings, paraspinals). This strategy is used whenever sway is small, slow and near midline. It occurs when the surface is broad and stable enough to allow pressure against it to produce forces that can counteract sway to stabilize the body.

Hip strategy describes postural sway control from the pelvis and trunk. Muscle contractile patterns are from proximal to distal (i.e., abdominals, quadriceps tibialis anterior). This strategy is observed when sway is large, fast, and nearing the limit of stability, or if the surface is too narrow or unstable to permit effective counter-pressure.

Suspensory strategy describes a lowering of the COG toward the base of support by means of bilateral lower-extremity flexion or a slight squatting motion. By shortening the distance between the COG and the base of support, the task of controlling the COG is made easier. This strategy is often used when a combination of stability and mobility is required.

Stepping and reaching strategies describe steps with the feet or reaches with the arms in an attempt to reestablish a new base of support with the active limb (s) when the COG has exceeded the original base of support.

The ankle movement strategy, described earlier, appears to be used most commonly in situations in which the perturbation to equilibrium is small and the support surface is firm. Use of the ankle strategy requires intact range of motion and strength in the ankles. The ankle strategy and its related muscle synergy were among the first patterns for controlling antero-posterior stability. The ankle strategy restores the COM to a position of stability through body movement centered primarily about the ankle joints.

Backward displacement of COG direction causes the subject to sway forward. Nashner., 1982 stated that muscle activity begins at About 90 to 100 msec after perturbation onset in the gastrocnemius, followed by activation of the hamstrings 20 to 30 msec later and finally by the activation of the paraspinal muscles. Activation of the gastrocnemius produces a plantarflexion torque that slows, then reverses the body's forward motion [31].

Forward displacement of COG direction causes the subject to sway backward._Muscle activity begins in the distal muscle, the tibialis anterior, followed by activation of the quadriceps and activation of abdominal muscles if the perturbation to balance is large or if we are unable to generate force using ankle joint muscles [3].

Horak and Nashner., 1986 suggested that the hip strategy is used to restore equilibrium in response to larger, faster perturbations or when the support surface is compliant or smaller than the feet, for example when standing on a beam. This strategy controls motion of the COM by producing large and rapid motion at the hip joints with antiphase rotations of the ankles [32].

Winter., *et al*. 1993 found that in contrast to anteroposterior muscle response patterns, which are organized in a distal to proximal manner, medio-lateral muscle patterns are organized in a proximal to distal direction, with hip muscles being activated before ankle muscles [33].

Lucy and Hayes., 1985 reported that Postural sway can increase until the person reaches his or her limit of stability. If the limits of stability are exceeded, one must take a step, reach for support, or risk a fall [34].

If car is not moving, then sitting in a driving seat is not significantly different than sitting in a padded chair. As soon as the vehicle starts moving, however, conditions change dramatically. Unlike regular sitting, while a vehicle is in motion the body is subject to different influences. When the feet are active, they cannot be used to support and stabilize the lower body. Additionally, the driver must maintain a vigilant watch for traffic all the time, which requires a fairly static head and neck posture. To maintain this steady driving posture, a static tension over a prolonged period of time for different muscles is required. Konz and Johnson, 1998 concluded that, a steady low level muscle contraction can lead to localized muscle fatigue which produces muscle aches and pains [35].

Several definitions of muscle fatigue have been used throughout the literature. Muscle fatigue has been defined by some researchers as the reduction in maximal force- generating capability during exercise. Others have defined fatigue as any exercise-induced reduction in the maximal capacity to generate force or power output. Another definition, suggested that fatigue is the inability to generate the maximal force that can be produced by the muscle in its fresh state [7].

Fatigue as Hancock and Desmond, 2001 clarified is a manifestation of stress. The definition of fatigue is difficult to determine precisely, as it is somewhat subjective and varies from one person to another. They added, for long-haul drivers in particular, fatigue is a serious matter with implications for their own safety and the well-being of others [36].

Researchers have defined fatigue based upon its effects. Fatigue can be classified into three distinct types: physical, mental, and chronic**.**

Williams and Routledge, 2009 listed that symptoms of physical fatigue may include: a temporary loss of muscle power to respond to demands, a feeling of tiredness, soreness, or discomfort and physical performance declines. Symptoms of mental fatigue may include: a feeling of tiredness after extended or repeated tasks, particularly non-physical tasks, such as driving, and a feeling of monotony or boredom caused by lack of varied stimulation. Mental fatigue negatively affects one's level of alertness at the wheel and leads to poor driving performance. Symptoms of chronic fatigue may include: a feeling of persistent tiredness, soreness, or discomfort, a feeling of persistent monotony or boredom caused by lack of varied stimulation, and the inability to feel refreshed after a brief rest period [37].

Taylor and Dorn, 2006 stated that Chronic fatigue is of particular concern for long-haul car drivers, as it results from repeated and cumulative stresses. Chronic fatigue is a short-term condition that can be relieved by adequate rest and sleep. Usually, a driver can recover full alertness in just a few days with longer periods of sleep. Drivers' physiological behavior patterns repeat daily in synchronization with their internal biological clock. Sleeping, working, and eating meals on a new schedule require a period of time to adjust [38].

Many literatures such as that had done by Miller., *et al*. 1995 and Baker., *et al*. 1993 focused on 2 widely accepted classes of fatigue: that caused by peripheral weakness (peripheral fatigue) and that caused by a progressive failure of voluntary neural drive (central fatigue). Two Peripheral fatigue is the classification that most often comes to mind, because it is the more local fatigue that affects one muscle or muscle group. Peripheral factors in fatigue primarily include metabolic inhibition of the contractile process and excitation-contraction coupling failure. Central fatigue can be described as more of a psychological aspect of fatigue, in that it may originate from a lack of drive or motivation [39,40].

McArdle., *et al*. 2009 illustrated that to produce muscle contraction, a muscle metabolizes energy molecules derived from food in the form of nutrients. Within the muscle cells, the nutrients are converted to mechanical energy in the form of muscle contractile force. In the presence of oxygen, the metabolic reaction occurs through an aerobic process. Aerobic energy production is efficient, in the sense that complex nutrient molecules are broken down to more elementary molecules releasing a greater amount of energy per nutrient molecule. The metabolic end products for the aerobic metabolism are carbon dioxide and water. When the oxygen supply is inadequate, the cell can supplement energy production through an anaerobic pathway, which metabolizes the nutrient molecules to an intermediate stage. They added that the anaerobic metabolic process produces less energy per nutrient molecule. But more important is the fact, that the intermediate molecules produce lactic acid, which when accumulated to a certain level of concentration, produces a localized sensation of muscle pain, known as localized muscle fatigue [41].

Powers and Howley, 2008 reported that the extent of muscle ischemia (lack of oxygen) and concentration level of lactic acid accumulation depends on the type of muscle work (dynamic or static) and the force level of muscle contraction [42].

Taylor and Dorn said that static muscular contraction is mostly involved to counter the gravitational forces that are acting on body segments. For example, when a driver is constantly watching the road, the neck muscles are constantly acting to hold the head (average weight 14 pounds) in a fixed position. To maintain a driver's fixed driving posture, muscles at the shoulder, neck, back, and the lower extremities, are at a continuous contractile state for a prolonged period of time [38].

Ischemia due to static contraction and accumulation of lactic acid is hypothesized to bring localized muscle fatigue. While the fatigued cells are not themselves permanently damaged, reperfusion after ischemia in muscle cells lead to micro-vascular and cellular dysfunctions, initiating longer-term symptoms and functional changes in skeletal muscle (National Research Council and Institute of Medicine., 2001) [43].

Konz and Johnson, 1998 clarified that holding the foot over the pedal continually and over an extended period, may also cause stiffness and spasms in the legs and lower back. Maintenance of the same posture over a long period with continued muscle tension becomes uncomfortable and can cause health problems. Static contractions at low level over a prolonged period of time can cause muscle to atrophy, splitting, necrosis and other degeneration, which intern precipitate as chronic muscle pain and discomfort, even when the static muscle forces are not present [33].

In a study performed by Boyas., *et al*. 2011 aimed to compare the effects of ankle muscle fatigue on postural control when plantarflexors (PFs) and dorsiflexors (DFs) are fatigued simultaneously compared with separately and to investigate the recovery of postural control after fatigue. It found that an effect of fatigue present only when both muscle groups are fatigued simultaneously. It could be due to impairment in the compensatory activity between agonist and antagonist muscles and/or a greater decrease in proprioception due to a greater number of fatigued muscles. In addition, when PFs and DFs were fatigued simultaneously, sway area and antero-posterior (AP) velocity returned to pre-fatigue values within two minutes, whereas a posterior shift in AP position persisted for ten minutes. This last result may suggest a longer-lasting change in postural strategy needed for optimal postural control [44].

Yaggie., *et al*. 2004 indicated a decline in proprioceptive function after fatiguing exercise and the center of balance shifted anteriorly and mediolateral sway during unilateral stance increased after subjective fatigue of specified ankle muscles, namely the gastrocnemius and soleus [45].

The effects of fatigue on driver motor and balance performance have been documented in numerous studies. The results of these studies showed that fatigue is an important risk factor in driver health, as well as the safety of the general public [18,22,46,49].

The effects of vibration and physical shock on human beings have been known for a long time. Every day, people are exposed to vibrations from many sources, including vehicles and vibrating machines. Most people have a good idea of what vibration feels like, but not necessarily what vibration is or what kinds of physical consequences it can have.

Makhsouse., *et al*. 2005 mentioned that vibration is the oscillation of a mass about a fixed point. In the human body, vibrations are produced by either regular or irregular periodic movements of a tool or vehicle, or other mechanisms that come in contact with a human and which displace the body from its resting position. If the human body were on a rigid bulk of mass, in translation all parts would undergo the same motion [50].

Benstowe, 2008 explained that vibration can be divided into the following types: harmonic and periodic vibration, random vibration, and transient vibration. In practice, drivers of all types, whether private or commercial, short-haul or long haul, tend to experience a combination of harmonic, random and transient vibrations [51].

Whole body vibration is injurious to the body, regardless of the type of vibration. For drivers, the dangers of whole-body vibration are more serious than for other populations because the variety, frequency, and intensity of vibrations are generally higher than those general public experiences. Whole body vibration is generated by a system that accelerates the body in a motion. Vibration is dangerous, and as such, different systems of the body attempt to absorb some of the shock to reduce deleterious effects on a single organ or system. The distributive impact of the vibration, then, may affect the whole body, as opposed to just the zone that would otherwise be targeted if the rest of the body did not play this absorptive function. Above the frequency of 2 Hz, the human body does not vibrate as a single mass with one natural frequency; rather, it reacts to induced vibration as a set of linked masses [52,53].

Muscle fatigue also occurs as the muscles try to react to the vibration energy to maintain balance and control and protect and support the spinal column, but these are often too slow as the muscular and nervous systems cannot react fast enough to the vibration shocks and loads being applied to the body. During active natural motion, postural motor and balance control mechanisms act as a feed-forward control that are constantly adjusted by additional feedback from sensors in muscles, tendons, and joints. Whole-body vibration causes a passive artificial motion of the human body, a condition that is fundamentally different from the self- induced vibration caused by locomotion [48,50].

Conclusion

From the results of this study, we can conclude that car driving for long distance and for long period definitely affect human postural balance control for a certain period followed stopping of driving and descending from the car but the actual period the driver may suffers from balance threatening need further studies. Also, the longer the distance and time of continuous driving, the lower the rate of balance performance. This may be explained by the effect of fatigue either physically or mentally.

Recommendations

Car driving for long distance and long period of time reduce the human motor balance capabilities which make the drivers after stop driving more vulnerable to balance threatening or balance loss when performing motor tasks following descending from car for a period of time. In this period, they are at the risk of balance disturbance and falling. So great precautions should be considered during motor task or activities performed following car driving stop and come out from the car such as railway or highway crossing on drivers' feet and risk of falling which may have a life-threatening conditions for them.

Fatigued driver may not remember the previous few minutes of driving due to mental fatigue and will be slower in evaluating oncoming hazards.

Special cautions for car drivers whose basically have either balance deficit or one of its causative or predisposing factors such as diabetes, hyper-tension, vestibular problems, visual problem, motor problem, aging people --- etc, from being more subjected for balance loss following descending from their cars after long distance of driving.

Heavy trucks, buses and freight cars and transportation drivers whom their work natures let them drive for a long period of time and for a long distance should be advised to avoid fatigue and informed about the different ways for relieving fatigue to protect themselves from the road oncoming hazards and life-threatening road accidents.

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Conflict of Interest

The author declares no conflict of interest exists.

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