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## PSYCHOPHYSIOLOGICAL CHANGES OF CIGARETTE SMOKERS TO STIMULI OF AEROBIC AND ANAEROBIC EXERCISES

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### ABSTRACT

This study was aimed to determine the chronic effects of smoking on some psychophysiological performances in healthy male volunteers with 20-45 years of age and working at the Police General Hospital. The volunteers were divided without randomization into 2 groups of 10 smokers and 10 nonsmokers. Then, the left arm and left leg of both groups were stimulated by hot water (42°C), cold water (12°C), aerobic exercise and anaerobic exercise to legs. Psycho-neurological performances changes before and after the above stimulations were measured. The results were 1) 'Psycho-neurological performance' before Astand exercise and Wingate exercise showed was no significant difference between both groups in terms of visual reaction time (VRT), response time and tapping speed. However, after exercise, warned auditory reaction time of the right big toe, warned tactile reaction time of the right lateral malleolus stimulation and the level of the right index finger response and warned tactile reaction time at 7<sup>th</sup> cervical spine level of the right index finger response were significantly higher in smokers than nonsmokers; 2) 'Physical performance' in nonsmokers in relation to oxygen consumption and agility was significantly higher than in smokers. In conclusion, smoking was associated with reduction in physical performance, psycho-neurological performance and vasomotor responses. This may explain smoking related atherosclerotic changes of blood vessels in the brain and organs and the severity may depend on duration and amount of smoking.

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**KEY WORDS :** VASOMOTOR RESPONSE, REACTION TIME, PSYCHOMOTOR SPEED,  
EXERCISE, SMOKER, CIGARETTE

## INTRODUCTION

Hypertension, diabetes mellitus, hyperlipidemia, obesity and cigarette smoking for long enough time can cause atherosclerosis in body parts including in the brain (1, 2, 3, 4, 5, 6, 7). Reaction responses of human contain sensory neurons, interneurons and motor circuits (8, 9, 10, 11). Vascular damage to the brain can cause damage to neuronal functions which can be detected by in behaviours and functional and psychophysiological changes by various instrument such a reaction timer and critical flicker fusion frequency (CFF) meters (10, 11, 12, 13, 14, 15). Effects of blood vessels malfunctions will causes various changes in the neuronal functions in the brain depending on where and how much the damage will cause. The objectives of this study were to compare the normal control subjects and long time cigarette smokers in various psychomotor speeds and the patterns of changes to imply the degree and extent of direct damage of cigarettes smoking on the neuronal functions or possibly by indirect effects on the brain circulatory functional changes such as early signs of ischemic strokes (4, 5, 6, 7).

## MATERIALS AND METHODS

Twenty healthy males (average age 29.50 yr; range 20-45 yr) volunteered to serve as subjects for this study. All subjects were living in the community with a normally active life style. They were normotensive and were recruited from the workers of Police General Hospital, Bangkok and none were taking medications except vitamins or ergogenic aids for health. The two subject groups were matched for their average age, physical activity and the body mass index (BMI). The smokers abstained from smoking for at least 4 hours before the experiment. This time interval was shown to be sufficient to reduce serum nicotine levels to nearly unmeasurable levels (16).

All subjects gave informed consent to the experimental protocol that was approved by the Human Right Committee of Mahidol University NO.68/2005. No subjects reported skin or cardiac disease or was known to be suffering from any chronic disease. None was on any regular medication.

On the first test day, each subject was familiarized once with each test. Data collection includes anthropometric measurement such as body weight, height, waist and hip circumference, vital signs and physical fitness tests. The test were conducted at Sports Science Laboratory, College of Sports Science and Technology, Salaya Campus, Mahidol University, Bangkok, Thailand. The  $\text{VO}_2$  max test (Astrand-Rhyming protocol test), the subject was seated on the saddle which height was adjusted appropriately, started pedaling the ergometer at 0 Watt for 1 minute as a warm up period. Thereafter, the resistance was increase by 100-150 Watts (600-900 kgm/min) until heart rate (HR) more than 120 beat/min. Start recording HR every minute until 6 minutes (17). The volume of the left upper extremities and lower extremities were measured at volumeter. The Wingate test, start pedaling the ergometer at freeload for 1 minute as a warm up period. The resistance was set to 75 g/kg body weight for Monark ergometer. Subject continued pedaling at highest speed as possible for 30 seconds (17).

The reaction time (auditory, tactile, visual) tapping speed and critical flicker fusion (CFF) measurement before and immediately after the Astrand and Wingate tests of NG and SG were carried out (17). The data on vasomotor changes on SG and NG were also reported in Chentanez et al 2012 (18). Blood pressure of each subject were measured by using blood pressure monitor (Hico, Japan), resting heart rate by using Polar (Polar Electro OY SF-90440 Kampele, Finland), body temperature was measured by using thermometer (Matsuda, Japan), after arriving the laboratory and rest on a chair for about 10 minutes.

Body weight of each subject was measured by using Digital weight balance (AD-6201, Japan). Body Mass Index was calculated from ratio of weight (kg) and height  $^2(m^2)$ . Isometric handgrip strength was measured by using digital handgrip dynamometer (Takei & Company, Japan). The subject was asked to perform to grip with a relaxed standing and hold the dynamometer both right and left hand, which the dynamometer was adjusted to comfort grip. The subject was asked to squeeze the handles as much force as possible. The best of three attempts was recorded (coefficient of variation < 10%) (17).

Isometric muscle strength of knee extensor (Quadriceps femoris muscle) were measured by back and leg dynamometer (Takei & Company, Japan). First, the subject was asked to perform to measure the leg strength by subject stand with a squat position and straight back on the dynamometer. The hand bar was adjusted to comfortable pull, then the subject was asked to pull the hand bar with fully extend elbows and back, with maximum effort. Three trials were performed and the highest value was recorded (coefficient of variation < 10%) (17). Flexibility was measured by sit and reach box (College of Sports Science and Technology, Mahidol University). The subject was asked to perform to relaxed long sitting and hold the position. The subject was asked to stretch the body toward together with as much force as possible. The best reach in centimeter of three attempts was recorded (17).

Agility was measured by nine square test. The subject was asked to perform to left step move to each corner of square (150 x 150 cm.) as much and as fast possible for 10 seconds and to the right step as fast as possible the same as the left step. The summation of the right and left values per 20 seconds was calculated as agility index (17).

Before warned simple reaction time (WRT) testing, each subject was asked to sit comfortable on a chair and forearm was rested. The subjects were instructed to rest the index fingers lightly on the microswitch key of the reaction timer (Made by Thiphan Co. Ltd., Thailand) and be ready to push the key as fast as possible after sensing the stimulus (9).

Various site of stimulation (SOS) were varied by using red light (Visual reaction time; VRT), 1000 Hertz sound to ear (Auditory reaction time; ART), tactile on posterior midline at C7 (Cervical 7<sup>th</sup> tactile reaction time; C7RT) and lateral malleolus stimulation (TRTH).

The site of response (SOR) assessed for 10 times through right index finger (RI), left index finger (LI), right big toe (RBT), and left big toe (LBT). (17).

The tapping speed testing was using a denominator (The Denominator Company Inc. Woodbury, CT). The subjects were instructed to tap the denominator as fast as possible for 10 seconds. Three repetitions were determined for the right index finger (RI), left index finger (LI), right big toe (RBT), and left big toe (LBT). The tapping speed test recorded maximum tapping speed and the average of three sessions of tapping for 10 second. (17).

Grass stimulator (Grass Instrument, Quincy, USA) was used to generate the flicker light. The frequency of alternating light and dark of a frequency monitor bulb of the stimulator could be increased or decreased by knob controller. The stimulator was adjusted 10 millisecond of duration time, 10 millisecond delay time. Subjects were asked to sit still and look at the flickering light which was adjusted by the researcher at the frequency knob. Each subject was instructed to observe the light and looking at the monitor carefully to see the bulb of flicker changed from flickering to the smooth light. The critical flicker frequency (CFF) would be read at any time from frequency control knob. The CFF was tested from low to high frequency (CFF<sub>L</sub>) and high to low frequency (CFF<sub>H</sub>) and recorded for each subject of each groups. (17).

Anaerobic power and capacity was determined by 30 second Wingate test. Anaerobic power and capacity of each subject was measured by using bicycle ergometer (Bodyguard 990). Before testing the procedure was explained to each subject until full familiarity was achieved. The subject was asked to perform to relaxed sitting on bicycle. The subject was asked to spin a wheel that increase load together with as much force as possible into 30 seconds. Revolutions for every 5 sec were detected by infrared sensors and the data were collected by the computer software system and the anaerobic power and capacity value was calculated (17).

The  $\text{VO}_2$  max was determined by using a bicycle ergometer (Bodyguard 990). Before testing the procedure each subject was explained to each subject until full familiarity was achieved. The subjects were asked to relax sitting on bicycle. The maximal oxygen consumption test was calculated from submaximal exercise with Astrand-Rhyming protocol test (17).

All data were presented as mean  $\pm$  SEM and graphs were plotted. A repeated measure ANOVA was used to determine whether or not there was a statistically significant difference between the mean values obtained before and after the periods within the same subject. Baseline characteristics and physical fitness were analyzed by using paired t-test. The change of blood flow during exercise was compared between study groups. All the statistical tests were performed using the SPSS for Window Versions 11 program. The level of significance for differences between groups or time intervals was set at  $p < 0.05$ .

## RESULTS

Table 1 shows that the nonsmoker group (NG) had significantly higher maximal oxygen consumption and agility than to smoker group (SG) ( $p < 0.05$ ). There was no significant difference in age, weight, height, heart rate, systolic blood pressure, diastolic blood pressure, waist, hip circumference and waist hip ratio, the right and left handgrip

strength, leg strength, and flexibility between the two subject groups. However, the  $VO_2$  max and agility of NG group were significantly greater than SG group. The average cigarette consumed/day and the average period of smoking (yr) of SG were  $10 \pm 0.02$  and  $12.80 \pm 0.15$  respectively.

**Table 1** General characteristics of nonsmoker group (NG) and smoker group (SG) used in this study.

Parameters	NG (n=10)	SG (n=10)
Age (yr)	29.50 $\pm$ 2.16	34.70 $\pm$ 1.63
Height (cm)	165.50 $\pm$ 2.21	165.40 $\pm$ 1.75
Weight (cm)	62.50 $\pm$ 2.32	62.30 $\pm$ 2.78
Body mass index (BMI kg/m <sup>2</sup> )	22.88 $\pm$ 0.52	22.82 $\pm$ 0.93
Heart Rate (HR) (bpm)	69.60 $\pm$ 2.28	74.70 $\pm$ 2.83
Systolic BP (mmHg)	119.90 $\pm$ 3.65	123.30 $\pm$ 4.56
Diastolic BP (mmHg)	73.30 $\pm$ 3.40	78.60 $\pm$ 2.46
Waist circumference (cm)	79.60 $\pm$ 1.65	81.70 $\pm$ 2.45
Hip circumference (cm)	92.80 $\pm$ 1.80	90.80 $\pm$ 2.03
W/H ratio	0.85 $\pm$ 0.01	0.89 $\pm$ 0.01
$VO_2$ Max (ml/kg/min)	20.77 $\pm$ 0.96	17.82 $\pm$ 1.56*
Wingate anaerobic power (Watt/kg)	6.08 $\pm$ 0.41	5.24 $\pm$ 0.23
Rt handgrip strength (kg)	37.70 $\pm$ 2.34	37.45 $\pm$ 1.85
Lt handgrip strength (kg)	36.05 $\pm$ 2.32	36.89 $\pm$ 1.79
Leg strength (kg)	126.55 $\pm$ 13.53	115.62 $\pm$ 9.40
Flexibility (cms)	7.10 $\pm$ 3.13	6.10 $\pm$ 2.67
Agility (step/20 sec)	13.30 $\pm$ 0.78	10.06 $\pm$ 0.54*
Cigarette smoking (cigarette/day)	-	10 $\pm$ 0.02
Period of smoking (years)	-	12.80 $\pm$ 0.15

Values are mean  $\pm$  SEM. HR, Heart Rate; Sys BP, Systolic Blood Pressure; Dias BP, Diastolic Blood Pressure; BMI, Body Mass Index;  $VO_2$  Max, Maximal Oxygen consumption; Wingate, Anaerobic power ; Significantly different from control at \*  $p < 0.05$

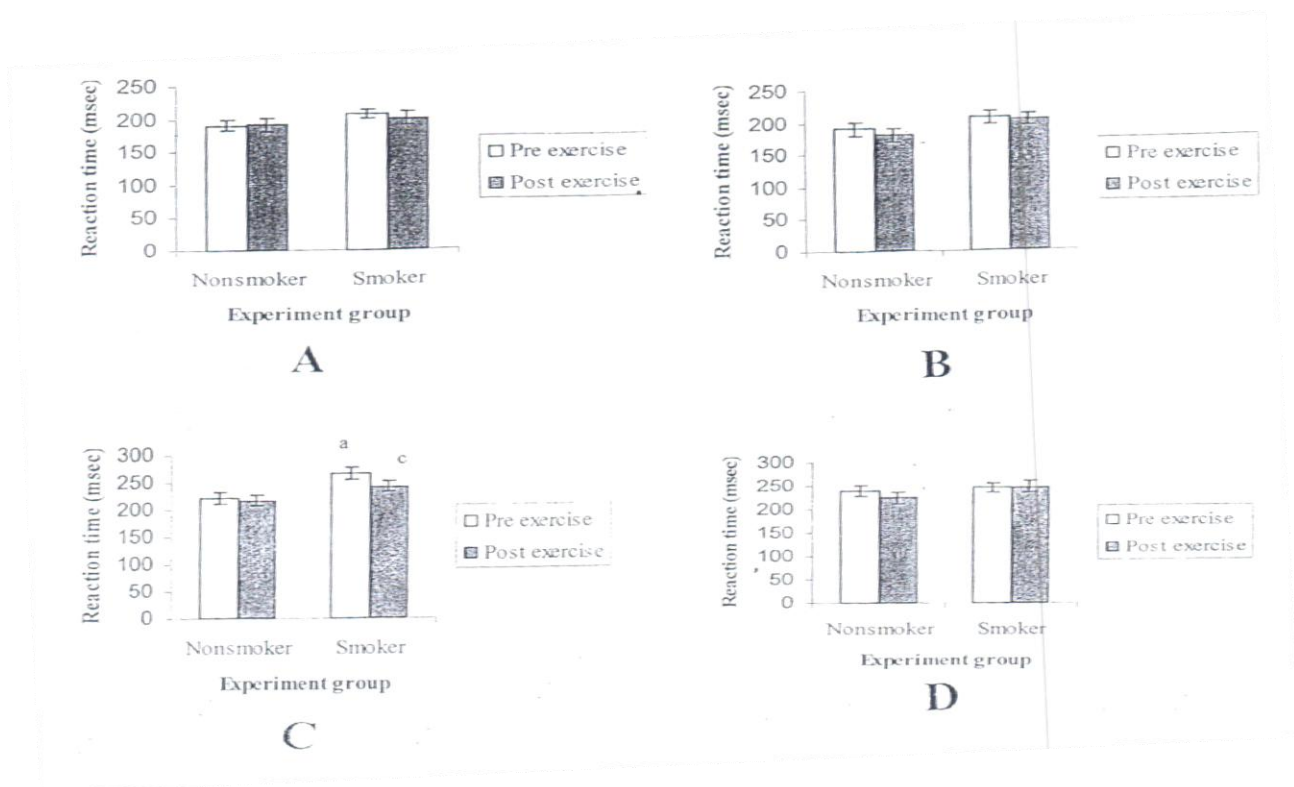
Several neuropsychophysiological parameters were investigated for examples; warned visual and auditory reaction time (WRT) determination was milliseconds, finger and toe tapping speed test (TST) was times per 10 seconds and critical flicker fusion frequency (CFFF) was Hertz. The mean values of the pre-post exercise were demonstrated.

Firstly, the mean values of warned auditory reaction time of the right index finger (WARTr) at the two sessions (Pre and Post exercise) are shown in Figure 1A. The descriptive statistics of WARTr had no significant difference between the two groups of subjects and the repeated measures WARTr within each group of subject was not significantly different between the two groups.

Secondly, the descriptive statistics of warned auditory reaction time of the left index finger (WARTl) at the two sessions (Pre and Post exercise) shown in Figure 1B. The descriptive statistics of WARTl showed no significant difference between the two groups of subjects and the repeated measures WARTl within each group of subject also showed no significant difference between the two groups.

Thirdly, the mean values of warned auditory reaction time of the right big toe (WARTrbt) at the two session (Pre and Post exercise) shown in Figure 1C : nonsmoker group (NG) had significantly greater values than smoker group (SG) in two sessions ( $p < 0.05$ ). The WARTrbt of smoker group was significantly higher in Post exercise compare to Pre exercise.

Fourthly, the mean values of warned auditory reaction time of the left big toe (WARTlbt) at the two sessions (Pre and Post exercise) shown in Figure 1D. The pre exercise WARTr was not significantly different between the two groups of subjects and the post exercise WARTr within each group of subject was not significantly different between the two groups.



**Figure 1** Comparison of two sessions of warned auditory reaction time (WART) of the right (A) and left (B) index fingers (WART), right (C) and left (D) big toes of NG and SG presented by mean  $\pm$  SEM. Statistical test shown was paired t-test, Pre exercise and Post exercise 30 minutes, Significant value  $p < 0.05$ , a; different from pre exercise nonsmoker, b; different from pre exercise smoker, c; different from post exercise nonsmoker, d; different from post exercise smoker.

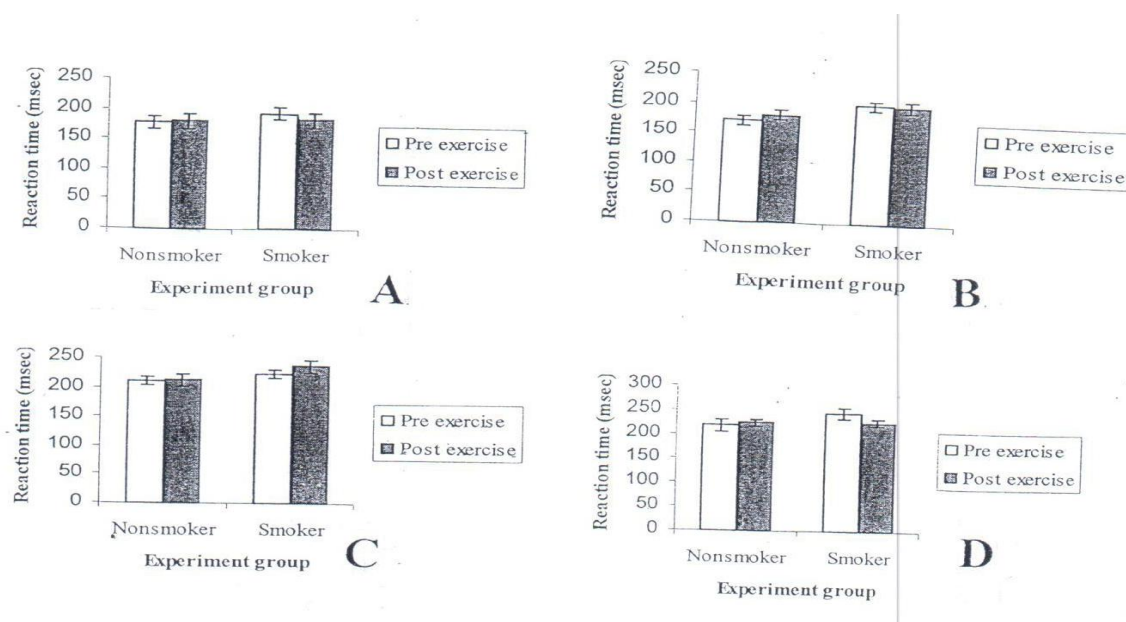
#### Warned Visual Reaction Time (WVRT)

The two sessions of warned visual reaction time in Pre and Post exercise, first; warned visual reaction time of the right index finger (WVRT<sub>r</sub>) are shown in Figure (2A). The pre exercise of WVRT<sub>r</sub> was not significantly different between the two groups of subjects and the post exercise of WVRT<sub>r</sub> within each group of subject was not significantly different between the two groups.

Secondly, the mean values of the two sessions of warned visual reaction time of the left index finger (WVRT<sub>l</sub>) are shown in Figure (2B). The pre exercise of WVRT<sub>l</sub> was not significantly different between the two groups of subjects and the post exercise of WVRT<sub>l</sub> within each group of subject was not significantly different between the two groups.

Thirdly, the descriptive values of the two sessions of warned visual reaction time of the right big toe (WVRT<sub>rbt</sub>) are shown in Figure (2C) two groups of subjects had no significant differences and the post exercise of WVRT<sub>rbt</sub> within each group of subject was not significantly different between the two groups.

Fourthly, the descriptive values of the two sessions of warned visual reaction time of the left big toe (WVRT<sub>lbt</sub>) are shown in Figure (2D); two groups of subjects were not significantly different and the post exercise of WVRT<sub>lbt</sub> within each group of subject was not significantly different.



**Figure 2** Comparison of two sessions of warned visual reaction time (WVRT) of the right index finger (RI) (A), left index fingers (LI) (B), right big toe (RBT) (C) and left big toes (LBT) (D) of NG and SG presented by mean  $\pm$  SEM, statistics shown as paired t-test, Pre exercise and Post exercise 30 minutes, Significant value  $p < 0.05$ , a; different from pre exercise nonsmoker, b; different from pre exercise smoker, c; different from post exercise nonsmoker, d; different from post exercise smoker.

#### Warned Tactile Reaction Time (WTRT)

The determination of warned tactile reaction time (WTRT) was divided into tactile reaction time at the cervical 7<sup>th</sup> level (TRTC<sub>7</sub>) and tactile reaction time at the lateral malleolus level of the right ankle.

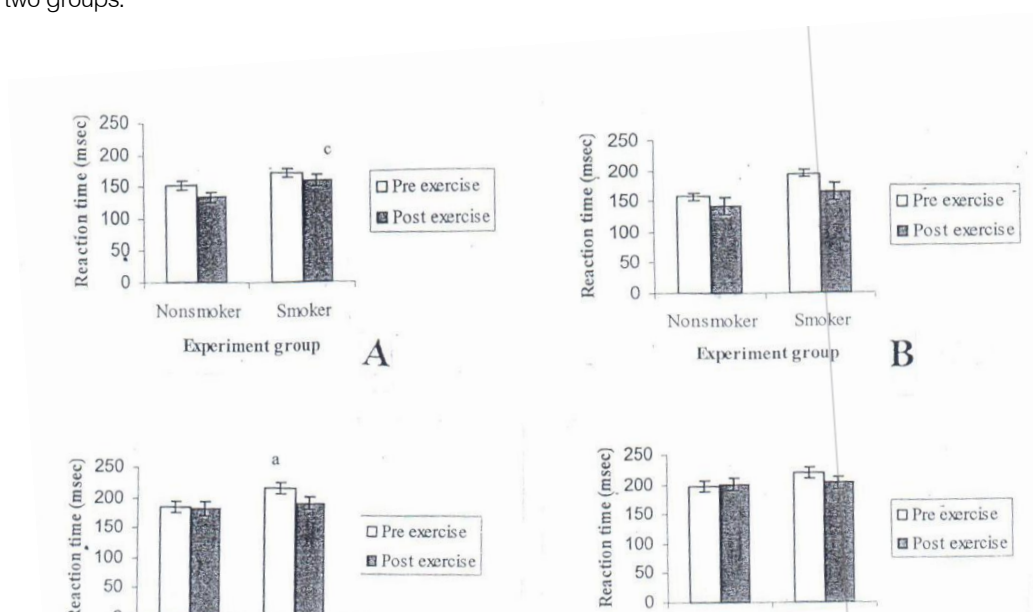
#### Tactile reaction time at cervical 7<sup>th</sup> level (TRTC<sub>7</sub>) stimulation

The two sessions of warned tactile reaction time at the cervical 7<sup>th</sup> level (TRTC<sub>7</sub>) in Pre and Post exercise, first: the values of warned tactile reaction time at the cervical 7<sup>th</sup> level and the right index finger response (TRTrC<sub>7</sub>) are shown in Figure (3A): the nonsmoker group had significantly greater in Post exercise compare to the smoker groups. The mean values from repeated measure of TRTrC<sub>7</sub> within each group of subject was not significantly different between the two groups.

Secondly, warned tactile reaction time at the cervical 7<sup>th</sup> level in the left index finger response (TRT1C<sub>7</sub>) are shown in Figure (3B); the descriptive statistics of TRT1C<sub>7</sub> was not significantly different between the two groups of subjects and the mean values from repeated measure of TRT1C<sub>7</sub> within each group of subject had no significant difference between the two groups of subjects.

Thirdly, warned tactile reaction time at the cervical 7<sup>th</sup> level in the right big toe response (TRTrbtC<sub>7</sub>) are shown in Figure (3C) nonsmoker was significantly greater in Pre exercise compare to smoker. The mean values from repeated measure of TRTrbtC<sub>7</sub> within each group of subject had no significant difference between the two groups.

Fourthly, warned tactile reaction time of the cervical 7<sup>th</sup> level in the big toe response (TRT1btC<sub>7</sub>) are shown in Figure (3D); the descriptive statistics of TRT1btC<sub>7</sub> had no significant differences between the two groups of subjects and the mean values from repeated measure of TRT1btC<sub>7</sub> within each group of subject had no significant difference between the two groups.





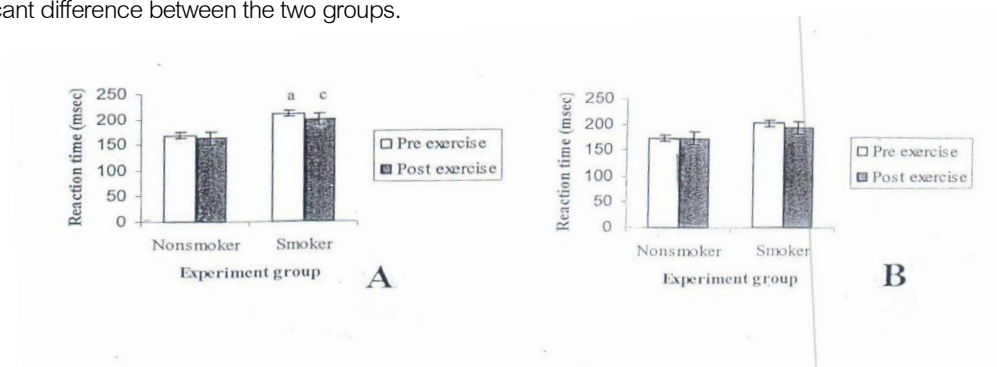
**Figure 3** Comparison of two sessions of warned tactile reaction time (WTRT) of the cervical 7<sup>th</sup> level of the right index finger (RI) (A), left index fingers (LI) (B), right big toe (RBT) (C) and left big toes (LBT) (D) of NG and SG presented by mean  $\pm$  SEM, statistics shown as paired t-test, Pre exercise and Post exercise 30 minutes, Significant value  $p < 0.05$ , a; different from pre exercise nonsmoker, b; different from pre exercise smoker, c; different from post exercise nonsmoker, d; different from post exercise smoker.

#### Tactile reaction time at the right lateral malleolus level (TRTH)

The two sessions of warned tactile reaction time at the right lateral malleolus level (TRTH) in Pre and Post exercise, first: the descriptive values of warned tactile reaction time at the right lateral malleolus level in the right index finger (TRTrH) are shown in Figure (4A) the nonsmoker group had significantly shorter in TRTrH compare to the smoker group in Pre and Post exercise. The repeated measures TRTrH within each group of subject had no significant difference between the two groups.

Secondly, the descriptive values of warned tactile reaction time at the right lateral malleolus level in the left index finger (TRTIH) are shown in Figure (4B); the descriptive statistics of TRTIH had no significant difference between the two groups of subjects and the mean values from repeated measure of TRTIH within each group of subject had no significant difference between the two groups. Thirdly, the mean values of warned tactile reaction time at the right lateral malleolus level in the right big toe TRTrbH are shown in Figure (4C) the descriptive significant of TRTrbH had no significant difference between the two groups of subjects and the mean values from repeated measure of TRTrbH within each group of subject had no significant difference between the two groups.

Fourthly, the mean values of warned tactile reaction time at the right lateral malleolus level in the left big toe (TRTlbH) are shown in Figure (4D); the descriptive statistics of TRTlbH had no significant differences between the two groups of subjects and the mean values from repeated measure of TRTlbH within each group of subject had no significant difference between the two groups.



**Figure 4** Comparison of two sessions of warned tactile reaction time (WTRT) of the right malleolus stimulation and the right index finger (RI) (A), left index fingers (LI) (B), right big toe (RBT) (C) and left big toes (LBT) (D) of NG and SG presented by mean  $\pm$  SEM, statistics shown as paired t-test, Pre exercise and Post exercise 30 minutes, Significant value  $p < 0.05$ , a; different from pre exercise nonsmoker, b; different from pre exercise smoker, c; different from post exercise nonsmoker, d; different from post exercise smoker.

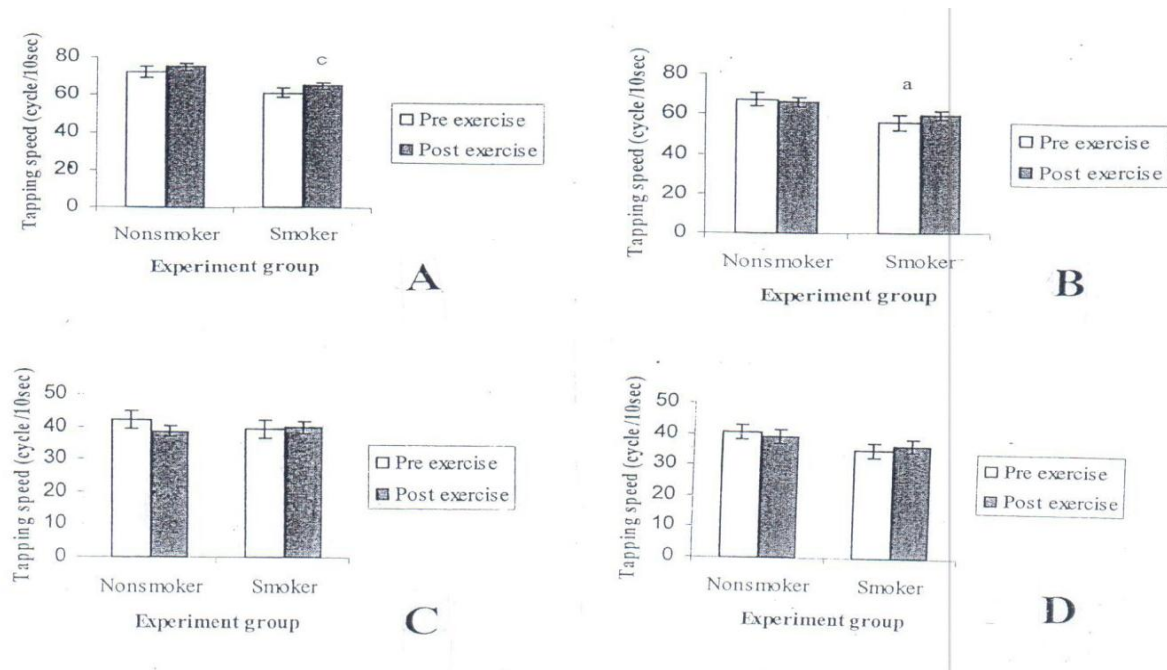
#### Tapping Speed Testing (TST)

Firstly, the mean values of tapping speed (cycle/10 sec) of the right index finger (TSTr) at the two sessions shown. The descriptive statistic of TSTr, the smoker group had significantly greater value than the nonsmoker group in Post exercise ( $p < 0.05$ ) and the repeated measures within each group of subject had shown in Figure (5A) had no significant difference between the two groups of subjects.

Secondly, the mean values of tapping speed of the left finger (TSTl) at the two sessions shown. Which shown that the smoker groups had significantly greater than the nonsmoker group in Pre exercise ( $p < 0.05$ ) and the repeated measures within each group of subject had shown in Figure (5B), smoker group had significantly greater value in Post exercise than Pre exercise ( $p < 0.05$ ).

Thirdly, tapping speed of the right big toe (TSTrbt) at the two sessions shown in Figure (5C), the mean values showed that no significant difference between the two groups of subjects and the repeated measures had shown no significant difference to these variables as well.

Fourthly, tapping speed of the left big toe (TSTlbt) at the two sessions shown in Figure (5D), the mean values showed no significant difference between the two groups of subjects and the repeated measures showed no significant difference among these of variables as well.



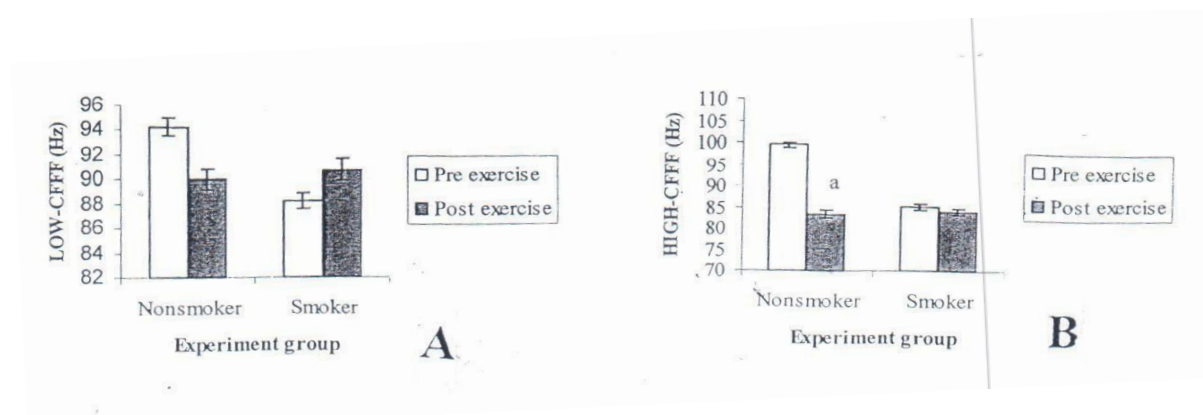
**Figure 5** Comparison of two sessions of tapping speed of the right index finger (RI) (A), left index fingers (LI) (B), right big toe (RBT) (C) and left big toes (LBT) (D) of NG and SG presented by mean  $\pm$  SEM, statistics shown as paired t-test, Pre exercise and Post exercise 30 minutes, Significant value  $p < 0.05$ , a; different from pre exercise nonsmoker, b; different from pre exercise smoker, c; different from post exercise nonsmoker, d; different from post exercise smoker.

#### Critical Flicker Fusion Frequency (CFFF)

The frequency of flicker changes were investigated from flickering to the smooth of light. The CFFF was tested from low to high frequency (CFFF<sub>L</sub>) and high to low frequency (CFFF<sub>H</sub>).

The two sessions of the critical flicker fusion frequency (CFFF) in Pre and Post exercise had shown in Figure (6A) and (6B). Firstly, the descriptive values at CFFF<sub>L</sub> in the first evaluation showed no significant difference between the two groups of subjects. The repeated measure within groups had shown no significant difference to these variables as well.

Secondly, the descriptive values at CFFF<sub>H</sub> in the first evaluation showed no significant difference between the two groups of subjects. The repeated measure within groups showed that; the nonsmoker group had significantly lesser in CFFF<sub>H</sub> when compared the Post exercise to the Pre exercise ( $p < 0.05$ )



**Figure 6** Comparison of two sessions of the low-CFFF ( $CFFF_L$ ) (A) and high CFFF ( $CFFF_H$ ) of NG and SG presented by mean  $\pm$  SEM, statistics shown as paired t-test, Pre exercise and Post exercise 30 minutes, Significant value  $p < 0.05$ , a; different from pre exercise nonsmoker, b; different from pre exercise smoker, c; different from post exercise nonsmoker, d; different from post exercise smoker.

## DISCUSSION

In this study, the basic physical characteristics of the subjects including age, body weight, heart rates, systolic blood pressure, diastolic blood pressure and body mass index of smoker group and the control group were similar. Compare to the smoker group, the control group showed greater of some fitness parameters such as maximum oxygen consumption and agility. There are at least two proposed mechanisms that could explain the difference in performance gain in the nonsmoker and smoker groups. Firstly, cigarette smoking has been shown to cause endothelial changes with ultrastructural damage to aortic and pulmonary blood vessels (19). Secondly, nicotine in the cigarette can stimulate the sympathetic nervous system leading to increased heart rate and blood pressure (5, 7). Carbon monoxide in cigarette smoke can also displace some oxygen from hemoglobin, thus its oxygen transport capacity; interfering with unloading of oxygen in tissue (7). So, these factors may explain why cigarette smoking has an adverse effects on exercise performance. In support of this notion, Timisjarvi et al. (1980) studied effects of smoking on the circulation at rest and during exercise, The radiocardiography showed that the heart rate and pulmonary capillary pressure attained significantly higher values after smoking than before smoking. In the exercise tests, there was a significant decrease observed in stroke volume, pulmonary blood volume and pulmonary dispersion volume (20). Conway and Cronan (1992) studied both males ( $n=272$ ) and females ( $n=333$ ) navy personnel in maximal treadmill exercise testing on male members of the Indiana police force showed that the duration of exercise for smoker was significant shorter with higher peak systolic blood pressure and lower maximal heart rate (21) Furthermore, Albrecht and coworker (1998) evaluated the possible effects of smoking cessation on exercise performance in middle-aged female smokers who underwent vigorous exercise training as an adjunct to a cognitive behavioral smoking

cessation treatment program. The result showed that women who undergo vigorous exercise training program and quit smoking demonstrated improved exercise performance over those who continue smoking (22).

In this study, the neuropsychophysiological performance were investigated by psychomotor tests including reaction time (RT) determination, response time task (ResT), speed of tapping (TST) and critical flicker fusion frequency (CFFF) by visual activation.

Firstly, reaction time (RT) is the time from stimulation by using various forms of an appropriate sense organ to the quickest voluntary response of a given effector organ (9). This study used warned simple reaction time (WRT) obtained from a subjects who was warned a few seconds before an actual stimulation, therefore the subjects is mentally more prepared to respond to the actual stimulus. Our data showed that the nonsmoker displayed significantly shorter in warned auditory reaction time of the right big toe (WARTrbt) when compared to the smoker in both pre-exercise and post-exercise. This result may imply that the smoker may have some pathology of cerebrovascular systems. This finding is supported by a previous study showing that smoking induced constriction of basal cerebral arteries as well as an incomplete dilation of resistance vessels, as a result vasomotor reactivity was decreased after smoking (29). The combined effects of smoking on brain basal arteries and arterioles might contribute to the increased and reversible stroke risk in smokers (23). Chentanez and co-workers (1988) suggested that the measurement of reaction time and tapping speed test in arms and legs could be used in confirming the location of lesion in the patients with neuronal circuits damaged in brain, spinal cord or peripheral nerve pathways (8).

Secondly, the response time, the time spent of an individual to react to an external stimulus shows that the level of sensory-motor coordination. In the present study, the data were shown that the nonsmoker displayed significantly shorter in warned tactile reaction time at cervical 7<sup>th</sup> level of the right index finger (TRlrC7) response than the smoker in post-exercise. Furthermore, the nonsmoker displayed significantly shorter in warned tactile reaction time at cervical 7<sup>th</sup> level of the right big toe (TRTrbtC7) response than the smoker in pre-exercise. In warned tactile reaction time of the right lateral malleolus stimulation and the level of the right index finger (TRTrl) response, the nonsmoker displayed significantly shorter than the smoker in both pre-exercise and post-exercise. These results suggested that chronic smoking could lead to a reduction in cerebral blood flow. This finding was supported by effects of smoking induced constriction of basal cerebral arteries as well as an incomplete dilation of resistance vessels, as mentioned above was decreased after smoking (23). The present study suggests that both exercise may promote psychomotor and cognitive performance. Chentanez and colleague (2004) stated that the response time related to the athletes fitness levels (24).

Thirdly, the tapping test has been applied to assess the accessory muscular control and motor ability as early as the 19<sup>th</sup> century (25). Previous studies reported that tapping ability increased significantly in some higher performance athletes. Finger tapping is a fine motor task and was oftenly used as a clinical neuropsychological test of

controlled sequential responses. For example, Wilson and co-worker (1971) reported that there was positive correlations and have been demonstrated between tapping speed and intelligence (26). The maximum tapping performance reveals for motor center and present about the summation of functional intensity passed the perception and cognition controlled (27). In this study, it was found that the nonsmoker had significantly higher maximal speed of the voluntary tapping performance than the smoker in post-exercise, the results showed that exercise can improve the psychomotor performance in the nonsmoker.

Fourthly, the critical flicker fusion frequency (CFFF) is useful for assessing the temporal characteristics of the visual system (28) and believed to reflect activity in the central visual system. However little is known about how these temporal frequencies are processed in the visual cortex. The ability to process temporally varying visual stimuli is important for the perception of moving targets. Critical flicker fusion frequency threshold is the lowest frequency flicker light was measured in cycles per second or Hertz (Hz) that is required to produce an appearance of steady light during observing. When light is flickered at a rate equal to or greater than the critical threshold, the individual flashes cannot be resolved and the light is indistinguishable from steady, non flickering light. At flicker rates below the CFFF threshold, each flash can be resolved and flickering lights can be discriminated from steady lights. Behaviorally derived CFFF threshold are approximately 70 Hz in human (29).

In present study, the nonsmoker had critical flicker light higher than the smoker before exercise, but the nonsmoker had significantly decline of critical flicker light in post-exercise. These result suggest that the smoker may have pathological of episcleral vessels. This supported by Iyamu and co-worker (2002) who suggested that habitual smokers have some level of nicotine in their plasma which could sustain some amount of vasoconstriction of episcleral vessels, thus leading to a slight decrease in facility of aqueous out of the anterior chamber angle thereby tending to raise intra-ocular pressure and this could enhance the chances of developing ocular hypertension in patients that are predisposed to glaucoma (30)

In conclusion, psycho-neurological performance before Astand exercise and Wingate exercise was not significantly different between the two groups in terms of visual, response time, tapping speed. However, warned auditory reaction time was significantly higher in smoker. After exercise, warned auditory reaction time of the right big toe, warned tactile reaction time of the right lateral malleolus stimulation and the level of the right index finger response and warned tactile reaction time at 7<sup>th</sup> cervical spine level of the right index finger response were significantly higher in smoker than smoker.

These data indicate poorer neurological functions in smoker than non-smokers. In addition. physical performance such as in nonsmoker oxygen consumption and agility was significantly higher than in smoker.

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