The Thesis Committee for Wonil Park
Certifies that this is the approved version of the following thesis:

Habitual Aerobic Exercise and Smoking-associated Arterial Stiffening

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

Hirofumi Tanaka

Mary Steinhardt

Habitual Aerobic Exercise and Smoking-associated Arterial Stiffening

by

Wonil Park, B.S., M.P.Ed.

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Abstract

Habitual Aerobic Exercise and Smoking-associated Arterial Stiffening

Wonil Park, M.S. Kin

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Supervisor: Hirofumi Tanaka

The largest percentage of mortality from tobacco smoking is cardiovascular-related. It is not known whether regular participation in exercise mitigates the adverse influence of smoking on vasculature. The purpose of this study is to determine if regular aerobic exercise is associated with reduced arterial stiffness in young men who are cigarette smokers. Using a cross-sectional observational study design, the sample included 78 young men (22±5 years) with the following classification: sedentary smokers (n=12); physically active smokers (n=25); sedentary non-smokers (n=20); and physically active non-smokers (n=21). Arterial stiffness was assessed by brachial-ankle pulse wave velocity (baPWV). There were no group differences in height, body fatness, systolic and diastolic blood pressure. As expected, both physically active groups demonstrated greater VO_{2max} and lower heart rate at rest than their sedentary peers. The sedentary smokers demonstrated greater baPWV than the sedentary non-smokers (1,183±33.5 vs. 1,055±25 cm/sec). baPWV was not different between the physically-active smokers and the physically-active non-smokers (1,084±26 vs. 1,070±28.6 cm/sec). Chronic smoking is

associated with arterial stiffening in sedentary men but a significant smoking-induced increase in arterial stiffness was not observed in physically active adults. These results are consistent with the idea that regular participation in physical activity may mitigate the adverse effect of smoking on the vasculature.

Table of Contents

List of Tables

List of Figures

CHAPTER 1

INTRODUCTION

1.1 Background

Cardiovascular disease (CVD) is the leading cause of mortality and morbidity in the United States and results in 40% of all-cause mortality in developed countries. CVD is caused by non-modifiable risk factors (e.g. genetic predisposition, age, and gender) as well as those that can be modified by lifestyle intervention such as diet, exercise, and smoking cessation (Campbell et al. 2008). Cigarette smoking is one of the most preventable risk factors for CVD (Rhee et al. 2007). Despite progress in reducing the prevalence of cigarette smoking, tobacco remains as one of the most important public health burdens (Ng et al. 2014). The effect of smoking on CVD appears to be mediated, at least in part, by arterial stiffening (Rhee et al. 2007). Both blood pressure (BP) and carotid-femoral PWV are increased significantly after acute smoking (Mahmud & Felly. 2003; Rhee et al. 2007; Scallan et al. 2010), and chronic smoking is associated with increasing arterial stiffness (Xing & Wang. 2004; Kim et al, 2005).

Increasing physical activity is a potential strategy that can reduce harmful effects of chronic smoking (Tanaka & Safar. 2005). However, it is not known whether regular exercise mitigates the adverse effects of smoking on large artery distensibility. The primary aim of this study was to determine if smokers who perform regular aerobic exercise demonstrate lower arterial stiffness than their sedentary peers. To do so, we

measured pulse wave velocity, a measure of arterial stiffness, in non-smoking control groups and groups of smokers who were either physically active or not. Even though the majority of smokers remain sedentary (Conway & Cronan. 1992; Deruiter et al. 2008), the proportion of chronic smokers who perform regular physical activity is surprisingly high comprising almost one quarter of the entire smoking population (Deruiter et al. 2008). We reasoned that the potentially important message would arise from this study for chronic smokers who remain physically active in spite of repeated attempts to quit smoking.

1.2 Statement of purpose

The purpose of the present investigation was to determine if regular aerobic exercise is associated with reduced arterial stiffness in cigarette smoking. The specific objectives of the study were to:

1. Determine habitual aerobic exercise effects on arterial stiffening.
2. Determine smoking habit effects on arterial stiffening.

1.3 Hypothesis

In the current study, we tested the following hypotheses:

1. Reduction on vascular function would be greater in sedentary smokers compared with physically active smokers.
2. Regular aerobic exercise reduces the effects of smoking on the vasculature.

CHAPTER 2

LITERATURE REVIEW

This literature review summarizes the relevant research that shows habitual aerobic exercise mitigates cigarette smoking-associated arterial stiffening. The topics in this review of literature include cigarette smoking, arterial stiffness as it relates to cardiovascular diseases, the evidence of arterial stiffness in healthy young men, and the use of pulse wave velocity to assess arterial stiffness.

2.1 Tobacco-related mortality

Smoking causes many diseases and reduces quality of life and life expectancy (CDC. 2013). The World Health Organization Framework Convention on Tobacco Control indicates that tobacco has a harmful effect on our body and its' use needs to be prevented (WHO. 2013). In the United States, one in every five deaths is caused by cigarette smoking each year, and more than 480,000 people die from smoking cigarette (CDC.2013; MMWR. 2013). Approximately 6 million people die and more than half a trillion dollars of economic loss is caused by tobacco in the world (WHO. 2013). Both male and female middle-aged smokers have three times higher overall mortality than age-matched non-smokers (CDC. 2013). Life expectancy is at least 10 years shorter in smokers than nonsmokers (Jha et al. 2013). However, smoking cessation before the age

of 40 can reduce the estimated number of overall mortality related to smoking-related diseases (Villablanca et al. 2000; CDC. 2013).

In addition to the first-hand smoke, exposure to second-hand smoke causes serious health problems such as cardiovascular disease, respiratory disease, and lung cancer (CDC. 2013). Second-hand smoking results in approximately 42,000 deaths each year among adults in the United States (USDHHS. 2014). The annual smoking-related mortality is expected to remain high for decades into the future. One particular concern of this is that youth and young adults demonstrate consistently high levels of prevalence of current smoking and initiation (USDHHS. 2014).

2.2 Cigarette smoking and cardiovascular disease

For the past 80 years, cardiovascular disease (CVD) has been the leading cause of mortality and morbidity in the United States and is the cause of more than 800,000 deaths annually, and results in 40% of all-cause of mortality in developed countries (WHO. 2013; CDC. 2013; Freeman et al. 2014). Cigarette smoking is consistently associated with increased CVD compared with nonsmokers (Campbell et al. 2008). Nearly one-fifth of deaths from CVD are attributable to smoking (USDHHS. 2014). Smoking is one of the major, preventable, and independent risk factors for CVD, including myocardial infarction, angina pectoris, stroke, heart failure, atrial fibrillation, and peripheral arterial disease (Villablanca et al. 2000). Current estimates for the United States are that 25.9 million men (27.8%) and 23.5 million women (23.3%) are smokers,

putting them at increased risk of heart attack (CDC. 2013). Cigarette Smoking increases the risk of dying from coronary heart disease among middle-aged men and women by 4 and 5 times, respectively. Second-hand smoking causes 33,951 annual deaths from heart disease (USDHHS, 2014). Differences potentially exist between males and females with smoking and the incidence of CVD. Even though both men and women smoked the same amount of cigarettes, women have twice the risk of CVD compared with men (Carpenter et al. 2006). This has been attributed to the hormonal difference between genders (Campbell et al. 2008).

Tobacco is a complex mixture of more than 4,000 chemical components, in addition to tar and nicotine. Because of the complexity of smoke, pathophysiologic relationships and mechanisms with smoking were difficult to mediate and elucidate (Villablanca et al. 2000). Although many studies are in progress, further studies are warranted to better understand the cardiovascular responses and other consequences in cigarette smoking and second-hand smoke exposure (Masironi & Chiba. 1992). One previous study showed that chronic smoke exposure in rats demonstrated significant cardiovascular effects, but acute nicotine infusion in the rat did not alter cardiovascular responses during chronic smoke exposure (Barron et al. 1988).

There are many of the constituents in blood, including white blood cells and platelets, those are changed upon exposure to cigarette smoking (Villablanca et al. 2000). Smoking leads to an increase in white blood cells due to an increase in the number of peripheral blood neutrophils (Barbour et al. 1997). Smoking even a few cigarettes activates leukocytes (Blann et al. 1998). Activation of neutrophils may increase the

development of cardiovascular disease. This is because neutrophils cause an increase in oxygen-derived free radicals or elastases, which may deteriorate the endothelium and vessel wall, and promote the progression and development of atherosclerosis (Villablanca et al. 2000). Therefore, these hematological changes hasten thrombus formation, which may result in myocardial infarction in patients with and without coronary atherosclerosis.

Overall, lipoproteins have an important role in the shuttling of triglycerides and cholesterol in the blood, and maintain homeostasis of lipids in the body. Smoking leads to lipid and lipoprotein abnormalities that smokers had an increase in low-density lipoprotein (LDL) and a decrease high-density lipoprotein (HDL) compared with nonsmokers (Freeman & Packard. 1995). Furthermore, elevated cholesterol concentration in smokers shows an increased risk of coronary artery disease (Blann et al. 1998; Chignard. 1993). In particular, elevated LDL by cigarette smoking has been linked to the initiation and progression of atherosclerosis (Villablanca et al. 2000).

Therefore, Cigarette smoking is a strong risk factor for cardiovascular disease in both men and women. The pathophysiological mechanisms between smoking and cardiovascular disease that are responsible for smoking-related vascular damage include changes in hemostatic factors, endothelial function, and blood lipids. However, because of the complexity of interactions between the different components of cigarettes, more studies are needed to investigate the relation of cardiovascular disease to cigarette smoking.

2.3 Cigarette smoking and arterial stiffness

The large and medium-sized arteries in the cardiovascular system play an important role in the delivery of blood flow to peripheral arteries. The elastic properties of these vessels allow for the smoothing of oscillations in blood pressure (BP), reduction of pulse pressure (PP), and perfusion of the myocardium (Vlachopoulos et al. 2004). These properties are all dependent on the arterial stiffness, which determines the velocity of incident and reflected traveling pressure wave (Mahmud & Feely, 2003; Scallan. Et al. 2010).

Noninvasive measurements and techniques (e.g., ultrasound, Doppler, applanation tonometry, and echo-tracking) have been developed and used widely to measure arterial stiffness (Kim et al. 2005; Doonan et al. 2011; Kawabata et al. 2012). To date, pulse wave velocity (PWV) has been used as a simple, noninvasive, and reproducible measurement of arterial stiffness. PWV is a measure of the traveled distance divided by the total time for the wave to travel distance [PWV = distance (m)/transit time (s)] (Scallan et al. 2010). PWV can be measured between two sites a known distance apart, and represents the arterial stiffness in the vascular tree. The stiffer the artery is, the faster the pressure wave moves through artery and the extent to which the arterial wave is applied from the periphery (Mahmud & Feely. 2003; Kim et al. 2005).

Carotid-femoral PWV (cfPWV) is the recognized "gold-standard measurement" of arterial stiffness. Increased pulse wave velocity (PWV) can lead to the reflected wave arriving at the heart during late systole to diastole in normal conditions (Kim et al. 2005). This rapid return of the reflected wave increases systolic pressure causing an elevation of

afterload on the heart with a potential effect on left ventricular hypertrophy and stiffening. In addition, diastolic pressure decreases, which may reduce coronary perfusion and increase ischemia. Previous studies show that PWV reflects age-related changes in vascular stiffness (Kim et al. 2005; Scallan et al. 2010). Functional change in the arterial response to pulsatile pressure associated with impaired compliances of vessels can increase atherosclerosis and vascular damages.

Arterial stiffness is increasingly being recognized as an important cardiovascular risk factor and an independent predictor of all-cause and cardiovascular death rate (Nurnberger et al. 2003). Acute smoking and chronic smoking lead to increased arterial stiffness in several studies (Kim et al. 2005; Raymond et al. 2012; Scallan et al. 2010; Rhee et al. 2007). For example, acute smoking significantly increased both blood pressure and cfPWV (Mahmud & Feely. 2003) and significantly increases both arterial stiffness (e.g. cfPWV, baPWV) and BP in chronic smokers (Mahmud & Feely. 2003; Kim et al. 2005; Rhee et al. 2007). Cigarette smoking changes both central and peripheral vascular function in all aged smokers. Impaired Flow-mediated dilation (FMD) was present in subjects who have systolic blood pressure (SBP) <120mmHg due to cigarette smoking (Jatoi et al. 2007). Smoking has been reported to reduce arterial distensibility in both large and medium arteries (Vlachopoulos et al. 2004). Acute smoking in healthy smokers has demonstrated acute changes of arterial stiffness and blood pressure. Smokers have deteriorative arterial stiffness than nonsmokers, and chronic smoking can certainly increase arterial stiffness (Kim et al. 2005).

Mechanisms underlying elevated arterial stiffness by acute smoking may include endothelial dysfunction, enhanced platelet, impaired nitric oxide synthase (NOS) activity, increased inflammation, decreased kidney function, insulin resistance, and changes in prosyacyclin and vasopressin levels (Rehill et al. 2006). Chronic smokers have a decreased NOS activity and an increased oxidative stress; those factors inducing lower NO bioavailability (Kim et al. 2005; Rehill et al. 2006; Doonan et al. 2011). Increased calcification also plays an important role in contributing to chronic changes in arterial stiffness (Scallan et al. 2010). Thus, smoking worsens arterial stiffness presumably through both lower NO activity and worse vascular walls.

2.4 Cigarette smoking and exercise

Smokers may be less likely to perform regular exercise than nonsmokers (Deruiter et al. 2008). Smoking is associated with a decrease in the ability to perform vigorous exercise because of decreased lung function, increased blood levels of carboxy-hemoglobin, a blunted heart rate response to exercise, and decreased maximal oxygen consumption (Boudreaux et al. 2003). Smokers participate in a lesser amount of vigorous activity than nonsmokers, but the difference for moderate or low intensity activities was not affected (Kaczynski et al. 2008). Several studies indicate that smoking results in lower physical fitness levels even among relatively young and fit military personnel (Ward et al. 2002; Dhaliwal et al. 2013; Conway & Cronan. 1992). That means that lower

physical fitness levels in smokers is not attributed to less exercise, rather smoking has a detrimental effect on physical fitness (Conway & Cronan. 1992).

Although the relation between smoking and physical inactivity has been studied diversely (Ward et al. 2002; Dhaliwal et al. 2013; Conway & Cronan. 1992; Boudreaux et al. 2003), we are unaware of how these two risk factors are related in individuals. A recent study suggests that physical activity can act as a potential tobacco harm-reducing strategy for smokers. Improved arterial compliance has been observed in physically active individuals (Tanaka & Safar. 2005). Data from the Cooper Institute for Aerobics Research has shown that smokers who maintain a strenuous level of physical fitness have lower death rates from all causes than lower fitness non-smokers (Blair et al. 1996).

Smoking in healthy individuals shows harmful effects on vascular function, affecting the ability of the vascular bed to respond to acute exercise (Doonan et al. 2011). Cigar smoking increases acute detrimental effect on arterial stiffness in healthy individuals who smoked one cigarette during the test (Vlachopoulos. 2004). Particularly, occasional cigarette smoking can lead to chronic attenuation of arterial function in healthy young individuals (Stoner et al. 2008). Exposure to environmental tobacco smoke also plays a role in increased aortic wave reflection and impaired micro-vascular function (Argacha et al. 2008). Chronic smokers who engage regularly in aerobic exercise have a reduced incidence of developing cardiovascular disease (Doonan et al. 2011).

Physically active females have a better arterial compliance. For example, sedentary healthy females have an age-related central arterial stiffness, but this is not observed in physically active women (Tanaka et al. 1998). A cross-sectional study also

shows that habitual aerobic exercise in smokers increases peripheral blood flow and decreases peripheral vascular resistance (Anton et al. 2006). Therefore, understanding the effects of exercise on arterial stiffness is important in reducing cardiovascular disease related cigarette smoking. This is because regular exercise decreases the effects of chronic smoking on vascular structures, which have a cardio-protective effect.

2.5 Exercise and arterial stiffness

Lifestyle modifications, in particular aerobic (but not resistance) exercise and sodium restriction, are clinically efficient interventions for preventing and alleviating arterial stiffening (Tanaka & Safar. 2005). Exercise that decreases the age-related increase in arterial stiffness may have the potential to improve outcomes including increased cardiovascular risk factors (Ferreira et al. 2002). There are the mechanisms underlying the observed effect of exercise on vascular trees. In general, acute exercise results in a remodeling of blood flow to the working muscles caused by vasodilation of working muscles and vasoconstriction in other organs such as the splanchnic circulation. Exercise can trigger by an increase release of endothelin-1 (ET-1) and nitric oxide (NO), which mediate blood flow redistribution during exercise (Edwards et al. 2012). In an animal study, local ET-1 increases in the splanchnic circulation and decreases in the coronary circulation, and NO production increases in the coronary circulation during exercise (Kim et al. 2005; Argacha et al. 2008).

A recent study has shown a positive effect of exercise on arterial health including arterial stiffness, endothelial function, and intima-media thickness in adults (Seals et al. 2008). Several studies have demonstrated that physical activity reduces systemic blood pressure and improves arterial stiffness in children (Farpour-Lambert et al. 2009; Sakuragi et al. 2009). Exercise training studies demonstrate that physically active individuals have reduced arterial stiffness compared with their sedentary counterparts (Boreham et al. 2004; Ferreira et al. 2002). Therefore, exercise-related ameliorations in arterial stiffness could be mediated by concurrent improvements on endothelial function, inflammation, and sympathetic activity. However, the evidence for a protective effect of exercise on arterial stiffness is poorly studied in humans, the mechanisms underlying the effect of regular exercise on arterial stiffness need to be elucidated.

2.6 Smoking cessation

Smoking cessation is one of the most important lifestyle modifications to improve health and well-being. Stopping smoking prolongs life and reduces morbidity (USDHHS. 2014; Ussher et al. 2012). People who stop smoking decrease their risk of cancer, heart disease, stroke, and early death (Jatoi et al. 2007). Smoking cessation can decrease the incidence of CVD and acute myocardial infarction (Campbell et al. 2008) and may delay the atherosclerosis by 10 years compared to individuals who continue to smoke (Livingston & Lynm. 2012). Quitting smoking before the age of 40 reduces the risk of dying from smoking-related disease by about 90% (CDC. 2013). Many

physiologic benefits are associated with smoking cessation. However, the effect of smoking cessation in arterial stiffness remains poorly established. Some studies observed a decrease in arterial stiffness after acute and chronic smoking cessation (Oren et al. 2006; Rehill et al. 2006; Yu-Jie et al. 2012), but other studies found that no significant change occurred in arterial stiffness after smoking cessation (Polonia et al. 2009; Scallan et al. 2010). Therefore, the impact of smoking cessation on arterial stiffness should be clarified precisely using the suitable devices and parameters of arterial stiffness in future studies.

Most smokers in the United States stop smoking through a combination of behavioral counseling and nicotine replacement therapy, bupropion, or varenicline. However, smoking cessation can be challenging because of addiction to the nicotine in tobacco (Ussher et al. 2012). In fact, only 6% of smokers can successfully quit smoking within a year (Livingston & Lynm. 2012). More effective smoking cessation interventions are clearly needed.

2.7 smoking cessation and exercise

Exercise and physical activity may play a role as an aid to quitting smoking adjunct to conventional smoking cessation treatment (e.g. cognitive behavioral therapy, nicotine replacement) (Hill et al. 1981). According to the previous study, smokers trying to quit are more likely to an active lifestyle than other smokers in most populations (Albrecht et al. 1998; Marcus et al. 1995). In fact, it has been observed that physically

active individual with smoking who had quit has many general health benefits. In addition, exercise has a positive effect on other factors that may prohibit smokers form the smoking relapse including perceived coping ability and self-esteem (Ciccolo et al. 2011).

Regular exercise may help stop smoking by controlling nicotine withdrawal and cravings (Ussher et al. 2012). A previous study found that highly physically active smokers exhibited lower nicotine dependence and were observed to have a significant increase in smoking cessation attempts (Ward et al. 2003). Additionally, physically active smokers had smoked for a shorter duration and smoked fewer cigarettes per day (deRuiter et al. 2008). Many studies showed that smokers may be more likely to physically active (Ward et al. 2003; deRuiter 2008) and regular exercise can help successfully stop smoking (Albrecht et al. 1998), but other studies revealed null effects of exercise on smoking cessation (Ussher et al. 2008). It is still unclear whether exercise treatments have a positive effect on smoking cessation. Therefore, further studies are needed to elucidate the potential role of exercise on smoking cessation in general.

CHAPTER 3

METHODOLOGY

3.1 Subjects

A total of 78 men (22±5 years) participated in the study. Subjects were assigned to groups based on their smoking habit and reported physical activity; sedentary non-smokers (n=20), sedentary smokers (n=12), physically active non-smokers (n=21), and physically active smokers (n=25). Smokers had been smoking at least 8 to 10 cigarettes per day for at least 2 years preceding the study. For at least the previous six months, the subjects had been either sedentary (no regular physically activity) or physically active (≥2 h/week of aerobic exercise). Exclusion criteria were: established obesity (body mass index ≥30 kg/m^2), hypertension (systolic >140 mmHg and / or diastolic >90 mmHg), and overt cardiovascular disease or other chronic diseases as assessed by the medical history questionnaire.

All experimental procedures were explained to the individuals, and subjects were informed of the potential risks of the study, and were given written informed consents to participate. All procedures were approved by the Institutional Review Board at the University of Texas at Austin.

3.2 Experimental Procedures

Subjects reported to the laboratory in the morning having refrained from alcoholic beverages, caffeine, food, and smoking for at least 4 hours prior to the experiments. All the testing was conducted at the same time of day among the groups. Physically-active smokers were studied at least 24 h after their last exercise session to avoid any acute effects of exercise while still being representative of their normal physiological state (i.e., habitually exercising). Subjects were studied under quiet, comfortable, and ambient laboratory (~24^{o}C) conditions.

Body composition assessment

Body composition was assessed by a dual-energy x-ray absorptiometry (Lunar DPX, GE Medical Systems, Fairfield, CT). During the body composition test, participants laid in the supine position on a table for the scan.

Blood pressure

Blood pressure was measured with an automatic device (VP-1000, Omron Healthcare, Lake Forest, IL) in duplicate on the right arm after five minutes in the upright seated position with the arm at heart level.

Arterial stiffness

A measure of arterial stiffness, pulse wave velocity, was determined using the automated vascular screening device (VP-1000, Omron Healthcare, Lake Forest, IL) as previously described (Cortez-Cooper et al. 2005). This device simultaneously measured multi-segmental pulse wave velocities for various segments. The pulse wave transit time is the time delay between the proximal and distal pulse wave, as determined by the foot-to-foot method.

Maximal oxygen consumption

All participants performed exercise testing on a treadmill in order to determine the maximal aerobic capacity via a modified Bruce protocol. Expired gases were sampled continuously via a mixing chamber and analyzed for the concentration of O_2 and CO_2 (Physio Dyne, Physio Dyne Inc., Quogue, NY, USA).

3.3 Statistical analysis

Group differences for variables were performed using ANOVA. If a significant F-value was shown, post-hoc test (LSD) was used to determine significant differences among groups. All data are represented as mean±SEM. A significant level of $\alpha<0.05$ was used to determine statistical difference. IBM SPSS version 22 was used for all the statistical analyses.

CHAPTER 4

RESULTS

4.1 Selected physical characteristics, blood pressure, and PWV

Selected physical characteristics of the subjects are shown in Table 1. The smokers were slightly older and greater in body mass and BMI than the nonsmokers. As expected, both physically active groups had significantly greater VO_{2max} than their sedentary peers ($P<0.05$). The smoking history of pack-years was not different between sedentary and active smokers.

As shown in Table 2, heart rate at rest was significantly lower in both physically active groups than their sedentary counterparts ($P<0.05$). There were no significant differences in brachial or carotid blood pressure among groups.

Figure 1 illustrates group differences in baPWV and augmentation index among 4 groups. baPWV was significantly elevated in sedentary smokers compared with the other groups. There was no significant group difference between active non-smokers and active smokers. Augmentation index was greater in sedentary groups than in physically active groups.

Table 1. Selected subject characteristics in 4 groups

	Sedentary non-smokers (20)	Sedentary smokers (12)	Active non-smokers (21)	Active smokers (25)
Age (yr)	22±1	26±2*	21±0†	23±1‡
Height (cm)	170±1	173±2	172±1	172±1
Body mass (kg)	64±3	73±3*	65±1†	70±2*
BMI (kg/m^2)	22±1	24±1*	22±0†	24±1
Body fat (%)	23±2	25±3	18±1	22±2
VO_2max (ml/kg/min)	39±2	35±2	52±1*†	46±2*†‡
Smoking history (pack years)	0±0	9±5	0±0	5±1

Data are means±SEM; * P<0.05 vs. sedentary non-smokers; † P<0.05 vs. sedentary smokers; ‡ P<0.05 vs. active non-smokers. BMI=body mass index, VO_2max=maximal oxygen consumption.

Table 2. Heart rate and blood pressure at rest in 4 groups

	Sedentary non-smokers (20)	Sedentary smokers (12)	Active non-smokers (21)	Active smokers (25)
Heart rate (bpm)	68±3	65±3	55±2*†	53±1*†
Brachial Systolic BP (mmHg)	115±2	118±3	118±2	117±2
Brachial Diastolic BP (mmHg)	66±2	67±2	66±2	67±1
Brachial Mean BP (mmHg)	84±2	84±2	83±3	86±1
Carotid Systolic BP (mmHg)	98±1	103±3	104±2	105±3
Carotid Pulse Pressure (mmHg)	36±2	36±3	35±2	38±2

Data are means±SEM; * $P<0.05$ vs. sedentary non-smokers; † $P<0.05$ vs. sedentary smokers. BP=blood pressure.

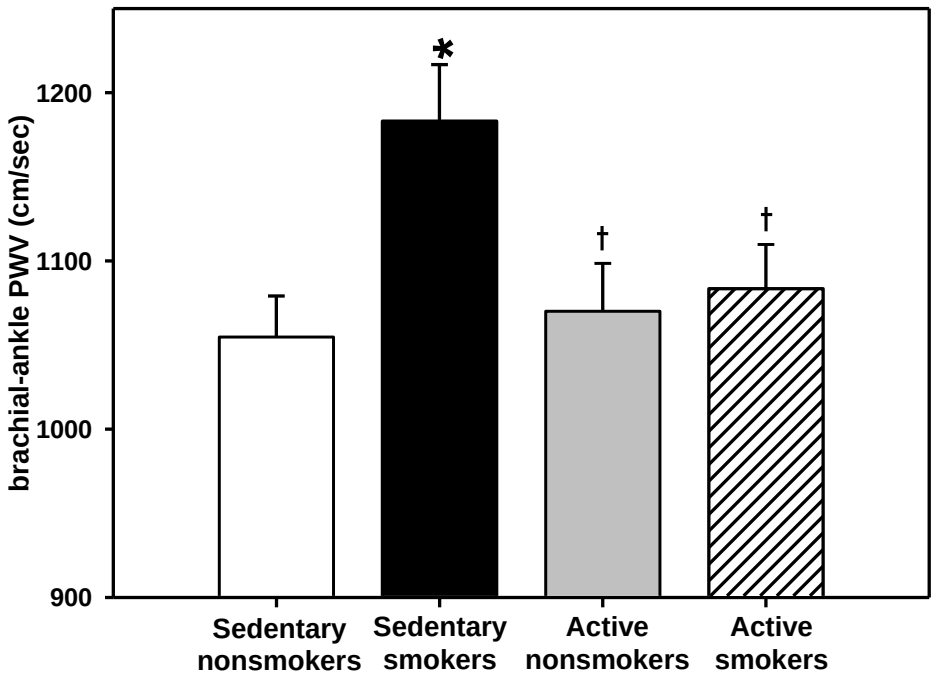

Figure 1: Bar graph of brachial-ankle PWV at rest is compared among sedentary non-smokers, sedentary smokers, active non-smokers, and active smokers by analysis of variance: Data are means±SEM; * P<0.05 vs. sedentary non-smokers; † P<0.05 vs. sedentary smokers.

CHAPTER 5

DISCUSSION

The present cross-sectional study was conducted to investigate the influence of habitual aerobic exercise on mitigating the smoking-induced arterial stiffening. Our findings indicate that chronic smoking elevates arterial stiffness in sedentary individuals but that smoking-induced arterial stiffening was absent in chronic smokers who engage in regular physical activity. To the best of our knowledge, this is the first study to indicate that habitual aerobic exercise can favorably oppose the smoking-associated deterioration in vascular stiffness.

Smoking can lead to the initiation and progression of atherosclerosis and other vascular diseases (Doonan et al. 2011). Arterial stiffness may be one of the mechanisms underlying the smoking-related vascular disease. In the present study, arterial stiffness as measured by baPWV was significantly elevated in sedentary smokers compared with non-smoking peers. The present finding is consistent with previous studies showing the arterial stiffening effects of cigarette smoking (Mahmud et al. 2003; Kim et al. 2005; Rhee et al. 2007). But this was observed in young healthy subjects in the present study.

There is no question that the most important strategy for improving cardiovascular health in smokers should be smoking cessation (USDHHS. 2014; Jatoi et al. 2007). However, sustained smoking cessation is very difficult to achieve due primarily to the addictive nature of nicotine (Ussher et al. 2012). Thus, interventions targeted for reducing or minimizing smoking-induced cardiovascular harm are needed.

In this context, physical activity may be a cost-effective harm reduction strategy for those who cannot use or afford medications or who cannot access traditional therapeutic choices (e.g., pregnant smokers) (Deruiter and Faulkner. 2006). Considering the multitude of benefits induced by regular exercise, it seems logical that the detrimental effects of cigarette smoking on vascular function could be antagonized through participation in regular physical activity. We found that baPWV of smokers who are physically active is not different from sedentary and active non-smokers. This was also observed in carotid augmentation index, a measure of arterial wave reflection and arterial stiffness. The epidemiological report that smokers who habitually exercise exhibit a lower relative risk for CVD than their sedentary peers (Ferrucci et al. 1999) is consistent with these findings. Taken together, these results suggest that regular aerobic exercise may be an important lifestyle modification for chronic smokers who attempt to reduce cardiovascular harm.

Skepticism over whether smokers will actually adopt regular physical activity is justifiable. In contrast to the prevalent thought, however, the proportion of chronic smokers who perform regular physical activity is fairly high. In the Canadian Community Health Survey, physically active smokers represented almost one quarter of the entire smoking population (Deruiter et al. 2008). These data suggest that a large proportion of the daily smoking population possess the motivation and willingness to make a deliberate effort to engage in physical activity and that any concerns regarding the practicality of prescribing physical activity as a smoking harm reduction therapy are unwarranted. Indeed, smoking has not been shown to be a barrier to participating in

regular physical activity (Crombie et al. 2004), and chronic smokers are capable of becoming more physically active (Ussher et al. 2008), and the exercise adherence of smokers with exercise intervention are comparable to that of non-smokers (Ussher et al. 2000). Interestingly, compared with their inactive peers, a greater proportion of physically active smokers had tried to quit smoking but failed (Deruiter et al. 2008). Collectively, these observations make the results of our present study clinically relevant.

Arterial stiffness is determined by the intrinsic properties of the arterial wall and may be improved by alterations in the contractile states of the vascular smooth muscle tone (Tanaka and Safar. 2005). In apparently healthy older adults, a reduction in alpha-adrenergic receptor-mediated vascular tone contributes to the decrease in arterial stiffness with endurance training (Sugawara et al. 2009). It is feasible to hypothesize that the similar physiological mechanism may act on the arterial wall of chronic smokers. Indeed we have previously reported that smokers who habitually perform physical activity demonstrate greater levels of peripheral blood flow and peripheral vascular conductance (Anton et al. 2006).

CHAPTER 6

LIMITATIONS AND IMPLICATIONS

There are several limitations in the present study that should be noted. First, as we used the cross-sectional study design to address the stated aim, the cause-and effect relation cannot be determined. Second, the sample size was relatively small. Third, groups were not matched for some characteristics as there were significant differences in age and body mass. However, these differences were fairly mild.

CHAPTER 7

CONCLUSION

In conclusion, the present study demonstrated that chronic smokers who habitually engage in aerobic exercise had lower arterial stiffness compared with sedentary smokers. These results suggest that regular participation in physical activity may mitigate smoking-induced arterial stiffening. Interventional studies are needed to confirm the present findings obtained using the cross-sectional approach.

Appendix A: Informed consent form

Title of Research Study: Tobacco Smoking, Regular Exercise, and Arterial Stiffness

You are being invited to voluntarily participate in the above-titled research project conducted under the directions of Hirofumi Tanaka, Ph.D., Alazne Anton and Miriam Cortez-Cooper in the University of Texas's Department of Kinesiology and Health Education. This form provides you with information about the study. The Principal Investigator (the person in charge of this research) or his/her representative will provide you with a copy of this form to keep for your reference, and will also describe this study to you and answer all of your questions. Please read the information below and ask questions about anything you don't understand before deciding whether or not to take part. Your participation is entirely voluntary and you can refuse to participate without penalty or loss of benefits to which you are otherwise entitled.

What is the purpose of this study?
The purpose of this study is to determine if regular exercise reduces adverse effects associated with tobacco smoking on arterial function. This study is a part of our ongoing research project assessing the influence of lifestyle factors on cardiovascular function. You are being asked to participate in the study because you are one of the smoking or non-smoking men and women aged18-75 years. If you participate, you will be one of approximately 45 people in the study.

What will be done if you take part in this research study?
If you decide to participate, you will be asked to participate in research testing over a 3-week period of time. This will include 4 experimental sessions that require you to come to our laboratory 4 different times. During each testing session, which will last between 1.5 to 2.5 hours, several measurements described below will be made on you. If you are a smoker, you will be asked to come in one additional time. In this extra session, you will be asked to smoke a cigarette outside of the building. After that we will make some of the measurements (your blood pressure and stiffness of artery) in the laboratory described below. All the measurements described below will be conducted in the Cardiovascular Aging Research Laboratory in Bellmont Hall.

- Your heart and blood pressure response to exercise will be evaluated during a treadmill stress test if you are over 45 years of age for men and over 55 years of age for women. You will be asked to walk on the treadmill for 10 to 12 minutes while we closely monitor your heart rate and blood pressure. If any abnormalities in response to the test are discovered, you will be referred to your primary care physician for further testing, and you may be ineligible to participate in the study;

- Your blood pressure will be measured non-invasively ｉ) by the arm cuff technique (as in your Doctor's office) and by the finger cuff technique, ii) by placing a pencil-like probe over the carotid (neck) artery;
- Your heart rate will be measured non-invasively using electrocardiography;
- Your body fat percentage will be measured non-invasively by skinfold thickness and dual energy X-ray absorptiometry (DEXA). This DEXA test involves you lying on a padded table while a small probe that emits energy to measure tissue density passes over your body;
- Your maximal oxygen consumption (an index of aerobic fitness) will be measured during a graded exercise test to exhaustion on a treadmill. During the test, the grade (slope) of the treadmill will be increased gradually. We will collect your expired air through a mouthpiece;
- Your blood cholesterol and fat levels will be determined by taking small blood samples (2 teaspoons) from a venous catheter (small plastic tube);
- Stiffness of your artery will be measured non-invasively by ｉ) placing a probe of an ultrasound machine (the same machine that is used to evaluate the development of the baby during pregnancy) on the skin of the carotid (neck), femoral (hip joint), and wrist arteries; and ii)placing two pencil-like probes over various arteries (carotid, femoral, brachial, wrist, and ankle arteries);
- Your heart structure and function will be measured non-invasively by placing a probe of an ultrasound machine on the chest;
- Manipulation of blood pressure regulating system will be induced by squeezing a gripping device with a hand (handgrip exercise) and placing a foot in ice cold water for 2 minutes;
- Your resting metabolic rate will be measured in the morning after you lie down quietly on a bed for about 45 minutes while expired air is collected in a hood placed over the head and shoulders.

What are the possible discomforts and risks?

Every effort has been made by the investigators to keep the risk and discomfort involved in this study to a minimum. You will be carefully screened at the beginning of this study to determine whether you can participate safely. Nevertheless, the potential risks associated with this study include 1) a very slight chance of irregular heart beat occurring during treadmill exercise, which could lead to fainting and heart attack (less than 1% of all subjects); 2) a slight risk of fainting, bruising, or infection associated with the dual energy X-ray absorptiometry which is 1/20 of the average X-ray; and 5) potential psychological and emotional risks for you and your family members in response to the results of genetic tests.

What are the possible benefits to you or to others?

We expect the project to benefit you in the following ways; 1) medical information derived from a medical history, physical examination, blood pressure readings, and

physician-supervised graded exercise test(if applicable) free of charge; 2) measurement of aerobic fitness and body fat percentage free of charge; 3) measurement of blood cholesterol levels free of charge; and 4) contribution to scientific knowledge that is likely to result in the documentation of a benefit that could significantly reduce the risk of cardiovascular disease in the documentation of a benefit that could significantly reduce the risk of cardiovascular disease in men and women.

If you choose to take part in this study, will it cost you anything?
No

Will you receive compensation for your participation in this study?
You will receive our laboratory t-shirt and monetary compensation of $50. If you decide to drop out in the middle of the study, the payment to you will be prorated.

What if you are injured because of the study?
The University has no facilities or insurance to cover research-related injuries. UT student participants will be afforded access to the designated services available to all students through the University of Texas Student Health Center. Other research participants are not covered. No treatment will be provided for research related injury and no payment can be provided in the event of a medical problem.

If you do not want to take part in this study, what other options are available to you?
Your participation in this study is entirely voluntary. You are free to refuse to be in the study, and your refusal will not influence current or future relationships with The University of Texas at Austin.

How can you withdraw from this research study and who should you call if you have questions?
If you wish to stop your participation in this research study for any reason, you should contact the principal investigator: Alazne Anton at (512) 471 - 8594. You should also call the principal investigator for any questions, concerns, or complaints about the research. You are free to withdraw your consent and stop participation in this research study at any time without penalty or loss of benefits for which you may be entitled. Throughout the study, the researchers will notify you of new information that may become available and that might affect your decision to remain in the study.

Whom to contact with questions concerning your rights as a research participant?
For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

How will your privacy and the confidentiality of your research records be protected?

Your privacy and the confidentiality of your data will be protected by identification number, not with your name, and will be kept in a locked file cabinet located in the Cardiovascular Aging Research Laboratory. Your blood sample will be stored for 10 years and then disposed of properly according to the University guidelines.

Will the researchers benefit from your participation in this study*?*

The researchers will gain no benefit from your participation in this study beyond the publication and/or presentation of the results obtained from the study.

Signatures:

As a representative of this study, I have explained the purpose, the procedures, the benefits, and the risks that are involved in this research study:

Signature and printed name of person obtaining consent Date

You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time. You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

Printed Name of Subject Date

Signature of Subject Date

Signature of Principal Investigator Date

Appendix B: Health research questionnaire

Personal Information

Today's Date _____ Please print your name _____
Phone Number _____ Email _____
Date of Birth _____ Age _____ Sex ☐ Male ☐ Female
Who is your physician? _____ Phone _____
In case of emergency, contact _____ Phone _____

Please circle the highest grade in school you have completed:

Elementary school	1	2	3	4	5	6	7	8
High school	9	10	11	12				
College/Post Grad	13	14	15	16	17	18	19	20+

What is your martial status? ☐ Single ☐ Married; ☐ Widowed ☐ Divorced; Separated

Ethnic Background: ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:

☐ White ☐ American Indian/Alaskan Native ☐ Pacific Islander

☐ Black or African American ☐ Asian

Symptoms or Signs Suggestive of Disease

Check appropriate box:

Yes	No		
☐	☐	1.	Have you experienced unusual pain or discomfort in your cheek, neck, jaw, arms or other areas that may be due to heart problems?
☐	☐	2.	Have you experienced unusual fatigue or shortness of breath at rest, during usual activities, or during mild-to-moderate exercise (e.g., climbing stairs, carrying groceries, brisk walking, cycling)?
☐	☐	3.	When you stand up, or sometimes during the night while you are sleeping, do you have difficulty breathing?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you suffer from swelling of the ankles (ankle edema)?
☐	☐	6.	Have you experienced an unusual and rapid throbbing or fluttering of the heart?
☐	☐	7.	Have you experienced severe pain in your leg muscles during walking?

☐ ☐ 8. Has a doctor told you that you have a heart murmur?

Chronic Disease Risk Factors
Check appropriate box:

Yes	No		
☐	☐	9a.	Are you a male over age 45 years or a female over age 55 years?
☐	☐		b. Are you a female who has experienced premature menopause?
☐	☐		c. If you answered "yes" to 9b, are you on estrogen replacement therapy?
☐	☐	10.	Has your father or brother had a heart attack or died suddenly of heart disease before the age of 55; has your mother or sister experienced these heart problems before the age of 65?
Yes	**No**		
☐	☐	11.	Are you a current cigarette smoker?
☐	☐	12.	Has a doctor told you that you have high blood pressure (more than 140/90 mm Hg) or a heart condition?
☐	☐	13.	Is your total serum cholesterol greater than 200 mg/dl, or has a doctor told you that your cholesterol is at a high risk-level?
☐	☐	14.	Do you have diabetes mellitus?
☐	☐	15.	Are you physically inactive and sedentary (little physical activity on the job or during leisure time)?
☐	☐	16.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	17.	During the past year, would you say that you have experienced enough stress, strain, and pressure to have a significant effect on your health?
☐	☐	18.	Do you eat foods nearly every day that are high in fat and cholesterol such as fatty meats, cheese, fried foods, butter, whole milk, or eggs?
☐	☐	19.	Do you weigh 30 or more pounds than you should?
☐	☐	20.	Do you know of any other reason you should not do physical activity?

Medical History
21. *Please check which of the following conditions you have had or now have. Also check medical conditions in your family (father, mother, brother(s), or sister(s)). Check as many as apply.*

Self	Family	Medical Condition	Self	Family	Medical Condition
☐	☐	Coronary heart disease, heart attack; by-pass surgery	☐	☐	Major injury/fracture to foot, leg, knee
☐	☐	Arrhythmias	☐	☐	Major injury to back or neck

☐	☐	Angina	☐	☐	Major injury/fracture to hip or shoulder
☐	☐	High blood pressure	☐	☐	Rheumatoid Arthritis
☐	☐	Peripheral vascular disease	☐	☐	Osteoarthritis
☐	☐	Phlebitis or emboli	☐	☐	Gout
☐	☐	Other heart problems	☐	☐	Osteoporosis
☐	☐	Stroke	☐	☐	Fibromyalgia
☐	☐	Asthma	☐	☐	Diabetes mellitus
☐	☐	Bronchitis	☐	☐	Kidney disease
☐	☐	COPD (emphysema)	☐	☐	Cataracts
☐	☐	Lung cancer	☐	☐	Glaucoma
☐	☐	Breast cancer	☐	☐	Hearing loss
☐	☐	Prostate cancer	☐	☐	Depression
☐	☐	Skin cancer	☐	☐	Anxiety, phobias
☐	☐	Colorectal cancer	☐	☐	Eating disorders
☐	☐	Other cancer. Specify:	☐	☐	Sleeping problems
☐	☐	Gallstones/gallbladder disease	☐	☐	Substance abuse problems (alcohol, other drugs, etc.)
☐	☐	Liver disease (cirrhosis)	☐	☐	Chronic Fatigue Syndrome
☐	☐	Hepatitis	☐	☐	Thyroid problems
☐	☐	Anemia (low iron)	☐	☐	Hysterectomy
☐	☐	Stomach/duodenal ulcer	☐	☐	Problems with menstruation
☐	☐	Rectal growth or bleeding	☐	☐	Post-menopausal (date:)
☐	☐	Crohne's disease	☐	☐	Raynaud's disease
☐	☐	Irritable bowel syndrome	☐	☐	Allergies
☐	☐	Marfan's syndrome			

Any other health problems. Please specify and include information on any recent illnesses, hospitalizations, or surgical procedures.

22. *Please check any of the following medications you take regularly and give the name of the medication.*

Medication	**Name of Medication**
☐ Heart medicine	_____
☐ Blood pressure medicine	_____
☐ Blood cholesterol medicine	_____
☐ Hormones	_____
☐ Birth control medicine	_____
☐ Medicine for breathing/lungs	_____
☐ Insulin	_____
☐ Other medicine for diabetes	_____
☐ Arthritis medicine	_____
☐ Medicine for depression	_____
☐ Medicine for anxiety	_____
☐ Thyroid medicine	_____
☐ Medicine for ulcers	_____
☐ Painkiller medicine	_____
☐ Allergy medicine	_____
☐ Other (please specify)	_____
☐ Do you have any drug allergies?	_____
☐ Dietary supplements (please specify)	_____

Body Weight

23. What is the most you have ever weighed? _____ pounds

24. Are you now trying to:

☐ Lose weight ☐ Gain weight ☐ Stay about the same ☐ Not trying to do anything

Stress

25. During the past month, how would you rate your overall level of stress?

☐ Very high ☐ High ☐ Moderate ☐ Low

26. In the past year, how much effect has stress had on your health?

☐ A lot ☐ Some ☐ Hardly any or none

27. On average, how many hours of sleep do you get in a 24-hour period?

☐ Less than 5 ☐ 5-6.9 ☐ 7-9 ☐ More than 9

Substance Use

28. How would you describe your cigarette smoking habits?

☐ Never smoked

☐ Used to smoke. How many years has it been since you smoked? _____ years

☐ Still smoke. How many cigarettes a day do you smoke on average?
___cigarettes/day

29. How many alcoholic drinks do you consume? (A "drink" is a glass of wine, a wine cooler, a 16oz bottle/12oz can of beer, a shot glass of liquor, or a mixed drink).

☐ Never use alcohol ☐ Less than 1 per week ☐ 1-6 per week
☐ 1 per day
☐ 2-3 per day ☐ More than 3 per day

30. In one sitting, how many drinks do you typically consume?

_____

31. How many cups (8 ounces) of coffee do you drink per day? _____

32. How many ounces of sodas containing caffeine do you drink per day? _____

Physical Fitness, Physical Activity/Exercise

33. Considering a **7-Day period** (a week), how many times on the average do you do the following kinds of exercise for **more than 15 minutes** during your **free time** (write on each line the appropriate number).

a) **STRENUOUS EXERCISE (HEART BEATS RAPIDLY)** **Times Per Week**
(i.e. running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling) _____

b) **MODERATE EXERCISE (NOT EXHAUSTING)**
(i.e. fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)
_____

c) **MILD EXERCISE (MINIMAL EFFORT)**
(i.e. yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)
_____

34. Considering a 7-Day period (a week), during your leisure-time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)

☐ OFTEN ☐ SOMETIMES ☐ NEVER/RARELY

35. How long have you exercised or played sports regularly?

☐ I do not exercise regularly ☐ Less than 1 year ☐ 1-2 years
☐ 2-5 years ☐ 5-10 years ☐ More than 10 years

Occupational Health

36. Please describe your main job title and duties.

_____

37. How much hard physical work is required on your job?

☐ A great deal ☐ A moderate amount ☐ A little ☐ None

Reproductive Health

38. What is the date of your last menstrual cycle?

_____

X-ray testing

39. Have you recently had or are you planning to have barium tests or a nuclear medicine scan or injection with an x-ray dye?

☐ No ☐ Yes If yes, when? _____

Appendix C: Smoking Questionnaire

Smokers

Cigarettes

1 Do you smoke cigarettes? If yes, continue……. *yes* *no*
2 What brand of cigarette do you smoke? _____
3 How many cigarettes do you smoke each day? _____
4 How many years have you smoked this number of cigarettes each day? _____
5 Before that time, how many cigarettes did you smoke/day? _____

Ownrolled cigarettes

6 Do you smoke ownrolled cigarettes? If yes, continue…… *yes* *no*
7 How many packages of tobacco (40 grams) do you use each week? _____
8 How many years have you used this number of packages/wk? _____
9 Before that time, how many packages did you use/wk? _____

Cigars/cigarillos

10 Do you smoke cigars or cigarillos? If yes, continue……. *yes* *no*
11 How many cigars/cigarillos do you smoke each week? _____
12 How many years have you smoked this number of cigars/cigarillos each week? _____
13 Before that time, how many cigars/cigarillos did you smoke/wk? _____

Pipe tobacco

14 Do you smoke pipe tobacco? If yes, continue…….……. *yes* *no*
15 How many packages of pipe tobacco (50 grams) do you use each week? _____
16 How many years have you smoked this number of packages each week? _____
17 Before that time, how many packages of pipe tobacco did you smoke each week? _____

Smoking History

18 How old were you when you first started smoking? _____
19 Have you ever tried to quit smoking from the moment you started to smoke regularly? ____
20 If yes, how many times did you quit smoking? _____
21 How long did these attempts last on average? _____
22 How old were you when you tried to quit smoking for the **first** time? _____
23 How old were you when you tried to quit smoking for the **last** time? _____

Non-Smokers

24 Have you ever smoked? If yes, continue…… *yes* *no*
25 How many cigarettes did you smoke each day on average? _____
26 How many years did you smoke this number of cigarettes? _____
27 How many packages of ownrolled tobacco did you smoke each week on average? _____
28 How many years did you smoke this number of packages? _____
29 How many cigars/cigarillos did you smoke each week on average? _____
30 How many years did you smoke this number of cigars/cigarillos on average? _____
31 How many packages of pipe tobacco did you smoke each week on average? _____
32 How many years did you smoke this number of packages? _____
33 How old were you when you first stared smoking? _____
34 How old were you when you quit smoking for the last time? _____
35 How many times did you quit before? _____
36 How long did these attempts last on average? _____

Appendix D: Physical activity during one week

Can you describe your regular physical activity during one week? Please, describe the duration of activity and the intensity.

	Intensity	**Duration (Time)**	**Activity**
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Appendix E: General questionnaire

SCREENING STUDY

GENERAL DATA

Name: _____ Date of Birth: _____

Age: _____

Email Address:

_____

Address:

_____

Phone Number: Home _____ Cell Phone: _____

Occupation: _____ When are you available for the test: ____

GENERAL HEALTH HISTORY

Height: _____ Weight: _____

What is your:

Blodd pressure? _____

Cardiovascular disease? _____

Diabetes? _____

Medication? _____

Total Cholesterol? _____

LDL Cholesterol? _____

Hormone replacement? _____

Do you participate in regular exercise? _____

Do you smoking? _____

Cigarette per day? _____

years smoking? _____

Appendix F: Godin Leisure-Time Exercise Questionnaire

INSTRUCTIONS

In this excerpt from the Godin Leisure-Time Exercise Questionnaire, the individual is asked to complete a self-explanatory, brief four-item query of usual leisure-time exercise habits.

CALCULATIONS

For the first question, weekly frequencies of strenuous, moderate, and light activities are multiplied by nine, five, and three, respectively. Total weekly leisure activity is calculated in arbitrary units by summing the products of the separate components, as shown in the following formula:

Weekly leisure activity score = (9 × Strenuous) + (5 × Moderate) + (3 × Light)

The second question is used to calculate the frequency of weekly leisure-time activities pursued "long enough to work up a sweat" (see questionnaire).

EXAMPLE

Strenuous = 3 times/wk

Moderate = 6 times/wk

Light = 14 times/wk

Total leisure activity score = (9 × 3) + (5 × 6) + (3 × 14) = 27 + 30 + 42 = 99

GODIN LEISURE-TIME EXERCISE QUESTIONNAIRE

1. During a typical **7-Day period** (a week), how many times on the average do you do the following kinds of exercise for **more than 15 minutes** during your free time (write on each line the appropriate number).

Times Per Week

a) STRENUOUS EXERCISE
(HEART BEATS RAPIDLY) _____
(e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)

MODERATE EXERCISE
(NOT EXHAUSTING) _____
(e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)

b) MILD EXERCISE
(MINIMAL EFFORT) _____
(e.g., yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)

2. During a typical **7-Day period** (a week), in your leisure time, how often do you engage in any regular activity **long enough to work up a sweat** (heart beats rapidly)?

OFTEN	SOMETIMES	NEVER/RARELY
1. |_|	2. |_|	3. |_|

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