THE PHYSIOLOGICAL FITNESS, CARDIOMETABOLIC HEALTH AND QUALITY OF LIFE OUTCOMES OF PARTICIPATION IN RECREATIONAL OFF-ROAD VEHICLE RIDING AS AN ALTERNATIVE MODE OF PHYSICAL ACTIVITY

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ABSTRACT

THE PHYSIOLOGICAL FITNESS, CARDIOMETABOLIC HEALTH AND QUALITY OF LIFE OUTCOMES OF PARTICIPATION IN RECREATIONAL OFF-ROAD VEHICLE RIDING AS AN ALTERNATIVE MODE OF PHYSICAL ACTIVITY

By

Jamie F. Burr
Doctor of Philosophy, Graduate Program in Kinesiology and Health Science, Faculty of Health, York University, 2010

The aim of this research is to provide a comprehensive understanding of the physiological fitness and health-related effects of participation in habitual recreational off-road vehicle riding (all-terrain vehicle (ATV) and off-road motorcycle (ORM)) as an alternative form of physical activity (PA). The research involved: 1) a cross-sectional characterization of the physiological fitness, clinical health and quality of life (QOL) of Canadians who habitually ride recreational off-road vehicles along with comparisons of these characteristics to average Canadians; 2) determination of the acute physical demands of a typical recreational off-road vehicle ride and comparison of these demands to recommended PA guidelines; and 3) a longitudinal training study to establish a cause and effect relationship between participation in recreational off-road vehicle riding and changes in fitness and health. Habitual recreational off-road vehicle riders were observed to have higher aerobic fitness and a lower incidence of the metabolic syndrome than the general population, despite higher body fat. With increasing age, recreational off-road vehicle riders did not manifest the same age-related declines in fitness as average Canadians. Important physiological and physical QOL differences were found

between ATV and ORM riders suggesting that ORM riders are less likely to have physical limitations or ill health. Recreational off-road riders have similar lifestyle behaviors to average Canadians except that a greater proportion consumes alcohol and a lower proportion smokes tobacco. Recreational riders are generally content, have high levels of mental and physical QOL and are not greater risk takers than average Canadians. A typical recreational off-road ride is of moderate intensity and falls within recommended PA guidelines similar to other common recreational activities; however, the metabolic demand of ORM riding is greater than that of ATV riding. In the training study, the demands of recreational off-road riding resulted in improvements in fitness and health. Also, the carbon monoxide levels measured while riding did not approach levels known to cause negative cardiovascular consequences. Recreational off-road vehicle riding is a viable alternative mode of exercise which, if aligned with PA guidelines, could increase the health-related fitness and QOL of Canadians and reduce their risk for morbidity and premature mortality.

For My Family

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

INDEX OF ABBREVIATIONS AND SYMBOLS

Δ	Delta (change)
≈	Approximately (roughly equal to)
ACSM	American College of Sports Medicine
ATV	All-Terrain Vehicle
BMI	Body Mass Index
Bpm	Beats per Minute
BW	Body Weight
CHD	Coronary Heart Disease
CHMS	Canadian Health Measures Survey
CO	Carbon Monoxide
CPAFLA	Canadian Physical Activity Fitness and Lifestyle Assessment
CSEP	Canadian Society of Exercise Physiology
d	day
DBP	Diastolic Blood Pressure
EMG	Electromyographic
GPS	Global Positioning System
Hb	Haemoglobin
HbA1c	Glycosylated Haemoglobin
HDL	High Density Lipoprotein
HR	Heart Rate
HRmax	Maximal Heart Rate
Kcal	Kilocalorie
LDL	Low Density Lipoprotein
M.I.	Myocardial Infarction
MCS	Mental Component Summary (SF-36)
MET	Metabolic equivalent
min	minute
MOS	Medical Outcomes Study
NCEP	National Cholesterol Education Program
OGTT	Oral Glucose Tolerance Test
ORM	Off-Road Motorcycle
PA	Physical activity
PAR-Q	Physical Activity Readiness Questionnaire
PCS	Physical Component Summary (SF-36)
ppm	parts per million
QOL	Quality of Life

RPE	Rating of Perceived exertion
RPEavg	Rating of perceived exertion for entire ride
RPEmax	Rating of perceived exertion at most difficult point
RT	Resistance Training
SBP	Systolic Blood Pressure
SO5S	Sum of 5 Skinfolds
TC	Total Cholesterol
TG	Triglyceride
VLDL	Very Low Density Lipoprotein
VO_2max	Maximal Oxygen Consumption
VO_2R	VO_2 Reserve
W	Watts
WC	Waist Circumference
wk	week

CHAPTER 1
INTRODUCTION

1.1 Background

Physical activity (PA) is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (48) and as such, is an unavoidable, although modifiable, component of human life. In contrast to exercise, which is “planned, structured and repetitive bodily movement undertaken to improve or maintain one or more components of physical fitness” (48), PA encompasses any and all movement of daily living including exercise, occupational work, functional activities of daily living and recreational leisure time pursuits. Physical *activity*, and physical *fitness* are closely related in that a large part of physical fitness can be explained by our PA patterns (28). Though part of human physical fitness is certainly determined before birth as a result of genetic heritability (32, 33), PA and nutrition are largely responsible as the modifiable environmental factors (80) that influence the final expression of this phenotype. Despite the broad opportunities for energy expenditure and movement in daily living, many Canadians do not accumulate the recommended amounts of PA; consequently, Canadians are not improving physical fitness, and inactivity related morbidity and mortality is on the rise.

Reports of PA participation indicate that more than half of North Americans are not meeting the recommended PA guidelines and thus are not sufficiently active to gain the health benefits of an active lifestyle (50, 125). Similar patterns have been reported throughout the U.K. with activity being even lower for females than males (7). It is generally accepted that the recent increase in overweight and obesity can be largely attributed to this decrease in daily PA coupled with an increase in calorically dense food. As a result of this shift in energy balance, it has been suggested that obesity now challenges undernourishment as the greatest nutrition related health threat (65). An estimated 68% of American adults are overweight with 33.8% classified as obese (75). Canadian estimates are similar, reporting that approximately 59% of Canadian adults are overweight (140) and 20-30% classify as obese (140, 212).

A negative relationship exists between PA and overweight/obesity (49, 193) and there is considerable evidence that inactivity and low cardiorespiratory fitness are related to a host of co-morbidities and chronic disease states. These include type 2 diabetes mellitus (144), insulin resistance (109, 173), metabolic syndrome (122, 259), hypertension (71, 92), cardiovascular disease (130, 256), dyslipidemia (114, 130, 204), coronary heart disease (111, 131) and colon cancer (234). Sufficient levels of PA can help prevent and treat mood disorders such as depression and anxiety (14, 78) increase perceived QOL (14, 36, 128), prolong independent living (128, 261) and maintain better cognitive functioning (154), especially in the aged. On a broader scope, cardiovascular fitness has been shown to generally decrease all-cause mortality and premature death (122, 143). Disturbingly, recently released data from the Canadian Health Measures Survey (CHMS) reveals that only approximately one quarter of young Canadians (20-39) and 10% of males and 5% of females aged 60-69 were classified as having very good or excellent aerobic fitness (212). Further, the CMHS data reveals that fitness and health measurements have been declining since the last representative Canadian population sample was collected, the Canada Fitness Survey, which was conducted in 1981.

1.2 Physical Activity Recommendations for Health

Past recommendations for PA participation encouraged exercise of vigorous intensity (e.g. jogging or running) for at least 20 minutes continuously, three times a week (8). When these recommendations were originally made by the American College of Sports Medicine (ACSM) it was believed that the quantity and quality of exercise necessary to attain health benefits was equivalent to that needed to improve fitness. It has since been recognized that health benefits can accrue irrespective of changes in fitness, and the recommendations for PA have been adjusted to reflect this new understanding (2, 47, 96). The ACSM has clarified that aerobic endurance training <2 days per week, at <40-50% of VO_2 reserve and for <10 minutes generally does not provide sufficient stimulus for maintaining fitness in healthy adults, but health benefits may be obtained if the frequency and duration are increased appropriately (2, 96). Even without changes in overall aerobic fitness, improvements can be made in both the metabolic profile and (96) the risk of developing many degenerative diseases (227). The reductions in risk associated with many disease states are generally stronger when accompanied by reductions in fat stores (193, 227), especially those in the visceral area (59).

Due to the difficulty of separating PA from fitness (since fitness is the result of the interplay between genetics and physical activity), it is challenging to analyze the effects of PA on health independent of fitness. Epidemiological studies, using the volume of PA (kcal) as an exposure variable reveal a clear inverse linear dose-response relationship between PA and mortality (10, 28, 143) with concurrent reduced risk of CHD (111), CVD (112), stroke (253) and colon cancer (1). However, these studies do not conclusively determine that PA (not fitness) is responsible for the observed changes due to their inability to differentiate between intensities, durations and frequencies which may or may not be expected to lead to changes in fitness.

There is evidence that expenditure of approximately 1000 $kcal \cdot wk^{-1}$, is associated with a 20-30% reduction in risk of all-cause mortality (143). This is in line with minimal adherence to current Canadian recommendations for exercise (243, 245) and is in agreement with Canadian experts that the range of intensity required for health falls between light to vigorous (99, 243, 244) effort (Appendix A). Warburton et al. have shown not only that musculoskeletal fitness is related to health outcomes but that changes in musculoskeletal fitness do indeed have effects on health (240). Increases in musculoskeletal fitness may also be beneficial in attenuating weight gain, preventing obesity and increasing insulin sensitivity as well as reducing a host of other risk factors for chronic diseases (240, 241, 245).

1.3 Leisure Time Physical Activity

Many Canadians no longer work at physically demanding jobs and the task of accumulating PA must therefore be met during leisure time. As PA competes against screen time (television, video games, the internet) and many other sedentary pastimes, PA accumulated during leisure time is of increasing importance.

Apart from the personal benefits of increased health and wellness that should motivate Canadians to become more active, there is a strong monetary incentive to increasing the PA levels of the population as a whole. Research from around the world demonstrates that diseases related to physical inactivity constitute a significant portion of total medical expenditures. In a U.S. study of a national health care plan, it was reported that physical inactivity, overweight and obesity were associated with 27% of the total costs (11). The burden of inactivity in the U.K. in 2002 was estimated to be approximately £1.06 billion which translates to approximately $2.3 billion Canadian (7). Canadian estimates for the total direct health care costs of inactivity in 1999 were conservatively calculated at $2.1 billion (124), and were re-estimated to $5.3 billion for 2001 by including both direct health care costs and indirect costs from lost economic output due to injury, illness and premature death (125). Clearly, there is a need for a preventive intervention to lessen the burden on the already strained health care system.

Canada's Physical Activity Guide to Healthy Active Living (99), which illustrates the importance of PA and makes recommendations on the frequency, intensity, duration and type of exercise, was published in 1998 and is easily accessible to all Canadians in hardcopy or on the world wide web. However, research from the University of Alberta in 2002 reports that of the nearly 3000 Albertan respondents questioned, only 20.7% were aware of the Guide and a mere 5.5% had actually followed the recommendations it contained (220). Similarly, a nationwide phone survey examining Canadian knowledge of the PA guidelines revealed that only 4% of Canadians could recall any guidelines for PA and this only increased to 37% when prompted (44). Based on the above evidence, it appears that the message about PA is not reaching, nor affecting the behaviors of, a large part of the population. In addition to better dissemination of the available information, new strategies for encouraging the public to become more active are necessary. Research by Morrow et al (2004) examining the American public's knowledge of exercise recommendations revealed that respondents were generally aware of traditional PA that provide a health benefit (ex. jogging) but were poorly informed as to the PA guidelines and activities of daily living that could result in a health benefit (163). Given that the public is aware of traditional modes of exercise that are related to positive health outcomes but choose not to participate, it is possible that traditional activities simply do not appeal to a large portion of the population.

1.4 Off-Road Vehicle Riding

Data from the Canadian Off-Highway Vehicle Distributors Council show that in 2007 over 170 000 motorcycles and off-highway vehicles were sold in Canada with All-Terrain Vehicles (ATV) and motorcycles representing approximately 50% of the market each. With an estimated retail value of approximately $2 245 000 000.00 (46), this indicates that the Canadian population is willing to invest their disposable income in this activity and thus documents an appeal of off-road riding. Actual participation rates in recreational off-road riding in Canada are unclear, as all motorized vehicle sports were intentionally excluded from sport data collection in the 1998 Sport Canada survey (57). Exclusion of these data seems to fittingly illustrate the existence of two distinct attitudes toward off-road motor sports. There is one group who view motor sports as inherently inactive, based on the assumption that motor vehicles are self propelled and will thus do most of the physical work and on the other hand there are those who believe all off-road riding to be an "extreme" sport and seemingly equate riding with the high flying acrobatics commonly seen on television. Further, the majority of current off-road riders hold the belief that recreational riding is extremely physically demanding (participants commonly cited that off-road riding was "second in physical demand only to soccer") and that fitness and health benefits from casual participation are assured. In reality, the true demands of the sport likely fall somewhere between elite level aerobic sports and sedentary activity and the fitness and health outcomes will depend on the interaction of exercise frequency, intensity and duration.

In the fall of 2006 our laboratory conducted a pilot study examining the metabolic demand of riding off-road motorcycles. These preliminary data suggested that participants were working at approximately 60% of their VO_2max while riding based on a comparison to a maximal treadmill test performed in the laboratory. This pilot work was promising as it suggested off-road riding may be a motivating, contemporary activity with potential beneficial effects on health and therefore warranted further research. In an investigation of the importance of activity appeal on health benefits of an exercise program, Warburton et al (2007) reported that interactive video gaming resulted in greater improvements in health related physical fitness than traditional exercise alone. The video game system, which was attached to a cycle ergometer and used games that involved motor vehicle racing and simulated off-road riding, resulted in greater program adherence and thus a higher volume of exercise with more favorable health outcomes

(235). This supports the theory that off-road riding is appealing, at least in a virtual world, and raises the possibility that real off-road riding might be an activity with potential to help decrease sedentary behavior in Canada.

The aim of this dissertation is to provide a comprehensive understanding of the physiological fitness and health-related effects of participation in habitual recreational off-road riding as a form of alternative PA. The objectives of this research are i) to characterize the physiological fitness, clinical health and QOL of Canadians who habitually ride off-road vehicles and to make comparisons of these characteristics with Canadian norms, ii) to identify the acute physical demands of a typical off-road vehicle ride with reference to recommended PA guidelines and iii) to establish cause and effect relationships between participation in off-road vehicle riding and changes in fitness and health measurements using previously non-habituated participants.

For the purposes of this dissertation, health is operationally defined as the absence of disease and disability, or risk factors for disease and disability, primarily from a physiological/fitness point of view. It is important to note that off-road riding is a sport with considerable inherent risk and there is a large body of research examining injuries from participation in off-road sports, especially in children. The current investigation deals only with adult riders and considers health and health risk factors from an inactivity-related chronic disease standpoint. Recognizing that overall health has physical, social and psychological implications which cannot be captured simply by the absence of disease or disability (47), this dissertation has focused on aerobic fitness;

muscular strength, endurance and power; cardiovascular risk factors; risk of metabolic disease; perceived lifestyle and QOL. Furthermore, we have considered the interactions between these factors considering age, gender and vehicle type (ATV vs. ORM) differences.

Chapter 2 provides a review of the literature pertaining to both off-road riding and the measurements of physical fitness and health considered in each phase of this dissertation.

Chapter 3 describes the rationale, objectives and hypotheses of the present work

Chapter 4 provides information on participant recruitment and screening further details about select measurements common to the four manuscripts

Chapter 5 includes all manuscripts which cover the following topics:

Manuscript I: Characterizes the physical fitness, clinical health and health risks of habitual recreational off-road vehicle riders, while making comparison to population norms, and between sexes, vehicle types and ages.

Manuscript II: Characterizes the lifestyle behaviors and QOL of habitual off-road vehicle riders, while making comparison to population norms and between sexes, vehicle types and ages.

Manuscript III: Distinguishes what a typical off-road ride entails and analyzes the physical demands of participation in off-road riding. Comparisons are drawn between the physical demands of riding an off-road vehicle and the demands of participation in more traditional recreational activities/sports

Manuscript IV: A longitudinal training study examining the cause and effect relationship of off-road riding participation with measurements of fitness and health. Carbon Monoxide exposure was also considered as an overall health risk of participation.

Chapter 6 summarizes pertinent findings, gives direction for future research and expands on the implications of this research for prescribing off-road riding as a form of alternative PA.

CHAPTER 2
REVIEW OF LITERATURE:
PHYSIOLOGY OF OFF-ROAD RIDING, ALTERNATIVE PHYSICAL ACTIVITY, MEASUREMENTS OF PHYSICAL DEMAND AND PHYSICAL FITNESS, CLINICAL HEALTH MEASURES / CARDIOVASCULAR RISK FACTORS

2.1 The Physiology of Off-Road Riding

Literature specific to off-road riding is sparse and of the few relevant articles that exist (18, 83, 135, 136), the majority relate specifically to the physiology of "motocross." Motocross is a distinct form of competitive off-road racing that involves navigation of a fabricated dirt track consisting of jumps, uneven terrain and winding turns. As a result of navigating the course in the shortest time possible, elite motocross riders have been shown to be placed under considerable physical and physiological demands, both aerobically and anaerobically (135) with significant plasma oxidative stress (18). In a study examining the physiological characteristics of high level off-road motorcyclists competing in three different types of competition (motocross, enduro and desert rally riding), Gobbi et al (2005) concluded that motocross riders have more muscle mass, higher grip strength, and greater anaerobic power than both enduro and desert rally riders (83). These results are important to the present investigation given that enduro and rally riding are much more representative of typical recreational riding when compared to motocross. The research team also found that desert rally riders tended to be overweight with maximum aerobic powers similar to those of normal, healthy individuals (83, 92). This study further indicates that motocross-style riding is physically demanding, but may not represent a typical riding situation. Although these studies examining elite riders indicate a possible training effect from participation in off-road racing, elite level motocross surely does not reflect the riding style of the majority of the population, and does not allow inferences to be made considering the demands of riding four wheeled off-road vehicles. In the commonly referenced compendium of PA (4), motocross is listed as having a physical demand of 4 METS (metabolic equivalents); however, no explanation of riding style is offered (whether this be racing or recreational off-road riding) and to date there is relatively little research confirming or denying this supposition.

2.2 Alternative Physical Activity

As a result of poor adherence to traditional forms of physical activity and structured exercise as recommended by Canadian and U.S. PA guidelines, increasing amounts of government and research attention is being directed to find novel approaches to encourage PA in the general population. Along with the promotion of PA recommendations through media campaigns, community and environmental/ecological based interventions have been implemented in an attempt to encourage non-exercise related physical activity. This approach works to encourage PA by guiding daily lifestyle choices through changes in the physical/social environment such as making stairways more convenient than elevators, blocking automobile access to certain areas of a city (downtown) and improving bike/walking lanes or granting tax returns for health-related behaviors (198). Another approach to increasing PA participation is to promote PA which is more appealing than more traditional and well known options. In recent years, a great deal of research has focused on non-sporting activities which are not native to North America such as yoga (258), combative martial arts (231), pilates (133), tai chi (223) and certain forms of dance (176). The use of culturally appealing interactive video game PAs have also become an area of much interest using simulated virtual activities such as dancing (164), cycling (246), off-road vehicle riding (236) and computer-guided fitness activities (171) (Wii Fit, Nintendo) among others. Although the general consensus appears to be that the physical demands of these simulated virtual sports are inferior to actual participation, caloric expenditures are increased above resting and moderate intensity physical demands can be imposed. Importantly, however, it has been shown that exercise adherence is increased by offering activities which are appealing to participants (236) and it is known that regular participation in moderate intensity PA can lead to important alterations in fitness and health as recommended in current PA guidelines.

2.3 Measurements of Physical Demand and Physical Fitness

2.3.1 Aerobic Power

Maximal aerobic power (VO_2max) has long been accepted as the standard for quantifying the highest peak oxygen uptake that an individual can obtain while performing exercise using large muscle groups at sea level (66). Maximal aerobic power is limited by underlying cardiovascular factors such as stroke volume, heart rate, cardiac output, hemoglobin concentration [Hb], blood volume in the cardiovascular system and oxygen extraction at the tissue level. Although debate exists as to the primary limiting factor of VO_2max (172, 237, 238), whether it be a supply, demand or "central governor" issue, there is evidence that these contributing factors are modifiable with exercise training, albeit to varying degrees.

In the 1960s, endurance training was shown to elicit an increase in stroke volume (67), oxygen uptake and cardiac output (12) with a slight decrease, or no change, in maximal heart rate (67, 199, 200). Analysis of the differences between untrained, trained and elite athletes further showed that the ability to use the oxygen in the blood ($avDO_2$) increased with training (29); however, compared to the changes in hemodynamic and cardiovascular function ([Hb], blood volume, stroke volume, cardiac output) this change was relatively small.

More recent investigations have shown that the training-related changes in VO_2max are strongly driven by the ability of the cardiovascular system to transport oxygen. Artificial alterations in hemoglobin and blood volume (which in turn affect stroke volume and cardiac output) have been shown to have beneficial effects on VO_2max (82) in untrained humans who have not already realized the benefits of an increased blood volume as a result of training (239). Furthermore, untrained subjects with naturally high aerobic power have been shown to have a genetically endowed high blood volume (155) showing the importance of this factor. Trained endurance athletes have been shown to have advantageous cardiac function, such that stroke volume does not plateau with increasing exercise intensity in the same manner as in untrained individuals (81). Although the heart has been shown to improve ejection fraction as a result of increased contractility from aerobic exercise (85, 226, 242), much of the training effect on increased SV has been attributed to an increase in diastolic filling and thus a greater reliance on the Frank-Starling mechanism (81, 84).

Training-related increases in VO_2max are generally expected to be around 15-25%, but a wide range has been reported from no change to almost 100%, with the majority of studies reporting ranges between 0-50% (34, 134, 185, 217, 218). Training-related change in VO_2max has been extensively studied and improvement in aerobic power has been shown regardless of initial fitness, age or sex (134, 217). In an examination of black and white members of the HERTIAGE study population, Skinner et al. have further shown no significant differences in trainability according to race (217). However, there is a large genetic influence on both initial values and trainability leading to a considerable heterogeneity of individual responses (34, 155).

For the purposes of this dissertation, aerobic power measurements were considered as an overall marker of cardiovascular fitness, given the modulating effects of the aforementioned underlying changes in cardiovascular function and O_2 delivery with training. As is explained in further detail in the included manuscripts, aerobic power can be monitored using traditional laboratory methods (open circuit spirometry with analysis of expired gas) or an ambulatory monitoring system using a metabolic computer and we have employed both of these techniques, as well as heart rate monitoring, for specific purposes. Portable metabolic systems, which allow oxygen consumption measurements to be made in the field, have been shown to be a feasible alternative to direct testing in the laboratory for quantifying energy expenditure (20). Heart rate monitoring is accepted as an accurate method for estimating energy expenditure of primarily steady-state aerobic work, and accuracy of this technique has been shown to increase when the linear relation between HR and VO_2 is determined for participants on an individual basis (222). Care must be taken, however, when HR may be influenced by excitatory factors unrelated to the physical demand or when the physical activity contains a high resistive exercise component.

2.3.2 Anaerobic Power and Blood Lactate

The lactate threshold is the point at which increasing exercise intensity leads to an exponential rise in blood lactate (153) and is readily altered with exercise training or detraining (27, 189). Changes in lactate threshold generally occur within the first 8-10 weeks of training and training adaptations are similar across age, gender, frequency duration and intensity of training once above a minimum threshold (150). The minimum sufficient intensity to stimulate a training effect in untrained participants is at, or just below, the lactate threshold and generally corresponds to roughly 45-55% of VO_2max (27, 150).

Because direct measurement of blood lactate in not always feasible due to the necessity of catheterization, ventilatory threshold (a.k.a. respiratory compensation threshold) is a commonly used alternative as an indicator of the accumulation of blood lactate (63). Exercise training at intensities above the ventilatory threshold result in rapid accumulation of blood lactate (38, 58), 22) and improvements in ventilatory threshold are accompanied by changes in the lactate threshold (88, 150, 184).

2.3.3 Perceived Exertion

In the late 1960s and early 1970s scientists realized the importance of a subject's perception of their own exertion while working or exercising in relation to performance, adherence, injury etc. A psychophysical measurement tool called the rating of perceived exertion (RPE) scale, was developed by G.A. Borg in the early 1980s with the recognition that "the overall perceived exertion rating integrates various information, including the many signals elicited from the peripheral working muscles and joints, and from the central nervous system" (30). The most commonly used version of this scale, which is recommended for use with exercise testing and prescription by the scale developers (30), consists of a numeric rating from 6-20 anchored at each end by the descriptors "very, very light" to "very, very hard" with ranges in between. Although Borg himself recognizes that the 6-20 rating does not perfectly correlate with heart rate because the exertion score accounts for other physiological changes, multiplying the scale rating by a factor of ten is useful in approximating the corresponding heart rate while exercising. However, this approximation deteriorates near maximal exertion in older participants due to a systematic decrease in maximal heart rate.

In an examination of the applicability of using RPE across genders while exercising at the respiratory compensation threshold (or ventilatory threshold) Green et al. have shown no significant difference in RPE between males and females (89).

However, recent findings by the same group have shown that despite similar physiological indices of stress (ventilatory threshold, rectal temperature, heart rate), the RPE of unfit individuals began to increase more so than the ratings of fit individuals during prolonged cycling starting at about 30 minutes and continuing until test completion at 60 minutes (90). Interestingly, when allowed to self-select a training intensity, both fit and unfit individuals tend to choose an intensity of approximately 60% of VO_2max, or 11-14 RPE (61) and self-adjust their overall power output accordingly to maintain this level. When prescribing exercise intensities for the purposes of training using a combination of both RPE and HR zones helps subjects more accurately train at the correct intensity than using either technique alone (60).

2.3.4 Muscular Strength, Endurance and Power

Increases in musculoskeletal fitness have important implications for health even in the absence of improvements in aerobic fitness (2, 244). Maintenance of muscular endurance and muscular power have implications for disease and disability, especially in aging populations (177, 243). The specific level of strength required to avoid disability is often dependent on other impairments, such that those with greater impairment (i.e. poor balance) commonly require greater strength for accident avoidance (187). In general, muscle strength is negatively associated with insulin resistance (174), the metabolic syndrome (120, 121, 252) and 2 hr glucose levels during oral glucose tolerance testing (202). Grip strength has been shown by numerous groups to be inversely correlated to premature mortality (123, 201) or morbidity including chronic diseases such as diabetes, stroke, arthritis, CHD, and pulmonary disorders (188). After controlling for the potential confounding effects of cardiorespiratory fitness, body composition and lifestyle factors, low musculoskeletal fitness has been shown to be predictive of substantial (>10kg) weight gain in a 20yr longitudinal follow-up study (156). In two highly cited reviews, Warburton et al. have reported that positive associations exist between musculoskeletal fitness and glucose homeostasis, bone health, functional independence, mobility, psychological well-being and overall QOL (240, 241).

2.4 Clinical Health Measurements / Cardiovascular Risk Factors

2.4.1 Blood Pressure

Meta-analyses of the reductions in blood pressure as a result of training have shown exercise to be effective in lowering blood pressure in both hypertensive and normotensive individuals (17, 92). Most training studies have used exercise protocols of aerobic exercise around 60-70% of VO_2max, 3x/wk and reported reductions in arterial blood pressure have ranged from 3-7mmHg for both systolic blood pressure (SBP) and diastolic blood pressure (DBP) (17, 72, 92). The acute effects of exercise on blood pressure are complex and depend on both the time frame considered (acute vs. chronic training) as well as the modality and intensity of the exercise.

2.4.1.1 During Exercise

Tremendous increases occur in arterial blood pressure during dynamic heavy resistance training (RT) exercise, with mean values reported at 320/250mmHg and peaks as high as 480/350mmHg (152). The increases in blood pressure during heavy RT result from the combined effects of the Valsalva maneuver, mechanical compression of blood vessels and a potent pressor effect, all of which are dependent on the degree of effort (central command) as opposed to the actual force produced (151). There is no apparent relation between peak blood pressure and muscle size when examining the effect of heavy RT using the leg press (151). The peak heart rate response to maximal dynamic resistance exercise is generally lower than that associated with maximal aerobic exercise, thus leading to a lower rate pressure product (183). An exaggerated blood pressure response to exercise occurs when performing ischemic resistance exercise, even while using small muscle groups such as those of the forearm. These ischemic conditions can occur in both clinically simulated occlusions and natural exercising conditions such as sports involving intermittent isometric contractions like rock climbing or off-road cycling. These reflex driven blood pressure responses are substantial and range 5-85 mmHg with greater effects in SBP compared to diastolic blood pressure DBP (6) . The rise in blood pressure during ischemic isometric hand grip exercise is attributable to a change in cardiac output, owing largely to a change in stroke volume from mobilization of central blood volume (214). A concurrent rise in heart rate and vasoconstriction of vessels in non-exercising muscles may augment cardiac output to a lesser degree (175, 211). Heart rate and blood pressure responses to isometric exercise are primarily proportionate to the percentage of maximal voluntary tension, rather than absolute tension of the muscle group (147).

During dynamic aerobic activity, mean arterial blood pressure increases approximately 40% due to a progressive increase in SBP with increasing workloads to maximum (141). This change occurs from an increase in sympathetic activity and a resulting increased peripheral resistance, heart rate, stroke volume and cardiac output. Increases in heart rate during aerobic activity are linearly related to exercise intensity, whereas stroke volume increases in a curvilinear fashion (183). Contrary to the progressive rise seen in SBP, DBP in healthy individuals remains virtually unchanged (257).

2.4.1.2 Post-Exercise

Following both resistance and aerobic exercise, blood pressure drops below resting levels in a state known as post-exercise hypotension. Immediately upon cessation of exercise, the drop in cardiac output without an increase in systemic peripheral resistance allows for pooling of blood in the extremities (228); however the contribution and responsiveness of each of these cardiovascular mechanisms changes with increasing age such that older exercisers maintain stroke volume (and cardiac output) but decrease total peripheral resistance to a greater degree than younger persons at the cessation of exercise (165). If of a great enough magnitude, the result of this acute hypotension may lead to syncope in both the young and old, despite the differing mechanistic factors (165).

The transient state of post-exercise hypotension, which has been shown to be elicited by workloads as low as 40% of max, is the result of decreased sympathetic and increased parasympathetic tone (among other factors including those related to endothelial function) and may last for up to 16 hrs post exercise (190, 228). High intensity RT has been shown to result in a drop of only SBP, whereas low intensity RT results in a drop in DBP as well (190). Due to the transient nature of this effect, PA for reducing resting blood pressure is often prescribed with a lower intensity and high frequency so that the short-lasting BP reduction is repeatedly triggered.

2.4.1.3 Habitual Exercise.

Aerobic exercise training is reported to reduce resting blood pressure, with greater lowering effects reported for those who are hypertensive, or pre-hypertensive versus normotensive (17, 70, 72). These changes in blood pressure with moderate intensity aerobic exercise training occur independent of weight loss and range from reductions of 3mmHg to 7mmHg for both systolic and diastolic pressure (17, 54, 70). Increases in intensity beyond moderate levels and in duration beyond approximately three times per week have not been shown to further improve blood pressure responses (92, 118).

The effect of habitual RT on resting blood pressure is similar to that of aerobic exercise training, although the decrease in both SBP and DBP is less, at around 3-3.5mmHg (70, 129). A large-scale cross-sectional study by Buck et al. (1985) shows that those in occupations with regular exposure to moderate or heavy isometric exercise tend to have a lower incidence of hypertension, independent of other confounders (40). Experimental studies using hand grip exercise support the effectiveness of isometric exercise to reduce blood pressure especially in hypertensive and pre-hypertensive subjects (161, 224).

2.4.2 Lipoproteins

An unfavorable blood lipid profile is an independent risk factor for coronary heart disease owing to the role blood lipids play in the pathogenesis of atherosclerosis. Accordingly, the 2006 Canadian clinical practice guidelines on the management and prevention of obesity in adults and children (140) gives a grade A recommendation for analysis of total cholesterol, low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), triglycerides (TG), and the ratio of total cholesterol to HDL.

High levels of LDL and very low density lipoprotein (VLDL) are associated with negative health outcomes such as the metabolic syndrome and coronary heart disease (94, 132). Training studies show exercise to have a modest, but clinically significant, effect on decreasing plasma levels of LDL, VLDL and TG (95, 114, 145, 146).

HDL is involved in the reverse transport of cholesterol for catabolism and is generally viewed as "good" or healthy. Higher levels of HDL are associated with beneficial health outcomes such as a reduced risk of atherosclerotic lesions and CHD. It is estimated that for every 1 $mg{\cdot}dL^{-1}$ (0.026 $mmol{\cdot}L^{-1}$) increase in HDL the risk for CHD is reduced 2% in men and 3% in women (168). HDL increases with exercise training have generally been shown to be of a larger magnitude than those demonstrated in LDL (114, 145, 255) and the expected changes have been reported to be dependent on baseline values with an apparent influence of obesity towards blunting the response (168, 255).

Blood lipids can be modified through PA and exercise. During moderate intensity aerobic exercise, fatty acids are the primary source of energy, thus explaining the acute drop in triglyceride (TG) that occurs with exercise (95, 114). With chronic aerobic exercise, changes in cholesterol also occur. Current research reports a favorable effect of aerobic exercise on blood cholesterol with increases in HDL (130, 146) and a less commonly reported decrease in LDL and VLDL (126, 145). Even in the absence of changes in LDL (which may or may not occur with exercise) changes in HDL and TG of 6% and 31% respectively, have been shown to decrease non-fatal M.I. and CHD by 22% (195). Although these changes are influenced by changes in body fatness, changes in blood lipids have also been observed in the absence of alterations in body composition (126, 145, 229).

Dose-response studies of the effects of exercise training on changes in the blood lipid profile reveal that normolipidemic subjects undergo a relatively modest change whereas hyperlipidemic subjects show greater improvements (146, 255). Meta analysis reveals the expected changes in LDL, HDL, TG and total cholesterol to be approximately 3-5% with no significant differences in training response as a result of sex, age, or race (black or white)(146). Despite some debate on the issue, the current literature on RT does not support this mode of exercise as an overly effective stimulus for altering blood lipid profiles (68, 91, 113).

2.4.3 Blood Glucose/Insulin

Elevated levels of blood glucose, or hyperglycemia, are associated with diabetes, insulin resistance, metabolic syndrome and a host of other metabolic disorders as well as cardiovascular disease. Even before fasting glucose levels reach the clinical cut-offs for diabetes, pre-diabetic levels can have serious health consequences; however, these levels can often be reduced back to normal with simple lifestyle modifications such as dietary changes and exercise (260). Blood glucose is typically measured by one of two methods: *i)* fasting blood glucose, or *ii*) 2-hour oral glucose tolerance (2-hr OGTT) test (9). There are arguments in favor of using both tests. The expert committee on the diagnosis and classification of diabetes mellitus (2003) recognized that the 2-hr OGTT is a more sensitive test based on the current cut points for diabetes in most populations; however the fasting glucose measure is more convenient, more reproducible and less costly (79). Current guidelines suggest the lower cut point for defining impaired fasting glucose should be 100mg/dL (5.6 mmol/L), thus individuals who are considered to be "normal" would fall below this value (9). The most recent recommendations made by the international expert committee (American Diabetes Association, European Association for the Study of Diabetes and the International Diabetes Federation) recommend that glycosylated hemoglobin (HbA1c), which has the added value of estimating average blood glucose over 2-3months, is now deemed an acceptable diagnostic tool, which it had not been in the past due to variability in assay precision (117). The committee has established a cut point of ≥ 6.5% for the diagnosis of diabetes and 6-6.5% for pre-diabetes based on the incidence of retinopathies in patients with HbA1c values above this level (117).

Epidemiological studies have shown that higher levels of PA and physical fitness are consistently related to lower incidence of type 2 diabetes, metabolic syndrome (122, 137), cardiovascular disease, insulin resistance (80) and glucose intolerance (31). These effects have been shown to be independent of the level of abdominal obesity, which is another predisposing factor for Type 2 Diabetes and impaired glucose tolerance (31). In earlier studies using the technique of euglycemic clamping, Mikines et al. have shown that insulin sensitivity, and hence glucose uptake, is increased in trained versus untrained individuals, as well as in untrained individuals versus controls after an acute bout of exercise (160). Many studies have since replicated these results showing both the chronic and acute effect of a single bout of exercise training on insulin sensitivity and glucose regulation (103, 105, 194).

Despite the fact that insulin sensitivity quickly changes, even in the absence of a loss of weight or a reduction in visceral fat, Ross et al. point out that the positive effects of exercise on insulin sensitivity quickly attenuates without regular exercise adherence (193). Dose-response studies have shown that exercise training of longer weekly durations had larger effects on insulin sensitivity than those of shorter duration and that intensity and volume were of no significant consequence (109). Further, a combination of aerobic and RT has been shown to have greater effects on glycosylated hemoglobin (HbA1c) than either modality alone (23). Data from the HERITAGE study reported a mean 10% improvement in insulin sensitivity following a 20wk endurance training program using healthy, previously sedentary participants (35).

2.4.4 Quality of Life

The SF-36 questionnaire is one of the most widely used psychometric assessment tools and has been extensively tested for validity and reliability of results (158, 159, 249). The SF-36 has been shown to have good criterion validity and a high internal consistency for population samples in independent research studies with the Chronbach's alpha statistic for all scales being above the recommended value of 0.7(119). Importantly, all specific measures in the 8 sub-scales of health of the SF-36 are closely associated with participant's own perception of general health with clear linear trends for decreasing SF-36 scores with worsening health (119, 196). The value of the scores obtained in the 8 categories of health (which range from mental and emotional to physical) lies in their ability to characterize subjects in relation to population normative data (107) and allows for pre and post intervention comparisons of health and QOL.

The SF-36 was selected for use in the current project based on an evaluation of 21 validated questionnaires, previously performed and published in an analysis from our laboratory (177) for an investigation of the health of Canadians. This evaluation of existing questionnaires considered the following seven criteria based on the recommended evaluation technique suggested by McDowell and Newell (157):

population description, indicator of levels of health, conceptual scope of the questionnaire, feasibility of method, method and clarity of questionnaire scoring, degree of change in health status, and strength of reliability and validity. It was determined that the SF-36 was most appropriate for use in this Canadian population health investigation based on discrepancies between the intended applications of the existing health measures and the framework of the study (177) . The SF- 36 was selected for the current investigation for these same reasons and to ensure consistency of measures for comparison between the current sub-population and Canadian Norms.

The 8 main SF-36 scales can further be transformed into two summary scales, the physical component scale (PCS) and mental component scale (MCS) which allow a greater power to detect changes and reflect physical function, mental well-being and QOL. The summary scores from each scale can be compared to comprehensive SF-36 normative data (107) from the medical outcomes study (MOS) for interpretation of scores as they relate to expected health outcomes determined from longitudinal study (248). Very low scores on the PCS scale are associated with substantial limitations in self care, problems with physical and social activities, bodily pain, fatigue and poor health. Very low scores on the MCS are associated with frequent psychological distress, emotional problems which interfere with social life and daily activity, and generally poor health (248).

CHAPTER 3
RATIONALE, OBJECTIVES AND HYPOTHESES

3.1 Rationale

The majority of Canadians are currently insufficiently active to accrue the aerobic or musculoskeletal fitness benefits of an active lifestyle and inactivity related disease is on the rise. Given the apparent disinterest in traditional PA and structured exercise of segments of the population, alternative modes of PA must be explored in an effort to appeal to the interests of these Canadians to increase PA participation. The ultimate goal of enhanced PA participation using both traditional and alternative modes of PA is to improve population health and help avoid inactivity-related disease which is diminishing the health-related fitness and QOL of the nation and burdening the health care system. Off-road riding has been suggested as a popular alternative mode of PA, which may appeal to rural- and urban-dwelling Canadians. At present, little is known about the fitness and health of those who currently participate in this recreational activity or the possible fitness and health outcomes of structured habitual participation.

3.2 General Objectives and Hypotheses

3.2.1 Objectives

The aim of this dissertation is to systematically assess the components of recreational off-road vehicle riding to determine the fitness and health outcomes of participation considering physiological fitness, QOL, and cardiovascular and metabolic health from an inactivity-related chronic disease perspective. Within this general aim, the objectives of the current research were threefold:

1) to characterize the physiological fitness, clinical health and QOL of Canadians who habitually ride off-road vehicles and to make comparisons of these characteristics with normative population data.

2) to identify the acute physical demands of a typical off-road vehicle ride with reference to recommended PA guidelines

3) to establish cause and effect relationships between participation in off-road vehicle riding and changes in fitness and health measurements using previously non-habituated participants.

3.2.2 Hypotheses

Based on the above general objectives, the main research hypotheses were:

1) Characterization and subsequent comparison of the aerobic fitness and musculoskeletal strength of habitual riders with population normative data would reveal no differences in aerobic or musculoskeletal fitness due to an insufficient frequency and duration of activity. Comparison of the health measures and QOL of riders with population normative data would reveal riders to have healthier blood lipid profiles, blood pressure, fasting blood glucose, body composition and QOL compared to non-riders.

2) The physical exertion measured while operating off-road vehicles will be of a sufficient intensity to be classified within the range associated with changes in aerobic and anaerobic fitness; however, the current frequency and duration of typical rides will be insufficient to reasonably expect such changes in fitness to occur.

3) The stimulus of off-road riding as a mode of PA will be insufficient to bring about significant fitness changes in non-habituated riders if performed according to typical participation patterns, but changes in fitness will be realized if performed according to recommended PA guidelines. Changes in markers of cardiovascular risks, metabolic health and QOL will occur irrespective of changes in fitness, but to a greater extent in those who participate more regularly and in line with national PA guidelines.

3.3. MANUSCRIPT I - Objectives and Hypotheses

3.3.1 Objectives

The objectives of the first investigation were threefold:

1) To characterize the fitness and health of habitual recreational off-road vehicle riders

2) To explore differences among recreational off-road riders with reference to vehicle type, age, and gender; and

3) To compare the fitness and health of recreational off-road riders to population norms and clinical health standards.

3.3.2 Hypotheses

This study was explorative in nature, with limited existing data on which to base strong hypotheses. Thus, concrete hypotheses were avoided within this manuscript. Based on personal observation and preliminary (unpublished) data from the pilot study, we expected that off-road riders would have slightly higher health compared to the normative population, and that differences would exist between ATV and ORM riders in measurements such as body composition and aerobic fitness.

3.4. MANUSCRIPT II – Objectives and Hypotheses

3.4.1 Objectives

The objectives of the second investigation were:

1) To characterize the health perceptions, lifestyle and QOL of habitual recreational off-road vehicle riders
2) To compare the levels of mental and physical function and QOL of recreational off-road vehicle riders to Canadian population norms and determine whether differences exist among genders, age categories, and vehicle types (ATV and ORM).

3.4.2 Hypotheses

As this study was explorative in nature, there was not a strong body of literature on which to base hypotheses. However, we expected that habitual participation in recreational off-road vehicle riding would lead to increases in the overall QOL of riders compared to non-riders and that there would be no age, gender, or vehicle type differences. We further expected differences would exist in lifestyle behaviors between off-road motorcycle and ATV riders.

3.5 MANUSCRIPT III – Objectives and Hypotheses

3.5.1 Objectives

The objectives of the third investigation were:

1) To characterize the physiological demands of recreational off-road vehicle riding under typical riding conditions using habitual recreational off-road vehicle riders.
2) To make comparisons of the physical demands of off-road vehicle riding between vehicle types and to common recreational activities.

3.5.2 Hypotheses

The hypotheses of this investigation were:

1) The physical demands of riding an off-road vehicle would be comparable to other, more commonly accepted, recreational activities and that the physical demands of riding an ORM would be greater than those involved in riding an ATV.

2) The demands of riding an off-road vehicle would be of sufficient intensity to be associated with health-related fitness adaptations.

3.6 MANUSCRIPT IV – Objectives and Hypotheses

3.6.1. Objectives

The objectives of the fourth investigation were:

1) To determine the fitness and health effects of a structured program of off-road vehicle riding in non-habituated riders using two different training volumes (typical habitual rider PA volume and population recommended PA volume) and two modes of off-road vehicle riding (all-terrain vehicle; ATV and off-road motorcycle; ORM).

2) To measure the ambient levels of carbon monoxide (CO) exposure during group rides and to estimate the potential ill-effects of this CO exposure on cardiovascular and respiratory health.

3.6.2 Hypotheses

The hypotheses of the fourth investigation were:

1) That fitness and health changes would occur as a result of off-road vehicle riding, with greater changes occurring in ORM riders than ATV riders and in those who trained using the recommended PA volume as opposed to the typical off-road participation volume.

CHAPTER 4

COMMON METHODOLOGY:
PARTICIPANT RECRUITMENT AND SCREENING; COMMON MEASUREMENTS

The following chapter outlines participant recruitment common to the four manuscripts and provides further detail about select measurements requiring further detail. Detailed individual methodologies are included in each study.

4.1 Participant Recruitment and Screening

Following approval of the York University Human Research Ethics Committee (see Appendix B) participants of investigations one through three were recruited from local off-road riding clubs at off-road riding expositions, by word of mouth and through online bulletins sent from provincial and national rider's organizations. Participants involved in investigation four were recruited from the York University community and surrounding area. Following a full explanation of procedures, discomforts and risks, all participants provided written informed consent appropriate to the study phase in which they participated (see Appendix C). All participants were pre-screened prior to testing using the Canadian Society for Exercise Physiology Physical Activity Readiness Questionnaire (See Appendix D). Potential subjects were excluded if they were taking medications, or could not undergo physical fitness testing measures. Further details on participants who did not require pre-screening for physical activity participation (i.e.

health survey, riding survey and focus group participants) are provided within the relevant manuscripts.

4.2 Measurements

4.2.2 Quality of Life and Physical Activity Participation

Information regarding PA participation and selected health-related lifestyle choices was collected from participants using a standardized information package. Participants read the questions from a pre-assembled booklet of questionnaires (see Appendix E) and answered questions on a computer marked answer sheet. If participants were uncomfortable or incapable of completing the "scantron" computer answer sheet, answers were recorded directly on the questionnaires and transferred to the "scantron" sheet post-hoc. All question booklets/answer sheets were checked for recording errors prior to computer marking. The questionnaire booklet contained the Quality-Metric SF-36 Quality of Life Questionnaire, the CPAFLA FANTASTIC lifestyle checklist and the CPAFLA Healthy Physical Activity Participation questionnaire (Appendix E).

The computer recorded answers from the SF-36 Quality of Life Questionnaire were coded according to unique subject ID numbers and transposed into a spreadsheet containing pre-programmed formulae to convert raw scores into the 8 scale profiles considered within the questionnaire. These profiles allow consideration of functional health and well-being as well as a psychometrically-based physical and mental health summary measure which were of primary importance for this project. The SF-36 is a generic measure, as opposed to one that targets a specific age, disease, or treatment group (License #R1-111708-38893).

The Fantastic Checklist is a questionnaire developed by Dr. Douglas Wilson from McMaster University (1985) and examines many facets of everyday life ranging from perceived social support to nutrition and tobacco use. The answers from each section of the checklist allow for the computation of a final score for categorization within population norms. Specific data on health behaviors was extracted from this form to answer targeted questions about lifestyle choices (Appendix E).

The healthy PA participation questionnaire examines the frequency, intensity and duration of activity over a typical seven-day week to determine a health benefit rating, adjusted for gender (47). Further information regarding weekly exercise participation was extracted from the Ainsworth questionnaire (5) (Appendix F) which is typically used for aerobic fitness estimation.

4.2.3 Physical Fitness Measurements

The majority of muscular physical fitness measurements (hand grip, partial curl-ups, vertical jump, Sorenson back extension, flexibility) employed have been adequately described in the manuscript in which they appear and are well referenced in the CPAFLA (47, 210). Below is supplementary material describing the unique measure of isometric push and pull strength.

Push strength and pull strength were quantified using a specially designed spring-resisted isometric dynamometer which allows for quantification of both extension and flexion of the shoulder and elbow joints. The device is secured to the participant's front with pads resting on their iliac crests and clavicles, with the handle positioned between the nipples and navel, just below the level of the xiphoid process. Strong straps pass over the shoulders and under the arms to securely hold the device from moving up, down or away from the participant. The handle is adjusted toward or away from the body so that the participant's elbows are flexed at approximately 110 degrees in the starting position (see Figure 4.1). This is verified using a pre-made triangle with an obtuse angle (110) for measurement. The participant is instructed to first push the handle away from their body in a slow controlled manner until the handle will not move any further (actual movement distance is approximately 1-2 cm). Following this, the participant returns to the starting position, the device is set to record in the other direction and the participants pulls the device towards their chest in a slow controlled manner until it will not move any further (similar movement distance to push). Participants are given three trials of each movement and the highest score is recorded. The dynamometer is calibrated against precision instruments over the measurement range such that the raw score multiplied by a factor of 533 is equivalent to maximal force in pounds. Over the range of 0 to 130 kg the force meter has a high precision (±0.0045 kg), high reliability (mean coefficient of variation = 0.6%), high validity (r=0.999 vs. cable tensiometer), no bias (Bland Altman analysis) and the mean coefficient of variation between force measures and calibrated weight = 0.2% (178).

Figure 4.1 The upper body isometric push and pull device being used by a participant in the field. Note the participant's elbows are at approximately 110 degrees and the handle is either pushed or pulled at a right angle to the body within the sagital plane.

CHAPTER 5
MANUSCRIPTS

5.1 Manuscript I

A Cross-Sectional Examination of the Physical Fitness and Selected Health Attributes of Recreational All-Terrain Vehicle Riders and Off-road Motorcyclists

Burr, J.F., Jamnik, V.K., Gledhill, N. A Cross-Sectional Examination of the Physical Fitness and Selected Health Attributes of Recreational All-Terrain Vehicle Riders and Off-road Motorcyclists. *Manuscript in Preparation*

5.1.1 INTRODUCTION

Physical activity (PA) includes all leisure and non-leisure bodily movements produced by the skeletal muscles resulting in energy expenditure and may include the more specific subcategory of structured exercise (47). Recreational off-road vehicle riding is an increasingly popular non-traditional PA in North America, Europe and around the world. Although true prevalence data is hard to obtain because off-road vehicles are often not registered, available statistics suggest that > 77% of rural Canadians have access to off-road vehicles (247). Statistics from the Canadian Off-Highway Vehicle Distributors Council for each of the two most current years of sales show that approximately 170,000 off-road vehicles were sold nationwide. Although off-road riding is popular and easily accessible in rural settings, it is also accessible to urban dwelling enthusiasts who are willing to commute to the rural trails. Despite the popularity of recreational off-road vehicle riding, little is known about the physical demands of riding or the consequent physiological characteristics of habitual recreational riders.

Off-road riding, for the purposes of our investigation, collectively refers to single passenger all-terrain vehicles (ATV) and off-road motorcycles (ORM) which are intended for non-racing recreational use. These vehicles are also commonly referred to as "quad cycles" or "dirt bikes" respectively. Critics of off-road riding suggest that riding offers no opportunity for fitness and health benefits, as the vehicle's engine performs the locomotive work. Literature examining "enduro" (83), "motocross" (18, 83, 135, 136), and "desert rally" (83) racing suggests that top level off-road ORM riders have aerobic capacities (45-58 $ml \cdot kg \cdot min^{-1}$) and body compositions (% fat 13-17) (83) comparable to other high-profile North American athletes such as hockey players (42). However, this body of literature only considers high-level ORM racers and the assumption that non-competitive, recreational riders share the same attributes as elite athletes should be made with caution. To date, off-road vehicle rider fitness research has exclusively examined ORMs and the differences that may exist in off-road riding between two-wheeled ORMs and four-wheeled ATVs have not been considered. Moreover, research has focused specifically on physiological performance attributes without considering health-related outcomes, but it is well documented that changes in health can occur in the absence of changes in fitness (244). For the purposes of this examination of off-road vehicle riders, health is operationally defined as the absence of disease and disability, or risk factors for disease and disability, primarily from a physiological/fitness point of view. It is important to note that off-road riding is a sport with considerable inherent risk and there is a large body of research examining injuries from participation in off-road sports, especially in children. The current investigation deals only with adult riders and considers health and health risk factors from an inactivity-related chronic disease standpoint. The authors recognize that overall health has physical, social and psychological implications which cannot be captured simply by the absence of disease or disability (47) and these related dimensions are considered in an adjunct paper (Manuscript II).

There were three purposes to this cross-sectional observational study: 1) to characterize the fitness and health of habitual recreational off-road vehicle riders; 2) to explore differences among recreational off-road riders with reference to vehicle type, age, and gender; and 3) to compare the fitness and health of recreational off-road riders to population norms and clinical health standards. This study was explorative in nature, with limited existing data on which to base strong hypotheses.

5.1.2 METHODS

5.1.2.1 Participants

Canadian off-road riders (n=141), of both genders and all ages >16 yr were recruited through local and national off-road riding organizations. Open invitations were extended via internet postings, word of mouth and information booths at off-road vehicle expositions to persons who identified as a habitual rider. Local clubs (from the provinces of Ontario and Quebec) were contacted by the researchers to gather volunteers for pre-arranged group testing in that geographic locale. Participant recruitment and selection was controlled by the research team, thus avoiding the introduction of selection bias from outside governing bodies. Exclusion criteria eliminated those taking medication which affected the health variables being considered and those who did not ride habitually, which was operationally defined as an average riding frequency of approximately 1/wk. Descriptive participant statistics are provided in Table 5.1.After verbal explanation of procedures, written informed consent was provided by all participants, with those under 18 yr (n=3) also providing parental consent. All assessments and information regarding volunteer participation in specific measures were blinded and held in strict confidence to avoid the possibility of deciphering other participant's scores. This project was approved and conducted in accord with York University Human Ethics Review Board guidelines.

Table 5.1. Demographics of the participants (n=141) combined and divided by gender for vehicle type, age and years of experience.

		Vehicle Type		Age			Years of Experience			
		ORM	ATV	16-30	31-50	50+	< 5	6 - 10	11 - 20	20^{+}
Combined	*141 (100)*	*78 (55.3)*	*63 (44.7)*	*29 (20.6)*	*67 (47.5)*	*45 (31.9)*	*43 (30.5)*	*29 (20.5)*	*27 (19)*	*42 (30)*
Male	*107 (75.9)*	*59 (75.6)*	*48 (76.2)*	*19 (65.5)*	*48 (71.6)*	*40 (88.9)*	*29 (67.4)*	*20 (69)*	*21 (77.8)*	*37 (88.1)*
Female	*34 (24.1)*	*19 (24.4)*	*15 (23.8)*	*10 (34.5)*	*19 (28.4)*	*5 (11.1)*	*14 (32.6)*	*9 (31)*	*6 (22.2)*	*5 (11.9)*

Combined values are expressed as n (% of overall group); gender specific values are expressed as n (% of gender split within group)

5.1.2.2. Assessments

Heart rate, blood pressure, height, weight, body composition, and waist circumference were measured prior to exercise. Riders reported physical activity participation using the Canadian Physical Activity and Lifestyle Assessment (CPAFLA) form (47) and weekly frequency was calculated from information collected with the Ainsworth questionnaire (5) for estimating aerobic fitness. This questionnaire was selected for consistency with data previously collected on the normative Canadian population (179). Weekly PA data were collected to document the amount of PA this sub-group of Canadians undertook as part of the overall characterization of off-road riders and to help explain potential between group differences should they exist. Riders also reported years of riding experience (Table 5.1) and weekly riding frequency.

Upper body strength was assessed using an isometric spring resisted dynamometer which allowed for quantification of both push and pull strength at an elbow joint angle of 110 degrees. Push strength involved the isolated use of chest and elbow extensor muscles, whereas pull strength involved muscles of the upper back and elbow flexors. A Smedley analog hand grip dynamometer was used to measure both right and left hand grip strength with the handle adjusted to the second knuckle. Core muscular endurance was quantified using the CPAFLA partial curl-up and the Sorenson back extension protocol (47). Vertical jump was measured using a jump timing mat (Just Jump; Probotics, Huntsville, AL) and leg power was determined from jump height using a single jump and applying the Sayers leg power equation which incorporates body weight (127).

The majority of participants (n=98) underwent an assessment of aerobic power via a progressively ramped treadmill exercise test and analysis of expired gas using open circuit spirometry (S-3A/II oxygen, CD-3A carbon dioxide, AEI Technologies, Pittsburgh, Pa). Those volunteers (n= 43) who did not participate in the aerobic fitness measures opted out for a variety of reasons including time constraints and scheduling conflicts (n=17), injury (n=4), and undisclosed personal reasons (n=22) which they were not required to provide in accord with human ethics protocol. Follow-up analysis revealed no systematic difference between those who did and did not complete the aerobic fitness testing on other fitness measures. Participants began walking (3.5 mph, 0% elevation) on the treadmill, progressed to a slow jog (5 mph, 0% elevation) and then ramped with 1 mph increases in speed until the individual's maximal safe running speed was reached, followed by 2% incremental increases in elevation. If subjects were unable to jog/run, the speed was adjusted to accommodate the fastest pace they could maintain and the incline was increased incrementally as above. On average, the aerobic fitness test involved a total of 11.6 ± 4.3 exercise minutes. The test was terminated when: oxygen consumption (VO_2) did not increase at least 150 $ml \cdot min^{-1}$ with an increase in workload, when RER was greater than 1.15, when heart rate (HR) did not increase with increases in exercise intensity, or when the participant reached volitional fatigue and had an RPE greater than 17 on the Borg 6-20 scale (104). All participants were encouraged to continue until a super-maximal value was obtained. If participants were unable to continue to this point VO_2 peak is reported.

Normative population anthropometric, health and fitness data were utilized as a standard reference for the participants' specific CPAFLA measures (179). Comparisons between riders and these norms were possible for all variables listed in Table 5.2. For the sub-set of participants whose aerobic fitness was measured directly (n=98), comparisons were made to norms specific to age and gender (225). This database was selected because equivalent Canadian normative data of this scope were not available.

Fasted blood glucose and blood lipid finger stick samples were analyzed using the Cholestech LDX system (Cholestech Corporation, Hayward, CA) collected from a randomly selected sub-sample of our participants (n=61). A sub-sample of participants were used to allow sufficient representation of all groups, while keeping costs at a minimum. This sub-population had representation from all groups as follows: ATV male 37.5% (18/48), ORM male 38.9% (23/59), ATV female 71.4% (10/14), ORM female 52.6% (10/19). This system has been evaluated in reference to National Cholesterol Education Program (NCEP) standards and is accurate for general classification of results (24).

Table 5.2. Anthropometric and health-related fitness measures (mean ±SD) for population norms, ATV and ORM riders divided by gender and age categories. BMI= body mass index, SO5S = sum of 5 skinfolds, WC = waist circumference, VJ = vertical jump height

		Age	n	Weight (kg)	Height (cm)	BMI	SO5S (mm)	WC (cm)	Push (kg)	Pull (Kg)	Hand Grip (kg)	Curl-ups	VJ (cm)	Leg Power (w)	Sorenson (s)
MALE	Population Norms	17-29	127	74.9 ± 14.1	175.0 ± 8.0	24.4 ± 3.8	50.0 ± 22.7	80.8 ± 9.0	128.8 ± 35.9	103.2 ± 21.8	96.9 ± 17.9	23.9 ± 3.1	48.7 ± 10.1	4294 ± 1179	127.9 ± 51.5
		30-49	71	80.7 ± 15.7	176.6 ± 7.7	26.0 ± 3.5	62.0 ± 20.9	88.5 ± 8.4	108.3 ± 33.7	95.7 ± 24.4	96.5 ± 20.8	19.8 ± 7.7	39.5 ± 11.6	4002 ± 1175	92.3 ± 52.5
		50+	61	80.8 ± 13.3	172.2 ± 8.3	27.3 ± 2.5	71.0 ± 27.2	95.7 ± 10.2	94.1 ± 26.3	87.9 ± 17.3	87.1 ± 16.6	13.4 ± 9.1	26.2 ± 12.5	3196 ± 1639	80.3 ± 63.7
	ATV	16-29	5	88.8 ± 23.3	183.2 ± 9.9	26.1 ± 4.3	76.4 ± 45.1	91.6 ± 17.3	100.0 ± 23.2	101.3 ± 14.7	103.6 ± 22.6	15.0 ± 1.4	39.3 ± 11.0	5630 ± 663	89.7 ± 13.9
		30-49	22	100.2 ± 17.1	177.9 ± 7.4	31.8 ± 5.9	103.1 ± 24.7	106.4 ± 12.8	111.0 ± 30.1	104.4 ± 20.6	101.5 ± 20.0	16.2 ± 10.9	43.8 ± 10.8	5154 ± 818	76.3 ± 48.6
		50+	21	102.3 ± 30.6	178.0 ± 5.9	32.5 ± 10.8	81.6 ± 29.5	102.9 ± 11.8	95.8 ± 21.2	94.3 ± 13.3	85.7 ± 24.0	10.6 ± 11.5	37.9 ± 8.6	4949 ± 1624	39.8 ± 37.0
	ORM	16-29	14	82.5 ± 12.9	182.8 ± 6.7	24.5 ± 2.6	64.0 ± 23.0	87.3 ± 5.9	118.9 ± 34.3	110.8 ± 20.2	101.3 ± 22.2	18.4 ± 9.0	43.4 ± 8.1	5002± 695	90.5 ± 50.0
		30-49	26	84.2 ± 12.0	177.8 ± 6.0	26.7 ± 3.8	69.9 ± 29.4	92.1 ± 17.1	105.4 ± 26.6	101.7 ± 11.4	99.0 ± 18.0	17.2 ± 9.7	43.9 ± 10.7	4556 ± 597	94.6 ± 56.3
		50+	19	87.7 ± 18.0	179.5 ± 4.4	27.2 ± 5.3	72.2 ± 40.3	97.4 ± 13.6	101.8 ± 26.2	98.6 ± 17.7	98.8 ± 23.4	17.6 ± 8.9	42.0 ± 12.5	4298 ± 862	97.0 ± 48.0
FEMALE	Population Norms	17-29	142	61.2 ±11.1	162.8 ± 6.9	23.1 ± 3.8	68.5 ± 26.9	72.5 ± 9.4	67.1 ± 20.0	53.9 ± 10.3	57.9 ± 11.7	22.4 ± 6.4	31.6 ± 7.3	2636 ± 642	132.1 ± 41.7
		30-49	103	64.3 ± 12.0	161.5 ± 11.0	24.2 ± 4.2	81.0 ± 28.4	77.3 ± 9.8	57.7 ± 19.0	52.8 ± 13.4	58.8 ± 12.2	17.4 ± 9.2	26.0 ± 7.0	2436 ± 653	119.7 ± 50.8
		50+	67	66.7 ± 12.6	160.8 ± 8.2	26.0 ± 5.1	94.8 ± 32.0	81.9 ± 10.8	48.2 ± 16.8	45.5 ± 13.8	49.6 ± 10.8	8.7 ± 10.0	15.6 ± 8.5	1915 ± 1088	61.2 ± 58.8
	ATV	16-29	3	88.1 ± 22.6	161.8 ± 8.4	34.1 ± 11.0	183.5 ± 49.9	101.3 ± 18.1	52.0 ± 14.9	57.1 ± 8.9	49.0 ± 11.8	8.5 ± 6.4	39.5 ± 16.4	3961 ± 966	25.5 ± 17.7
		30-49	8	83.7 ± 22.7	167.7 ± 8.9	29.7 ± 7.2	116.6 ± 36.7	91.2 ± 9.4	77.9 ± 25.7	70.7 ± 21.2	72.9 ± 12.6	12.3 ± 14.2	40.6 ± 5.8	3319 ± 422	62.3 ± 16.7
		50+	3	76.4 ± 22.1	159.8 ± 4.5	30.1 ± 9.6	103.7 ± 45.9	93.7 ± 18.5	38.9 ± 17.4	43.6 ± 17.0	42.2 ± 20.2	25.0 ± 1.0	35.6 (n=1)	2622 (n=1)	180.0 (n=1)
	ORM	16-29	7	62.4 ± 6.7	168.4 ± 6.7	22.0 ± 2.1	65.4 ± 14.7	78.8 ± 5.9	66.5 ± 20.8	66.4 ± 18.9	63.4 ± 21.0	23.6 ± 3.1	42.9 ± 5.9	2937 ± 831	115.0 ± 68.4
		30-49	10	66.1 ± 11.7	165.4 ± 7.7	24.3 ± 5.2	84.2 ± 42.0	81.4 ± 15.0	61.1 ± 11.8	60.6 ± 7.7	56.7 ± 11.6	16.4 ± 11.8	36.8 ± 10.4	3132 ± 485	151.7 ± 34.1
		50+	3	60.2 ± 2.5	167.5 ± 0.7	21.5 ± 0.8	54.8 ± 33.1	75.8 ± 8.1	67.5 ± 0.0	62.5 ± 10.1	72.5 ± 10.6	25 (n=1)	49.5 ± 1.0	3327 ± 565	94.4 ± 50.6

5.1.2.3 Statistical Analyses

Anthropometric, health, fitness and clinical measurements were compared to normative data by gender, vehicle type and age categories using a 3 (Norm, ATV and ORM) x2 (male and female) x3 (age tertiles) factorial ANOVA with post-hoc Bonferonni comparisons. Interaction effects with normative aggregate data (mean± SD) were verified using the post-hoc Simple Effects method with a Bonferonni correction for the number of comparisons under the guidance of an expert statistical advisor. Where appropriate, measures were compared to strength and endurance norms using a gender-split file and simple ANOVA to wash out the effect of a lower representation of female participants in the off-road cohort compared to the normative data set which was more equally represented. Due to variable participation in some tests and a low female representation in the youngest and oldest riding groups, interpretations were avoided for female age effects. Female data were included when logical collapsing or pooling groups allowed for consideration of the gender group as a whole and offered greater statistical power.

A partial correlation was performed to determine whether recreational off-road riding was related to aerobic fitness after controlling for age, gender, and non-riding workouts. Significance for all tests was set a priori at $p \leq 0.05$. Statistical power, for all between and within group comparisons was at >95%, calculated a priori based on the ability of our laboratory to differentiate aerobic fitness changes with a precision of 2.5

$ml \cdot kg^{-1} \cdot min^{-1}$established in an across laboratory validation. All analyses were performed using SPSS software (version 16.0; SPSS Inc, Chicago IL).

5.1.3 RESULTS

The frequency of weekly off-road riding was consistent across age groups and between genders (1.5±1.7) but differed between ATV (1.0 ±1.4) and ORM (1.8±1.9) riders (p<.001). Examination of all weekly physical activity (including other sports, work, fitness activities and riding) revealed a gender by vehicle interaction, male ATV 3.7±2.1 and ORM 3.8±1.8 riders reported a similar frequency, but female ATV riders (3.3±1.9) were less active than female ORM riders (4.5± 2.2; (p=.021).

5.1.3.1 Anthropometry

Descriptive anthropometric and fitness data are presented in Table 5.2. Relative to population norms, male riders were taller, (p<.001) heavier (p<.001) and had a greater WC (p<.001). The mean WC of all off-road male riders combined was above population norms owing primarily to the considerably higher WC values of ATV riders (p<.001), although ORM riders were also elevated above the norm, but by a smaller margin. In male ORM riders, similar to population norms, measures of WC were higher among older groups; however, the average WC of male ATV participants peaked in middle aged riders then did not increase when comparing middle aged to the oldest aged category.

ATV riders of both genders were heavier than ORM riders, had a greater WC and a greater body mass index (BMI) (all significant, p<.001). ORM riders were heavier than the corresponding population norms (p<.001) but had a similar BMI. Both male ATV and ORM riders had higher SO5S than average normative males ($p<.001$). However, unlike the population norms wherein the older aged groups had larger values SO5S values, male riders had a relatively lower level of SO5S measures when comparing the 30-49 age groups with those riders over 50. This was seen with both vehicle types. Nevertheless, adiposity was greater among ATV and ORM riders at all age levels of male riders compared to population norms. Using the CPAFLA healthy body composition composite scoring (0-4, scaled from "Needs Improvement" to "Excellent"; combined group mean 2.5±1.5) ATV riders had a mean score of (1.76±1.51) which was significantly lower than the ORM mean of (3.11±1.26; $p=.024$).

5.1.3.2 Fitness

Combined hand grip strength revealed a vehicle type by age interaction ($p=.013$) such that a decrease in grip strength from the youngest to the oldest age groups was evident in ATV riders and norms, but not in ORM riders as grip strength was not significantly lower in older age groups. A similar effect was observed in male riders for core muscular endurance, as the older ORM age group did not reveal a decreased curl-up ($p<.001$) or back extension ($p<.001$) ability compared to younger age groups whereas both the normative population and ATV riders did.

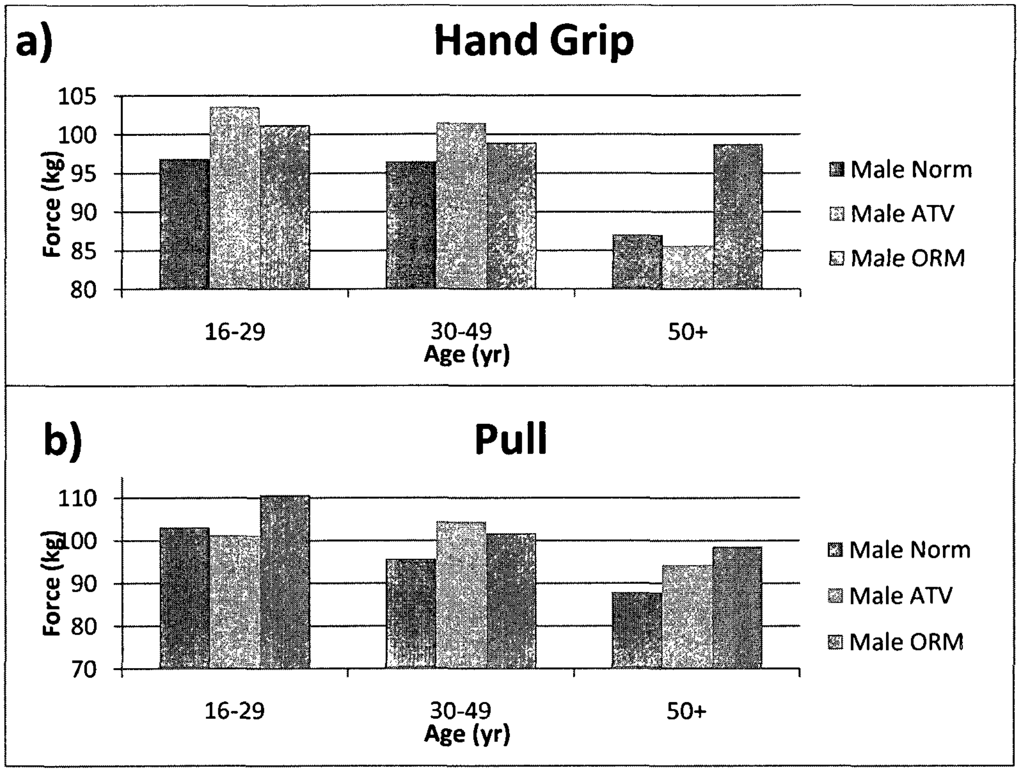

Figure 5.1. Strength, power and endurance according to age for male ORM riders, ATV riders and population norms **a)** Handgrip strength of population norms and ATV riders declines from the youngest to oldest age groups ($p<0.05$), whereas ORM riders are similar for all age groups. This same pattern was evident for core muscular endurance (partial curl-ups and Sorensen back extension) and leg power. **b)** General population norms show a significant decrease in pull strength between each of the age categories ($p<0.05$). Neither ATV nor ORM riders showed significant differences in pull strength with increasing age. The same pattern was apparent for push strength.

Similarly, the upper body push (p=.021) and pull (p=.013) of male off-road riders did not decrease in the older age groups in either vehicle type, while population norms indicate a significant drop in push and pull strength with increasing age groups. Vertical jump testing revealed ATV and ORM riders to have higher leg power than population norms (p<.001) and did not decrease in the oldest age group of either vehicle type as it did in population norms. Due to low numbers of female riders, strength patterns across age could only be validly interpreted for male riders.

Vehicle type, age and gender specific aerobic fitness data are reported in Table 5.3. The fitness of ORM riders (43.3±8.3 $ml \cdot kg \cdot min^{-1}$) was considerably higher than that of ATV riders (33.5±7.1 $ml \cdot kg \cdot min^{-1}$; $p<.001$). Similar to population norms, male riders had higher aerobic fitness values than female riders (p=.017) and the normative pattern of decreasing aerobic fitness with increasing age group was apparent (p=.005).

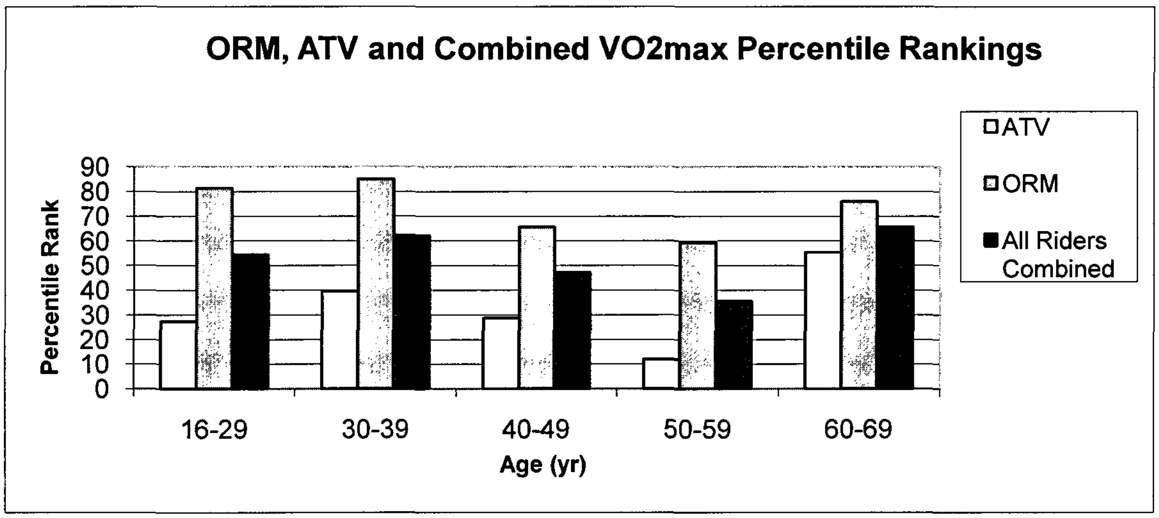

Figure 5.2. Percentile rank of ORM, ATV and combined riders referenced to age-matched normative VO_2max data from the Cooper database. ORM riders have significantly higher aerobic power than ATV riders (p<0.001). Male and female genders combined.

Overall, off-road riders have aerobic fitness which ranks them in the 58th percentile of the Cooper database (range 41st-90th percentile) compared to age and gender-matched normative controls. Mean group percentile rankings for ATV and ORM riders place them at the 40th and 79th percentile respectively, with females (ATV=44th, ORM=88th) ranking higher than males (ATV=36th, ORM=71st) for both vehicle types. Partial correlation revealed no statistically significant relationship between the weekly frequency of off-road riding and aerobic fitness after controlling for age, gender and non-riding workouts.

Table 5.3. VO_2 peak in $ml \cdot kg \cdot min^{-1}$ (mean ±SD) of habitual off-road riders by gender, age category and vehicle type referenced to the Cooper database by percentile rank and descriptive rating.

					Percentile Rank		*Descriptive Rating*	
	Age (yr)	**Vehicle Type**	**Group Mean ±SD ($ml \cdot kg \cdot min^{-1}$)**	**Participants (n)**	**Vehicle Specific**	**Combined**	**Vehicle Specific**	**Combined**
Male	16-29	ATV	42.8 ± 5.1	3	43	70	F	G
		ORM	51.8 ± 5.0	7	82		E	
	30-39	ATV	38.9 ± 9.2	6	32	53	P	F
		ORM	48.7 ± 5.9	5	79		G	
	40-49	ATV	34.4 ± 4.5	10	18	45	VP	F
		ORM	43.4 ± 9.0	15	63		G	
	50-59	ATV	29.7 ± 4.2	8	15	41	VP	F
		ORM	38.0 ± 8.2	16	55		F	
	60-69	ATV	32.4 ± 2.7	2	46	61	F	G
		ORM	38.4 ± 3.2	2	76		G	
	70-79	ATV	32.2 ± 0	1	65	n/a	G	n/a
		ORM	n/a	n/a	n/a		n/a	
Female	16-29	ATV	25.5 ± 6.9	2	4	50	VP	F
		ORM	44.0 ± 1.5	3	80		E	
	30-39	ATV	42.6 ± 0	1	85	90	E	E
		ORM	44.9 ± 7.3	6	91		S	
	40-49	ATV	34.1 ± 1.8	4	56	66	F	G
		ORM	40.0 ± 3.1	2	85		E	
	50-59	ATV	19.7 ± 3.3	2	2	50	VP	F
		ORM	43.8 ± 7.6	2	97		S	
	60-69	ATV	31.0 ± 0	1	75	n/a	G	n/a
		ORM	n/a	n/a	n/a		n/a	

VP = Very Poor, P= Poor, F= Fair, G= Good, E = Excellent, S= Superior

5.1.3.3 Clinical Measures

Pre-exercise mean arterial pressure (mmHg) of ATV (99.6±9.0) and ORM (91.2±14.0) riders was significantly different (p=.01), primarily as a result of an elevated systolic pressure in ATV riders (ATV SBP = 130.7±12.5, DBP=84.1±9.1, ORM SBP=121.1±10.7, DBP=78.4±9.3). Pre-exercise resting HR, which is often used as an indicator of fitness, differed between ORM (72.5±11.1) and ATV (79.5±10.6) riders (p=.001).

Mean blood lipid levels (mg/dL) for all riding groups combined were 112.0 ± 64.4 for triglycerides (TG), 175.4±50.8 for total cholesterol (TC), 49.2±13.2 for high density lipoprotein (HDL), and 98.0±38.3 for low density lipoprotein (LDL). Fasting blood glucose was 89.4±11.7 mg/dL. Females had elevated levels of HDL compared to males (p=.001) and also a lower total cholesterol/high density lipoprotein (TC/HDL) ratio (p=.039). There were no significant differences in blood lipids between ATV and ORM riders. An age effect was evident for total cholesterol (TC) and low density lipoprotein (LDL) with the youngest age tertile having the lowest TC (148.1±22.7 mg/dL) and LDL (74.5 ±29.8 mg/dL) after which values increased in middle age (194.7±61.4 and 110.7±35.3 mg/dL respectively) and then decreased again beyond 50 yrs of age (169.7±40.8 and 100 ±40.8 mg/dL; p<.05). There was no vehicle, gender or age difference for other lipid measures or fasting glucose.

Using NCEP ATP III classification guidelines, 12.9% of the combined riding sub-population presented with three or more risk factors indicating presence of the metabolic syndrome. Metabolic syndrome was present in the riding sub-groups as follows: 3 ATV Male (17%), 3 ORM Male (13%), 1 ORM female (10%), 1 ATV Female (10%).

5.1.4 DISCUSSION

This investigation reveals that the habitual recreational riders of off-road vehicles characterized in the current study collectively have physiological profiles which are slightly healthier than that of the general population. As summarized in Table 5.4, persons who ride off-road vehicles typically have increased WC, excess adiposity and an elevated BMI considering current clinical health recommendations. Overall, however, ORM riders participating in this study had higher levels of aerobic fitness compared to the general population and all off-road riders combined had healthy metabolic profiles considering both clinical standards and in comparison to population norms. The older off-road riders in this study had lower levels of adiposity and increased strength and power compared to population norms. It is impossible to determine if this difference from "normal" aging reflects a beneficial effect of off-road riding participation or if other factors such as sampling bias are influencing results and further investigation is warranted. We have attempted to highlight potential sources of bias specific to each measure in our discussion while presenting explanatory hypotheses.

Table 5.4. Summary of fitness and health of habitual recreational off-road vehicle riders by gender and vehicle type.

		Fitness Measures									Anthropometric and Clinical Measures						
		PA Participation	Aerobic Fitness	Lower body Power	Handgrip Strength		Push and Pull Strength		Core strength / Endurance		BMI	Adiposity	WC (cm)	BP	Blood lipids	Glucose	Prevalence of Metabolic Syndrome
					General	Age Δ	General	Age Δ	General	Age Δ							
Male	ATV	↓	↓	↔	↔	↔	↔	↑	↔	↔	↑	↑	↑	↑	↔	↑	
	ORM	↓	↑	↓	↔	↑	↔	↑	↔	↑	↑	↑	↔	↔	↔	↔	↓
	Combined	↓	↑	↔	↔	↔	↔	↑	↔	↔	↑	↑	↑	↑	↔	↔	
Female	ATV	↓	↓	↔	↔	-	↔	-	↔	-	↑	↑	↑	↑	↔	↔	
	ORM	↓	↑	↓	↔	-	↔	-	↔	-	↔	↔	↔	↔	↔	↔	↓ or ↔
	Combined	↓	↑	↔	↔	-	↔	-	↔	-	↑	↑	↑	↔	↔	↔	

Health-related fitness measures are compared to general population norms and anthropometric and clinical measures are referenced to clinical health standards. Key: ↑ = higher than mean norm or health standard, ↓ = lower than mean norm or health standard, ↔ = no difference, - = interpretation not possible

5.1.4.1 Anthropometry

The greater weight, BMI and body fat of ATV versus ORM riders in our sample highlights the vehicle type differences and emphasizes the need to consider riders as belonging to two distinct groups. The greater WC of ATV riders has meaningful significance in that the WC of both male and female ATV riders were above the health-related risk cut-offs of 102 cm for men and 88 cm for women (47), whereas both male and female ORM means fell below these cut-offs. Accumulation of adipose tissue, especially visceral fat, is associated with increased risk of cardiovascular and metabolic disease (15, 53). The greater SO5S of ATV riders, combined with their greater WC, indicates that the observed difference in weight was likely excess adipose tissue rather than metabolically active lean mass. The plateau in subcutaneous body fat accumulation of male riders from youngest to oldest age groups may suggest that participation in recreational off-road riding, for both vehicle types, attenuates the weight gain observed with increasing age in the normal population. However, it is also possible that this pattern was influenced by other factors which influenced representation within the current sample of off-road riders.

As a result of a similar height but greater weight, ATV riders had a high mean BMI which placed them into the World Health Organization classification of class 1 obesity (BMI>30 $kg{\cdot}m^2$); whereas ORM riders fell just above (0.5 $kg{\cdot}m^2$) the cut-off between normal and overweight (BMI>25 $kg{\cdot}m^2$). Persons with high BMIs are at increased risk for health problems including hypertension, high blood cholesterol, asthma, arthritis and poor general health (162). Although ORM males in the current investigation were significantly heavier than population norms, they did not have greatly elevated BMI values as a result of also being taller than average. The average height of male riders in our study is consistent with that reported in the literature for other off-road riders (83, 132, 135, 136). This finding of a greater average height in male riders supports previously published literature examining on-road motorcyclists that also found riders to be taller than the general population (191). The greater height of riders was suggested to be due to a selection factor for riding, since a high inseam allows comfortable sitting while straddling a motorcycle.

5.1.4.2 Fitness

Interestingly, ORM riders showed no muscular fitness differences across increasing age categories whereas the normal population revealed declines in muscular strength ,endurance and power. ATV riders showed declines in older compared to younger aged riders, similar to population norms in all variables except leg power, push and pull force. The reasons for greater hand grip and core endurance in older ORM versus ATV riders is unclear, but may relate to the demands of riding 2-wheel versus 4-wheel vehicles and warrants further investigation. The significant elevation in leg power of ATVand ORM riders compared to population norms may suggest that off-road riding requires lower body muscular involvement to steer and maintain control of the machine. However, it is also possible that off-road riders have increased musculature and leg power resulting from the everyday locomotion of their greater body mass, and again, this highlights the need for analyses of the acute physical demands of riding.

Elevated aerobic fitness is known to confer protection from numerous cardiovascular diseases and to decrease all-cause morbidity, mortality and premature death (122, 173, 250, 256). The differences in aerobic fitness between riders of the two vehicle types in our study population may result from an unequal PA stimulus of riding, but this dose-response issue is beyond the scope of the current investigation. Aerobic fitness could also be influenced by non-riding PA (which was highest in ORM females), excess fat weight (which was higher in ATV riders) and inherent group differences if a selection factor is occurring such that less aerobically fit individuals gravitate toward riding four-wheeled vehicles. It is plausible that four-wheeled vehicles appeal to those with lower aerobic fitness and PA levels because they appear more stable or that more highly fit adventure-seekers are drawn to two-wheeled vehicles. A final possibility is that hidden socioeconomic factors affect vehicle selection as it is known that those with higher socioeconomic status typically have higher levels of aerobic fitness (213).

Logically, if off-road vehicle riding leads to changes in aerobic fitness, one would expect riding frequency to be positively correlated with VO_2max. After controlling for the potential confounding factors of age, gender and non-riding PA, no such relationship existed. This lack of a relationship appears to suggest that recreational off-road riding as undertaken by the average habitual participant does not provide a sufficient PA dose to achieve improvements in aerobic fitness; however, the cross-sectional design of the current study does not allow a conclusive interpretation of cause and effect in this regard. It is likely that off-road riding 1-2 times a week is an insufficient PA stimulus to cause aerobic adaptation as a result of a low frequency of exercise (2) even if we assume an appropriate duration of activity and an intensity of 4 METS (moderate intensity) based on "moto-cross" as listed in the compendium of physical activity (4). However, as explicated by Bouchard and Rankinen (34), the heterogeneity in response to regular physical activity, and the range of activity itself may differ meaningfully from the group mean. As such, it is also possible that our measure of weekly exercise participation was insufficiently precise to detect a riding effect on aerobic fitness or that the variation in genetically determined fitness level (and adaptation to a PA stimulus) between individuals may have washed out the significance of a possible training effect from riding. At present, insufficient information on objectively measured intensity and duration (including duration above an appropriate intensity for changes in VO_2) are available to determine the PA dose of this type of activity. This is another important area for future study.

5.1.4.3 Clinical Measurements

The pre-exercise blood pressure measured in both ATV and ORM riders was below the widely accepted definition of hypertension of 140 systolic and 90 diastolic (45, 47). Due to study logistics, only a single measurement was performed on each participant. It is possible that this may have caused some degree of "white coat hypertension", however, extreme blood pressures were not observed and comparison between groups were not compromised as all groups would have been effected equally. ORM riders were at near optimal levels of 120/80 (systolic/diastolic), whereas ATV riders fell within the high-normal or pre-hypertensive category (47).

Blood lipid profiles of habitual off-road riders were at healthy levels, with no difference between ATV and ORM riders. This may provide evidence that some health changes have occurred irrespective of other major changes in adiposity or fitness. It is important to note that there are at least two possible explanations for all blood analysis finding in the current study 1) that these changes have occurred as a result of participation in off-road riding and 2) that the current sample has been skewed by selection bias or drop out, but neither explanation can be confirmed at this time without follow-up analysis. TC and LDL showed an age effect such that were highest in the middle age group, then and lower in those over 50 years. Similar to the effects observed in many of the strength measures, this could indicate a protective effect of riding against higher TC and LDL levels with age. If this does indeed represent a protective health benefit, and not merely a drop out of those who were less healthy, it is of clinical importance, as LDL is responsible for the majority of risk associated with high cholesterol levels and is directly involved in atherosclerotic propagation (77, 145). Analysis of long-term athletic involvement has shown improvements in the TC/HDL ratio (of which LDL typically makes up about 70% of TC) (56, 204) and a reduction in hypercholesteremia with increased PA dose or intensity (254). Thus, it is possible that those in the oldest age category are showing these benefits as a result of lifetime involvement. Importantly, the mean LDL levels of off-road riders classify them in an optimal category of <100 mg/dL (167).

In our sub-population of riders there was an overall rate of 12.9% of participants who presented with three or more risk factors for the metabolic syndrome. Using the same NCEP criteria, recent U.S. estimates predict 34% of men and 35% of women have at least 3 risk factors (76) with Canadian estimates at 17% for males and 13% for females (16). Given that the rate observed for all riders, as well as gender-specific incidence rates for both vehicle types, are at or below the normal population incidence rate, it is possible that off-road riding plays a role in the avoidance of the metabolic syndrome. Given that off-road riders, especially ATV riders, presented with high WC and body fats (which are strongly associated with other risk factors), the finding of a below average incidence of the metabolic syndrome is particularly interesting.

As with any observational cross-sectional study this characterization of off-road vehicle riders had limitations and sources of potential bias which we have attempted to highlight. Volunteer participants were aware of the study aims of assessing and characterizing rider fitness, thus, those who deemed their personal fitness to be sub-par may have self-selected out of the study. Volunteers were recruited primarily from Ontario and Quebec, thus it is possible that there are regional differences between these riders and riders in other parts of Canada, however, there is currently no other data on which to confirm or deny this possibility. Subjects were free to withdraw from the study at any time, and consequently some measures had lower representation than others. If those who withdrew from certain tests did so for a common reason it is possible that this introduced bias, however, no such systematic reason for withdrawal was apparent to the research team. As mentioned, differences between riders of each of the two vehicle types may be confounded by underlying differences in socio-economic status. Because a reliable measure of socioeconomic status was not collected in the current investigation, this cannot be fully explored, however it represents an area for future research. Lastly, information regarding subject exclusion criteria between our population and referent populations was unavailable, so comparisons of representativeness were not possible.

5.1.5 CONCLUSIONS

This cross-sectional study provides evidence that, with the exception of body composition, persons who habitually ride off-road vehicles have physiological characteristics which are equivalent, or slightly superior, to members of the general population on important fitness, and health variables. In the current study population, there is evidence which suggests a possible beneficial effect of riding on muscular fitness in older riders. ORM riders had healthier anthropometry and fitness levels than ATV riders and thus fewer health risk factors for future disease. This was particularly true in measures of blood pressure, BMI, body composition and WC wherein ATV riders were classified in unhealthy ranges. The finding of a lower than normal prevalence of the metabolic syndrome in both ATV and ORM riders suggests that off-road riding group membership may confer a health protective effect as the cardiovascular risk factors remain low despite elevated adiposity and WC. If these changes are indeed representative of the effects of habitual off-road riding, this may represent an alternative physical activity which has the capacity to cause health and fitness changes in the absence of significant changes in body composition or aerobic fitness. Further research is needed to elucidate the acute physical demands of off-road vehicle riding from an intensity and duration perspective and will provide insight into the differences between vehicle types and associated differences in physiological profiles of riders. Consideration of the possible health gains should also be weighed against the potential negative health consequences of participation such as traumatic injury or exhaust inhalation in determining the net benefit of off-road riding to population health.

ACKNOWLEDGEMENTS

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5.2 Manuscript II

Lifestyle Behaviors and Quality of Life of Habitual Off-Road Vehicle Riders

Burr, Jamie F. , Jamnik, Veronica K. , Gledhill, Norman. Lifestyle Behaviors and Quality of Life of Habitual Off-Road Vehicle Riders. *Manuscript in preparation.*

5.2.1 INTRODUCTION

Non-traditional forms of physical activity participation are becoming increasingly popular among segments of the population for whom traditional forms of physical activity (PA) (i.e. jogging, swimming, resistance training) may be impractical, unavailable or unappealing. Given the importance of PA in preventing avoidable morbidity and mortality (16, 52, 70), involvement in any recreational pursuit that elevates PA levels and decreases sedentary living is important. It is well known that participation in traditional PA has the ability to increase health-related quality of life (QOL) and decrease physical limitations of daily living (36, 128); however, little is known about the health-related outcomes of participation in alternative forms of PA. Habitual recreational off-road vehicle riding (both all terrain vehicles; ATV and off-road motorcycles; ORM) has recently received attention for its potential to bring about changes in health and fitness (41). When considering the utility of this type of activity for increasing overall population health, a participant's perception of their own physical function, mental health, and general well being are important factors to be considered. Furthermore, consideration of the lifestyle factors, such as diet and risk-related choices of participants who engage in these types of leisure time activities are informative. Despite being classed together as "off-road riding" the physiological profiles of riders using an ATV has been shown to be distinct from those using an ORM (41) and thus the two vehicle types need to be considered independently.

The purpose of this study was to characterize the health-related perceptions, lifestyle and QOL of Canadians who habitually participate in recreational off-road vehicle riding. A secondary purpose was to compare the levels of mental and physical function and QOL of recreational off-road vehicle riders to Canadian population norms and determine whether differences exist among genders, age categories, and vehicle types (ATV and ORM). As this study was explorative in nature, there is not a strong body of literature on which to base hypotheses. However, we expected that habitual participation in recreational off-road vehicle riding would lead to increases in the overall QOL of riders compared to non-riders and that there would be no age, gender, or vehicle type differences.

5.2.2 METHODS

5.2.2.1 Participants

Two separate cohorts were studied to characterize persons who habitually ride recreational off-road vehicles. The first group consisted of 302 riders from across Canada who participated in a self-report health survey, hereafter referred to as the "national" cohort. The survey asked specific questions to characterize the self-perceived health of riders and to differentiate the incidence of positive or negative health-related behaviour between vehicle types, ages and genders. The second group consisted of 141 riders from Ontario and Quebec who completed the SF-36 questionnaire and further probing questions concerning health, taken primarily from the Canadian Physical Activity Fitness and Lifestyle Assessment "FANTASTIC" lifestyle checklist published by the

Canadian Society for Exercise Physiology (47). This group will be referred to hereafter as the "provincial" cohort. Inclusion criteria included all Canadians who self identified as being a habitual off-road trail rider (ride > 1/ wk) and owned, or had open access to an off-road vehicle for recreational riding purposes. Exclusion criteria included those <16 yr of age (to comply with safety recommendations) and competitive racers. Descriptive statistics for both groups are provided in Table 5.5.

Health Perceptions and Behaviors

National cohort participants were recruited at off-road vehicle expositions, and through national and local ORM and ATV organizations. The survey was designed to solicit information regarding perceived overall health by gauging the occurrence of specific health behaviours and self-reported feelings about weight, automobile seatbelt use (%), missed days of work (yr), general happiness, fast-food consumption, frequency and quantity of alcohol consumption and smoking status. Outcome measures were either descriptive feelings (e.g. "very happy") or numerical ranges (smoke $\leq$10 cigarettes daily) and were thus categorical in nature. The further probing questions posed to the provincial cohort riders were quantified on a numeric scale from 1-5 anchored on subjective categorical descriptions which described the occurrence of specific health-related behaviours using terms such as "almost never" or "almost always." In all cases, a higher score reflected behaviour associated with a healthier outcome.

Table 5.5. Demographics of the national cohort who completed the health survey (n=302) and the provincial cohort who completed the SF-36 with follow-up questions (n=141) combined and divided by gender for vehicle type and age, expressed as n (%).

			Vehicle Type		Age (yr)		
			ORM	ATV	16-30	31-50	50+
National Cohort	*Combined*	302 (100)	162 (53.6)	140 (46.4)	37 (12.3)	164 (54.3)	101 (33.4)
	Male	264 (87.4)	144 (88.9)	120 (85.7)	28 (75.7)	146 (89.0)	90 (89.1)
	Female	38 (12.6)	18 (11.1)	20 (14.3)	9 (24.3)	18 (11.0)	11 (10.9)
Provincial Cohort	*Combined*	141 (100)	78 (44.7)	63 (55.3)	29 (20.6)	67 (47.5)	45 (31.9)
	Male	107 (75.9)	59 (75.6)	48 (76.2)	19 (65.5)	48 (71.6)	5 (88.9)
	Female	34 (24.1)	19 (24.4)	15 (23.8)	10 (34.5)	19 (28.4)	45 (11.1)

Combined values are expressed as n (% of overall cohort); gender specific values are expressed as n (% of gender split within cohort)

Health-Related Quality of Life

The provincial cohort was recruited through ORM and ATV riding clubs across Ontario and Quebec, using internet postings and word of mouth. The SF-36 was administered prior to the initiation of a comprehensive health and fitness screening undertaken for an adjunct project. Data collected from the riders on the 8 main SF-36 scales were transformed into two summary scales, the physical component scale (PCS) and mental component scale (MCS) which allow a greater power to detect changes and reflect physical function, mental wellbeing and QOL. These scores are calculated for each of the PCS and MCS using 4 of the 8 sub-scales of the SF-36 with no overlap. The PCS, which reflects physical health, is constructed using the SF-36 sub-scales of "physical functioning," "role-physical," "bodily pain" and "general health"; whereas the MCS, which reflects mental health and QOL, uses "vitality," "social functioning," "role-emotional" and "mental health" sub-scales. The construction, validation and associations of these summary measures have been described in detail elsewhere (248, 249). The summary scores from each scale were compared to comprehensive Canadian SF-36 normative data (107) as well as U.S. data included from the Medical Outcomes Study (MOS) for interpretation of scores as they related to expected health outcomes determined from longitudinal study (248). After verbal explanation of procedures, written informed consent was provided by all participants, with those under 18yr also providing parental consent. This project was approved and conducted in accord with York University Human Ethics Review Board guidelines.

5.2.2.2 Statistical Analyses

Self-reported health behaviours from the national survey and follow-up questions posed to the provincial cohort were divided into three age groups 16-30, 31-50 and 50^{+}. Using age, gender and vehicle type (ATV vs. ORM) classifications, ANOVA with post-hoc Bonferonni comparisons were used for interval variables and nonparametric chi-square tests were used to examine nominal variables.

The SF-36 data were split into a younger and older age group (< and ≥ 45yrs) for comparison with Canadian population norms and data from the MOS. Where no differences existed between vehicle types, the data were collapsed across ATV and ORM groups to make a "riding" group for comparison with the non-riding normative group. This increased statistical power and allowed an a priori estimate of a 5-10 point mean score sensitivity between groups (248). Further group comparisons were made using ANOVA. Significance for all tests was set a priori at $P < 0.05$.

5.2.3 RESULTS

Health Perceptions and Behaviors Survey

Weight perception and Fast-food consumption

The national cohort of riders reported near equal happiness (54.3%) and unhappiness (45.7%) with their current weight. ATV riders considered themselves overweight and ORM riders reported being at a satisfactory weight more than would be expected by random chance ($\chi^2_{(1)}=5.47$, $P<.02$). There were no significant differences in the perception of weight by gender or age. Approximately 12% of off-road riders reported eating fast-food often, with a significant tendency toward younger riders (16-30yr) eating fast-food more than those ≥50yrs ($\chi^2_{(2)}=9.61$, $P<.008$). There were no differences between genders or ATV and ORM riders regarding fast-food consumption.

Smoking and Drinking

Among all off-road riders, 13.9% (15.4% ATV, 12.6% ORM) reported being a current smoker, 36.5% had quit smoking and 49.6% never smoked. The likelihood of smoking varied across age tertile such that young riders had a lower than average number of smokers (10.8%), middle age riders had the highest representation of smokers (16.7%) and those ≥50yr had the fewest current smokers (9.5%) owing to a higher cessation rate ($\chi^2_{(4)}$=23.7, P<.0001). Examination of ATV and ORM as separate groups revealed significantly more ATV riders were past or current smokers and fewer had never smoked. ORM riders were more likely to have never smoked and consequently had less cessation ($\chi^2_{(2)}$=10.0, P<.007). Including both vehicle types, 15.3% of recreational off-road vehicle riders classified themselves as regular drinkers, 70.4% as occasional drinkers and 14.3% as non-drinkers. There were no significant age or vehicle type differences in the frequency of alcohol consumption. The quantity of alcohol consumed per day, defined as "few" = <2 drinks or "many" = >3 drinks, did not differ across age tertile. Vehicle type differences existed in the quantity of alcohol consumed per bout ($\chi^2_{(1)}$=4.66, P<.031) such that ATV riders were more likely to be heavier drinkers compared to ORM riders with 40% and 30% of the cohort, respectively, consuming "many" drinks per session.

Risky Behavior

Follow-up questions posed to the provincial cohort regarding drinking and driving revealed no age, gender or vehicle type differences with 89% of respondents reporting that they "never" drive after drinking. Reports of automobile seatbelt use revealed no differences by age, gender or vehicle type with roughly 90% of riders reporting seatbelt use "all of the time." Recreational off-road vehicle riders had a low self-reported use of illicit drugs (4.5 ± 1.3), infrequent abuse of over-the-counter medication (4.9 ± 0.6), a good perceived ability to cope with stress (4.63 ± 0.5) and a high likelihood of practicing safe sex (4.6 ± 1.1).

Work absenteeism

Off-road vehicle riders aged ≥50yrs were more likely to never miss work in a 12 month period due to sickness or injury, whereas those <50 were more likely than expected by chance to miss between 1 and 7 days, but not more than 1 week ($\chi^2_{(4)}$=15.01, P<.005). Comparison by vehicle type revealed that ATV riders were significantly less likely to miss work and ORM riders were more likely to miss 7 days or less ($\chi^2_{(2)}$=21.58, P<.001).

General disposition

Off-road riders generally viewed themselves as content people as 96.6% of all riders self-reported as either "pretty happy" or "very happy" and only 3.4% reported feeling "not too happy" or "very unhappy." There were no statistically significant differences by age, gender or vehicle type, however, every female rider reported being happy as did every rider over the age of 50 yrs.

Follow-up questions posed to the provincial cohort revealed a high level of optimism (4.3 ± 0.9) and a low incidence of feeling sad or depressed (4.5 ± 0.8). There were no age, gender or vehicle type differences on any of these variables. Overall, the group expressed a low occurrence of feeling angry or hostile (4.1 ± 0.8), but a gender difference existed (P< 0.01) such that men (4.0 ± 0.8) reported these feelings more than women 4.7 ± 0.6).

Health-Related Quality of Life

Combined group mean data from the SF-36 PCS and MCS scales are reported in Table 5.6. Differences between vehicle types were only significant for the PCS scale and are reported below separately, whereas the MCS scores were combined across vehicle types to form an overall group of recreational off-road riders.

Table 5.6. Physical (PCS) and Mental (MCS) Component Summary Scores of off-road riders and Canadian norms divided by gender and age (Young < 45yr, Old ≥ 45yr). Values are expressed as expressed as mean ± SD

			PCS	**MCS**
	Male	*Young*	53.0 ± 7.2	51.7 ± 8.6
Canadian Norms		*Old*	49.8 ± 8.8	53.9 ± 7.9
	Female	*Young*	51.9 ± 7.9	49.5 ± 9.7
		Old	48.0 ± 9.8	52.3 ± 9.0
	Male	*Young*	53.9 ± 5.0	56.3 ± 5.3
Riders		*Old*	51.1 ± 9.6	55.6 ± 7.1
	Female	*Young*	54.8 ± 4.9	57.0 ± 3.9
		Old	53.5 ± 7.1	50.2 ± 13.7

Mental Component Summary

Off-road riders (54.5 ± 7.5) have higher MCS scores than the non-riding normative Canadian population (51.7 ± 9.1, P=.001). An interaction between gender, age and riding status (off-road rider vs. non-riding population norms) was apparent for the MCS scale and is illustrated in Figure 5.3. Non-riding Canadian population norms of both genders have a gradual increase in MCS score as they age from the <45yr to the ≥45yr group. Male off-road riders did not have the same pattern of increase, as they have an elevated level while young which they maintained with increasing age until the difference between riders and normative Canadian males disappeared. Younger female off-road riders also have an elevated MCS score, but this decreased with age such that older female off-road riders score similar to normative Canadian females. Based on established score ranges associated with known health outcomes (248), the differences in the MCS scores between younger and older females for both Canadian population norms and off-road riders have meaningful implications for future health. With the exception of the youngest riders, males consistently had a higher MCS score than females.

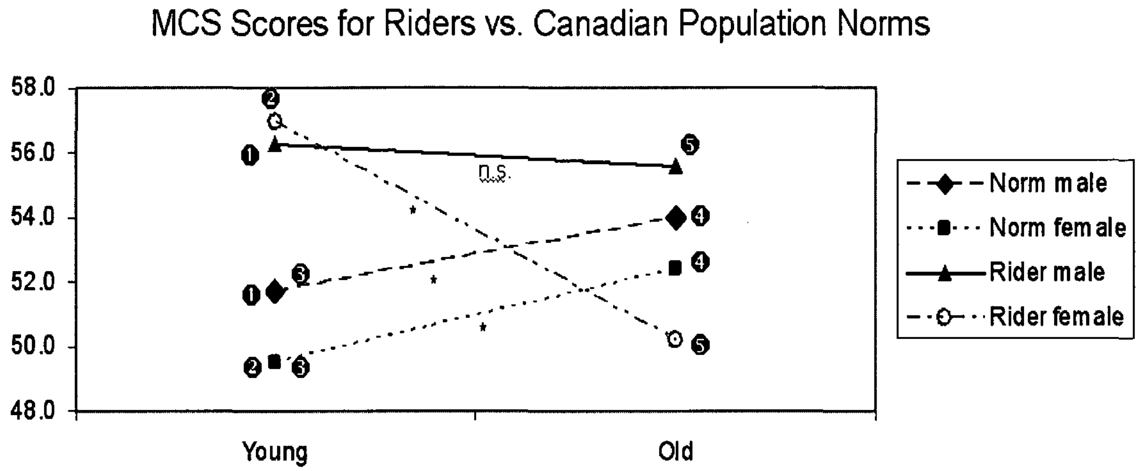

Figure 5.3. Three way interaction between age, gender and rider/non rider status on the Mental Component Summary (MCS) of the SF-36 * Significant at P<0.05 between ages, n.s = non significant.⓿ Significant at P<0.05 with corresponding number within age across gender and rider status

Physical Component Summary

Significant group mean differences were found for PCS scores between off-road riders (55.4 ± 7.1) and Canadian population norms (50.5± 9.0, P=.003). Further differences were found between ORM riders (male 54.6 ± 3.8, female 54.2 ± 6.5) who scored higher than Canadian population norms (males 51.4 ± 8.5, females 49.7 ±9.4) and ATV riders (males 49.4 ± 6.9, females 53.6 ± 4.6) who did not differ significantly from the Canadian population norms. The vehicle type PCS score differences relative to Canadian population norms are depicted in Figure 5.4.

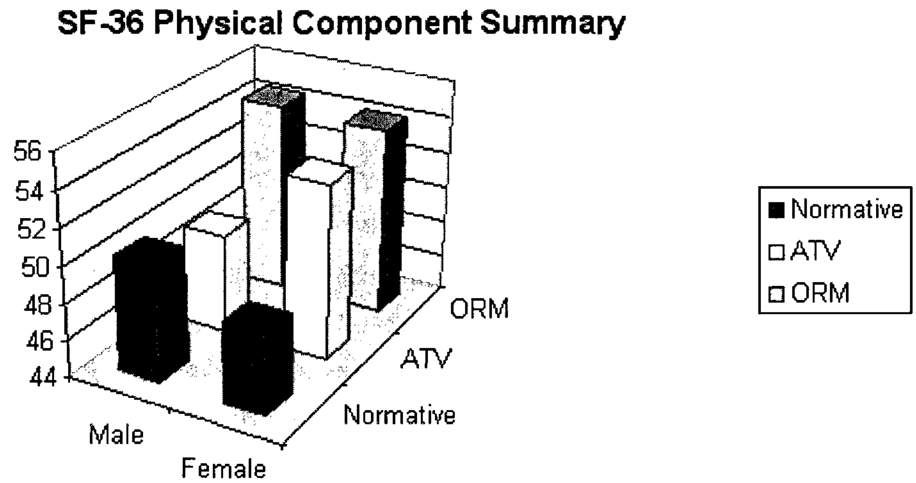

Figure 5.4. SF-36 Physical Component Summary (PCS), groups by gender and vehicle type compared with normative Canadian data. *Significantly different ($P<0.05$) from ATV and normative

5.2.4 DISCUSSION

Health Perceptions and Behaviors

Weight perception and Fast-food consumption

ATV riders' lower satisfaction with their current weight accurately reflects their excess scale weight, high BMI and elevated adiposity which were assessed and reported in an adjunct study (Manuscript I). Overall, fast-food consumption appears to be low for off-road riders compared to average Canadians. The Heart and Stroke Foundation of Canada reports that 30% of children living in North America go to a fast-food restaurant most days (100), whereas only 12% of all off-road riders and 24% of young riders (the off-road sub-group with the highest consumption) reported eating fast-food "often". This suggests that off-road riders are less likely than the general population to consume calorically dense and nutritionally deficient food on a regular basis. It is worth noting that self-reported consumption of "fast-food" is an ambiguous definition open to interpretation. It is also possible that reports were influenced by a desire to appear healthy as fast food consumption is socially viewed as a negative health behavior. Ideally an objective food diary would be more appropriate for quantification and direct comparison.

The decrease in fast-food consumption in the eldest riding group could indicate that individuals who continued to ride past age 50 had adopted healthier lifestyle habits. The adoption of healthier lifestyle habits in the ≥50yr group is also supported by a higher than expected rate of smoking cessation. However, it is not possible to determine if adopting these healthier behaviors was a cause (giving the ability for continued participation) or effect (resulting from the participation itself) of habitual participation in off-road riding.

Smoking and Drinking

Smoking prevalence in off-road vehicle riders combined, and by vehicle type, was lower than the nationwide prevalence reported by Health Canada of 23% men, 18% women (98). This could suggest that being an off-road rider decreased the risk of being a smoker. However, compared with other sporting groups (such as endurance-sport athletes) tobacco consumption seemed to be an atypical part of the accepted social culture. This effect of tobacco use amongst group members was more evident for ATV riders than ORM riders, especially considering the higher number of ORM riders who never smoked. Collectively 85.7% of the off-road riding group reported at least occasional alcohol consumption (81.6% female, 86.3% male) which was higher than the average Canadian population (76.8% female, 82% male) frequency (97). Of greater importance is the finding of larger quantities of alcohol consumption per drinking bout in ATV riders compared to ORM riders. Although a relationship between regular, moderate alcohol consumption and a decreased risk of cardiovascular disease and all cause mortality is well established (22, 106), recent literature suggests that heavy episodic drinking negates these effects and increases the risk of premature mortality (219). There is evidence that heavy drinking may reduce life-satisfaction and health-related QOL (149), although based on the reports of general happiness and QOL in the current group, this effect does not seem to be present.

Risky behavior

Despite popular opinion, recreational off-road vehicle riders do not appear to be "risk-takers" any more than the rest of the population as reflected by consistent seatbelt use while driving an automobile. The majority of riders reported wearing a seatbelt "all of the time" while the remainder wore a seatbelt "most of the time", or "some of the time" and there were no differences by age, gender or vehicle type. A rate of 90% seatbelt use falls between the Canadian population averages for urban (90.5 %) and rural (86.9%) seatbelt use, thus demonstrating that riders were not different from the average Canadian (230). In addition, off-road riders were no more likely than the general population to drive after drinking (26), they regularly practiced safe sex ("fairly often" to "always"), and had low rates of substance abuse ("almost never" to "never") – all behaviours which are commonly associated with a risky lifestyle.

Work absenteeism

ATV riders were less likely to miss work due to sickness or injury compared to ORM riders which suggests less illness and/or lower injury rates. These differences may also be explained by social class differences that may exist between the two types of vehicle riders and which are known to be associated with work absenteeism (182, 232). Further research on socioeconomic class differences between off-road riding sub-groups (vehicle types, age & gender) is needed to determine if meaningful differences that may affect health and health-related behaviours exist.

General disposition

Although the concept of general "happiness" is somewhat abstract, the finding that 96.6% of riders self-reported feelings of happiness suggests that, as a whole, this segment of the population is content and the addition of riding to the lives of these Canadians may play a role. Follow-up questions confirmed that this group consider themselves to be both positive, optimistic thinkers and persons with an ability to cope with stress "fairly often" to "almost all of the time."

Health-Related Quality of Life

The value of using the MCS and PCS summary scores is the interpretation they allow through association with known health states drawn from large databases such as the MOS. Using the content and criterion based interpretation guide for the SF-36, which allows for extrapolation of scores to expected health outcomes, along with comparison to Canadian normative data (107), PCS and MCS scores of off-road riders (Table 5.6) permit the interpretations discussed below.

Mental Component Summary

No difference existed for MCS scores between vehicle types, which indicates that ATV and ORM riders have similar feelings about mental/psychological functioning and QOL. Compared with normative Canadian data (rider % vs. norm %) and interpreted with reference to large population data from the MOS (248) these data reveal that male riders of all ages, and young female riders, had MCS scores associated with a low prevalence of feeling "downhearted or blue" (0.1% vs. 1.0%); a high likelihood of self-classification as a "happy person" (90% vs. 64%); little chance of having to cut down time at work (0.4% vs. 3.7%), accomplishing less than expected (1.9% vs. 11.5%), or working less carefully (1.0% vs. 5.3%); minor social activity limitation (2.5% vs. 7.8%); and high vitality, with 62% (vs. 36%) having lots of energy and only 3% (vs. 8%) feeling tired. Based on their MCS scores, all male and younger female riders are expected to have lower levels of stress and depression (11.5 and 18.4% respectively for riders vs. 18.4 and 29.1% for norms) and a higher overall life satisfaction (66.3%) compared to the normal population (47.5%).

Physical Component Summary

Group differences between riders and Canadian population norms were driven by the higher scores of ORM riders as opposed to ATV riders who were no different from non-riders in the general Canadian population. Based on data from the MOS published in the SF-36 interpretation guide (248), an overall score of 54.6 in ORM riders suggests that less than 30% of this group would be expected to have limitations in vigorous physical activities, whereas the ATV and non-riding Canadians have scores with an associated limitation range from 62-85%. ORM riders are expected to have a physical limitation rate for walking one block and climbing 1 flight of stairs of 0.3% and 0.6% respectively, whereas the range of limitation for ATV riders and the rest of the normative Canadian population would be 0.9 - 8.2% for walking and 3.2 - 12.9 % for stair climbing. Based on their high level of physical functioning, very few ORM riders would be expected to have physical difficulty at work (1.2%) or the need to cut down time at work (0.4%) whereas ATV and non-riding Canadians would have expected difficulties of 4.4 -16.6% and 4.1 - 9.5% would need to cut back time at work.

Given their higher level of physical functioning compared to ATV riders and non-riding Canadians, ORM riders belong to a group associated with higher levels of vitality; with 61% vs. 34-49% of group members reporting high energy levels and only 5.5% vs. 7-9% feeling tired "all or most of the time." In general, ORM riders are in a range wherein 34% (vs. 4-13%) of the population would rate their own health as "excellent".

ORM riders scored within the top quartile of the PCS rating in which approximately 15% of the population reports a recent visit to the doctor. Due to their lower PCS score an additional 5% of ATV riders and non-riding Canadians would be expected to have had a doctor's visit in the past month. Similarly, those who place in the top quartile of PCS scores are less likely to have one or more cardiovascular risk factors or disease manifestations including hypertension, congestive heart failure, myocardial infarction, diabetes, angina, chronic lung disease, arthritis, back pain/sciatica, or weakness/limitations in arms or legs (33% ORM vs. 55% ATV and non-riding Canadians).

It is known that those who accumulate too much or too little PA show an association with a lower health-related QOL (39) at all ages. High scores on the MCS and PCS suggest that off-road riding likely presents an appropriate dose of PA in this regard. Research has consistently shown that PA is related to the postponement of disability and increased independent living in older adults. Thus riding may play an important role into older age, possibly even beyond the age represented in the current study (221).

As with any cross-sectional study, this investigation was limited in its ability to establish cause and effect relationships with off-road riding participation and behaviour or QOL. Further investigation is required to establish if participation leads to these outcomes or if an uncontrolled selection factor is affecting participation rates in the activity as a whole or simply the participants of the current study. As this was the first study of its kind we are unable to determine if participants were representative of all

Canadian riders, however, the local cohort did reflect the national cohort very closely. Further investigation, including documentation of sociodemographic factors, which were not collected in the current investigation, will aid in determining the effects of activity participation on off-road riders.

5.2.5 CONCLUSIONS

Habitual recreational off-road riders appear to be a happy group who are mostly content with their lives and have a high QOL, possibly as a result of their participation in recreational off-road riding. Riders had a lower prevalence of smoking and a higher prevalence of alcohol consumption compared to Canadian population norms, with ORM riders revealing a lower prevalence of smokers or heavy drinkers compared to ATV. Off-road riders did not consume fast-food excessively and were no more prone than the general population for participating in risky behaviour such as drinking and driving, recreational drug use, unsafe sex or not wearing a seatbelt while operating an automobile. Both ATV and ORM riders revealed high QOL based on their MCS scores. Being an off-road rider had greater effects on the QOL of younger participants than older participants and was more influential amongst male riders than females across the lifespan. Overall, off-road riders had higher levels of physical functioning than Canadian population norms. This elevated PCS score, which is associated with lower physical limitations and health problems, was attributable primarily to ORM riders as opposed to ATV riders who were no different from the average Canadian. It is possible that the higher levels of vitality, general happiness and QOL of recreational off-road vehicle riders is a consequence of participation in the sport.

Acknowledgements:

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5.3 Manuscript III

The Physiological Demands of Off-Road Vehicle Riding

Burr, Jamie F., Jamnik, Veronica K. , Shaw, Jim A., Gledhill, Norman. The Physiological Demands of Off-Road Vehicle Riding. *Manuscript in Preparation*

5.3.1 INTRODUCTION

Examination of the physiological and psychological characteristics of recreational off-road vehicle riders has demonstrated that persons who are habitual off-road riders have some health, fitness and QOL advantages over the normative population (Manuscript I and II). Many of these changes, which are vehicle type dependent (all-terrain vehicle; ATV vs. off-road motorcycle; ORM) manifest in riders with increasing age and result from years of involvement (Manuscript I). It is unclear however, if the observed attributes of Canadians who habitually ride recreational off-road vehicles are different from the normative Canadian profile as a result of participation in the off-road riding itself, or if some underlying selection factor is responsible for the group differences. To more fully understand the health-related fitness consequences of participation in recreational off-road vehicle riding, an evaluation of the acute physical demands of riding is required.

The majority of scientific literature pertaining to the physical demands of off-road vehicle riding is specific to "motocross" racing, which is a competitive form of ORM riding in which riders navigate a man-made track consisting of obstacles and jumps. The heart rate (HR) response (≥90% HRmax) and oxygen consumption (70-95 %VO_2max) associated with motocross racing indicates that this sport is of extremely vigorous intensity and is associated with a considerable metabolic demand and physiological stress (18, 135, 136). However, the physical demands noted in competitive sprint-based motocross, which typically lasts <30 min, likely do not reflect the demands of the average recreational trail ride which is of considerably longer duration. It is also unlikely that the average Canadian recreational off-road vehicle rider chooses to cover riding terrain of the same difficulty or at the same speed as competitive motocross racers. To date recreational ORM and ATV riding have not been examined.

The purpose of this study was to characterize the physiological demands of recreational off-road vehicle riding under typical riding conditions using habitual recreational off-road vehicle riders. A secondary purpose was to make comparisons of the physical demands of off-road vehicle riding between vehicle types and to common recreational activities. We hypothesized that the physical demands of riding an off-road vehicle would be comparable to other, more commonly accepted, recreational activities and that the physical demands of riding an ORM would be greater than those involved in riding an ATV. We further hypothesized that the demands of riding an off-road vehicle would be of sufficient intensity to be associated with health-related fitness adaptations.

5.3.2 MATERIALS AND METHODS

5.3.2.1 Assessments

Composition of a Typical Ride

A nationwide survey was distributed to off-road vehicle riders (n=303; ATV=141, ORM=162) soliciting information regarding frequency and duration of occurrence of terrain features normally encountered on a ride. This informed the composition of a representative riding trail to be used during the assessment of physical demands. To clarify survey results and ensure accuracy when designing a representative trail riding course, focus groups were held (ATV =17, ORM = 20) to elaborate on survey responses, aid with interpretations and clarify questions of the research team. Prior to measuring the physical demands of riding, the lead researcher visited each selected site and with the guidance of an expert familiar with the local trails, developed a representative off-road trail circuit conforming to the information gained from the nationwide survey. Each course was scaled such that one lap contained all-terrain types of a typical ride and took an average rider approximately 20 min to complete. A ride length of 20 min was selected as it allowed sufficient time for data collection without causing undue discomfort to the participants who were required to wear the measurement apparatus throughout. Testing took place in a variety of summer weather conditions, with the majority of days clear and sunny with a mean temperature of 28 degrees Celsius (range 16-34).

Physical Demands Analysis

5.3.2.2 Participants

Habitual recreational off-road vehicle riders (n= 128) >16 years old, of both genders and both vehicle types (ATV males = 43, females = 13; ORM males 57, females = 15) were recruited from local off-road riding clubs. Male participants were 44 ± 12.9 yr, 179.1 ± 6.5 cm and 91.7 ± 20.8 kg and female participants were 38 ± 12.1 yr, 165.9 ± 7.4 cm and 72.2 ± 18.0 kg. The mean participant age was 41 ± 12.5 yr with representation from all age groups 16-29 (18.8%), 30-49 (49.2%) and 50+ (32%). This study was approved by the University Human Research Ethics Review Board and in accord with research ethics guidelines written informed consent was provided by all participants, with those under 18 yr also providing parental consent, following verbal explanation of procedures.

At the onset, riders were led through the trail for accommodation and safety. All riders used their own off-road riding gear and vehicle to avoid the necessity for habituation to new equipment. Prior to data collection, which is detailed below, participants rode laps of the course for varying amounts of time (range from 0 to 140 min, mean 48 ± 24.2) at a typical riding pace. This pre-testing ride volume was divided into quartiles of time (<30 min, 30-59 min, 60-89 min and ≥90 min) and used to determine if the demands of riding changed as the duration of a ride increased. Speed and distance were collected using portable GPS technology (T6, Suunto Oy, Vantaa, Finland). To determine the total time spent sitting and standing while riding, a randomly selected sub-set of participants (n= 40) were monitored using a specifically designed pressure sensitive seat switch with an automatic timing device to record the total time the rider's buttocks were not in contact with the seat. Standing time was subtracted from total ride time to calculate the sitting time.

Aerobic Involvement

The acute cardiorespiratory demand of off-road riding was assessed using ambulatory oxygen consumption (Cosmed Fitmate, Rome, Italy) and HR monitoring. Following the pre-testing ride of varying lengths, riders were monitored for one complete lap of the course. The analyzer, which has been shown to be valid and reliable for use with adults (169), was worn by participants in a backpack with the sampling lines running from the top of the bag, over the rider's shoulder and to the mouthpiece which passed through the front of a specially modified helmet (Figure 5.5). The mouthpiece, which contained both the open end of the expired air sample line and a flow meter, was secured in place by the chin guard of the helmet and enough length was provided in the sampling lines that the rider's movement was unrestricted. HR was recorded using a chest strap which transmitted information to a wristwatch where it was stored. A sampling frequency of five seconds was used, based on pilot study experience, to avoid data loss due to sampling noise. Data was uploaded to a computer using Suunto Training Manager Software (Suunto Oy, Vantaa, Finland) and visually inspected for noise outliers. Following the graphical confirmation of steady state exercise, points which fell more than 2 SD and did not represent a systematic divergence from the mean were considered outliers and were removed. In follow-up analysis, this represented very few data points and had no significant effect on the mean.

Figure 5.5. Ambulatory oxygen consumption measurement while riding an off-road vehicle. The rider's nose is plugged and all expired air is expelled through the mouthpiece which contains a volume meter and expired air sample line held in place by the modified chin guard of the helmet. **Inset top left:** reverse angle view of the metabolic computer (with protective padding) in the backpack as worn by riders.

The majority of riders (n=90) also participated in a laboratory exercise test with analysis of expired gas using open circuit spirometry (S-3A/II oxygen, CD-3A carbon dioxide, AEI Technologies, Pittsburgh, Pa) to determine VO_2 and HR relationship during a progressively ramped treadmill test to VO_2max using 2 min stages. Participants began walking (1.6 $m \cdot s^{-1}$, 0% elevation), progressed to a slow jog (2.2 $m \cdot s^{-1}$, 0% elevation) and then ramped with 0.45 $m \cdot s^{-1}$ increases until the individual's maximal safe running speed was reached, followed by 2% incremental increases in elevation. If subjects were unable to jog/run, the speed was adjusted to accommodate the fastest pace they could maintain and incline was increased incrementally as above. The test was terminated when: VO_2 did not increase at least 150 $ml \cdot min^{-1}$ with an increase in workload, when HR did not increase with increases in exercise intensity, or when the participant reached volitional fatigue and had an RPE greater than 17 on the Borg 6-20 scale (104). This allowed for comparison of the metabolic demand recorded while riding to the laboratory HR-VO_2 relationship throughout sub-maximal to maximal workloads (Figure 5.6).

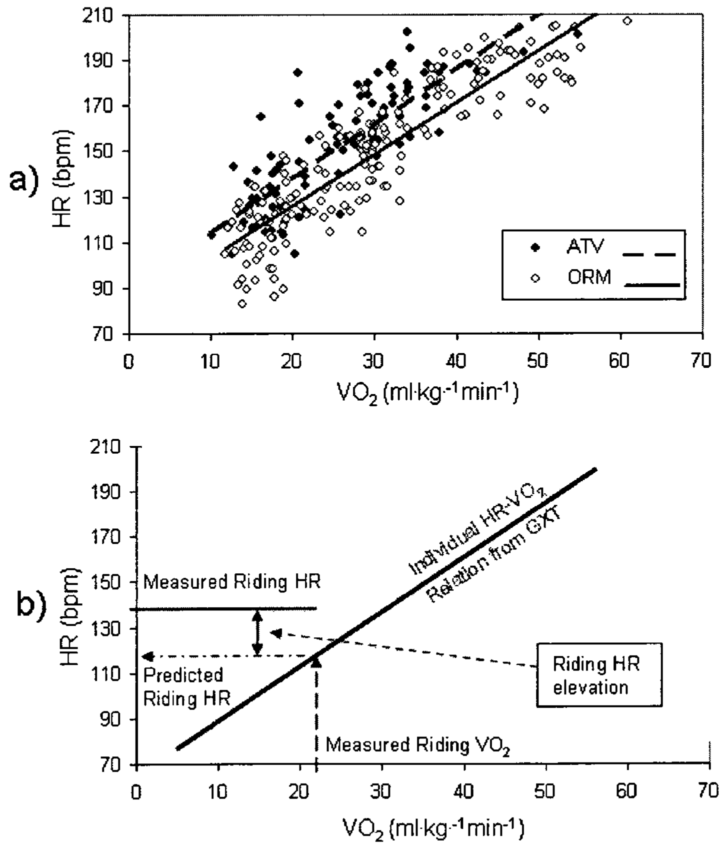

Figure 5.6. a) Group HR-VO_2 relationship of off-road motorcycle (ORM) and all-terrain vehicle (ATV) riders during a treadmill graded exercise test. Each participant is represented at walking pace (1.6 $m \cdot s^{-1}$, 0% grade), jogging (2.2 $m \cdot s^{-1}$, 0%) and at VO_2max **b)** An example of the determination of an individual rider heart rate elevation while off-road riding above the laboratory treadmill levels using the linear regression of HR-VO_2 determined during the exercise test and the measured VO_2 and HR while riding.

For analysis, the aerobic component of riding was described as both the mean $\%VO_2max$ and as the cumulative percentage of time spent above each intensity; 40, 50, 60, 70 80, and 90 percent of VO_2 reserve ($\%VO_2R$). To determine whether the HR response while riding was artificially elevated above the metabolic demand of the activity, we created a linear regression of HR and VO_2 for each rider to compare the riding HR to the laboratory exercise test HR, matched for oxygen consumption (Figure 5.6 b). The difference between the riding HR and the predicted riding HR, estimated from the linear regression of the graded exercise test, was calculated to determine if any group showed an inflation in HR over the metabolic demands of riding.

Anaerobic Involvement

A lactate sample was taken via a finger prick blood sample from each rider at the completion of the representative course. A stopwatch was started immediately upon riding cessation and a blood sample was taken one min post-riding which allowed removal of riding gloves and preparation of the hand. A one min rest period protocol was used based on the work of Heck et al. (101) and under the assumption that lactate would have equilibrated throughout the systemic circulation during the prolonged steady state ride. To maintain consistency, a one min post-exercise blood lactate sampling time period was also used following the laboratory maximal treadmill test for comparison with riding values.

Perceived Exertion

Riders reported their rating of perceived exertion (RPE) using the Borg 6-20 scale (30) considering the ride as a whole (RPEavg), and also during the part of the ride that they considered to be the most physically demanding (RPEmax).

Muscular Strength and Power Involvement

Muscular strength was assessed both pre and post-riding to determine if off-road vehicle riding is associated with quantifiable strength decrements. The assumption of this testing was that if riding is a fatiguing physical activity (PA), decreases in maximal strength would be observed after a typical ride. Hand grip strength was measured using a dynamometer (Smedley Hand Dynamometer,Stoelting Co, Wood Dale, Ill) adjusted to the second knuckle and three trials were allowed per hand, alternating hands each trial with maximum grip strength recorded. Upper body push and pull strength were assessed using a specifically designed isometric spring-resisted device which allowed for quantification of both push and pull strength at a standardized elbow joint angle of 110 degrees. Three trials were allowed, alternating push and pull with the highest value recorded. Leg power was quantified using a four jump repeated jumping protocol on a digital timing mat (Just Jump; Probotics, Huntsville, AL) which has been shown to be a valid method for assessing jump height (142). Subjects were instructed to jump four times as high and as quickly as possible without pausing between jumps, while keeping their hands on their hips to control for arm swing (43). This protocol allowed for the quantification of; 1) average jump height, 2) time on the ground between jumps (ground time) and 3) power factor, which is the air time divided by the ground time. For analysis, post-riding strength measures were subtracted from pre-riding measures and expressed as a fatigue score. Using these fatigue measurements, z-scores were calculated for each individual measure. For a greater power to detect fatigue, right and left hand grip, push strength and pull strength z-scores were summed to create a composite upper body fatigue score, referred to as the upper body fatigue index.

5.3.2.3 Statistical Analyses

Aerobic exercise intensities, riding characteristics (speed, standing time), lactate measurements, deviation in riding HR from the exercise test HR-VO_2 regression and muscular fatigue scores were compared across vehicle type, gender and age (16-29, 30-59, >50yr) using a 2x2x3 factorial ANOVA with post-hoc Bonferonni comparisons. An a priori power calculation, using VO_2 as the prime variable of interest, revealed the necessity of individual sub-group (vehicle type x gender) participation of n $\geq$13 to achieve $\geq$80% power to detect group differences of 5 $ml \cdot kg^{-1} \cdot min^{-1}$. Pre-post strength measures were examined using Wilks' Lamda repeated measures ANOVA to determine whether strength differed before and after riding. We examined the association between total riding time including ride time before data collection and RPE using Pearson correlation to determine if riders reported a higher RPE as a result of accumulated fatigue. Pearson correlation was further used to examine the association between RPE and end-ride lactate as well as standing time vs. work of riding and average speed. All analyses were performed using SPSS software (version 16.0; SPSS Inc, Chicago IL). Significance for all tests was set a priori at $p \leq .05$. Results are reported as mean ± SD.

5.3.3 RESULTS

Composition of a Typical Ride

The components of a typical off-road trail ride by vehicle type are presented in Figure 5.7. Differences were reported regarding the estimated trail width selected by ATV vs. ORM riders since the larger 4-wheeled ATVs do not fit on the narrow "single-track" trails often travelled by ORMs. Riders reported a perceived importance of standing while negotiating rough and/or difficult terrain and a belief that the use of this technique would greatly affect the demand of riding. The duration of an off-road trail ride varied between vehicle types with ORM riders reporting a typical duration of 60-120 min and ATV riders 120-180 min.

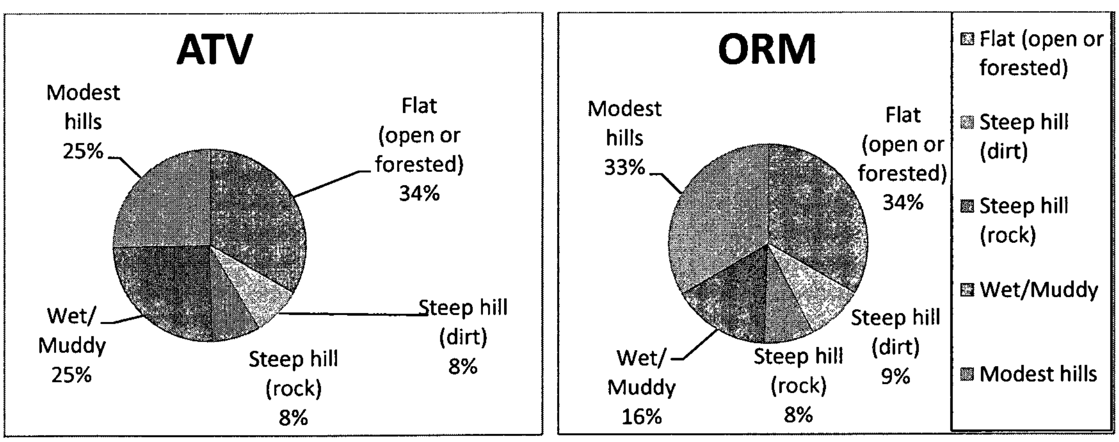

Figure 5.7. Percentage of a typical off-road ride spent navigating specific terrain features divided by vehicle type.

Physical Demands Analysis

General Riding

On average, riders required 24.2 ± 11.8 min to complete the 9.4 ± 4.0 km ride with no difference between ATV and ORM. Riding speed (mean 25.0 ± 8.6 km·h) differed among age groups with those in the 16-29 yr age group riding significantly faster (≈10 km·h) than both the 30-49 and >50 yr groups (p=.003). No relationship existed between years of riding experience and riding speed. There were no differences in riding speed between vehicle types or genders. The percentage of time spent standing on a typical ride was greater in ORM riders (62.0 ±28.3%) than ATV (23.1 ± 27.1%) riders (p=.003), but no differences existed among age groups or between genders. No relationship existed between time standing and riding speed or metabolic demand (VO_2).

Aerobic Involvement

The mean VO_2 requirement while riding an off-road vehicle was significantly different between vehicle types with a mean requirement ($ml \cdot kg^{-1} \cdot min^{-1}$) of 12.1± 4.9 for ATV and 21.3 ± 7.1 for ORM (p=.002). The absolute cost (L·min) of riding an ORM (1.6 ± 0.7) was higher than that required to ride an ATV (1.0 ± 0.7, p=.006). There were differences in VO_2 while riding between men and women (1.5 ± 0.7 and 0.9 ± 0.5 L·min respectively, p=.001), but no difference existed among age groups. The %VO_2max while riding was higher in ORM vs. ATV riders (51.3 ± 15.3% vs. 39.3 ± 19.9%, p=.004) with male riders of both vehicle types typically working at a higher %VO_2max than females (49.9 ± 16.9% vs. 39.3 ± 18.8%, p=.016). ORM riders had a higher HR while riding compared to ATV riders (141.3 ± 22.9 bpm, 123.1 ± 19.4 bpm respectively, p=.003) and there was a difference between age groups with the youngest riders exhibiting higher HR than the oldest riders (≈ 9bpm; p<.05). No association existed between the metabolic demand of riding and years of riding experience. There was also no evidence that the demands of riding change as the ride increases in duration, as there was no association between VO_2 and pre-test ride volume.

Riding an ATV was approximately 4.6 $ml \cdot kg^{-1} \cdot min^{-1}$ easier than walking at 1.6 $m \cdot s^{-1}$ with no incline for ATV riders (p<.001). The same comparison between ORM participants revealed the work of riding an ORM to be harder than walking, but 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$ less than jogging at 2.2$m \cdot s^{-1}$ with no incline (p<.001). Using linear regression, the difference between individual mean riding HR and the HR at the equivalent VO_2 during the treadmill test (Figure 5.6) revealed a HR elevation in both ATV (8.6 ± 20.7 bpm) and ORM (14.4 ± 20.0) in response to the riding, with no differences in the elevation by age, gender or between vehicle types.

The metabolic demand of riding, expressed as the cumulative proportion of time spent above a given $\%VO_2R$, is presented in Figure 5.8. Based on the typical ride length ranges of 60-120 min for ORM and 120-180 min for ATV, cumulative time per riding session above each 10% increment in $\%VO_2R$ is presented in Table 5.7.

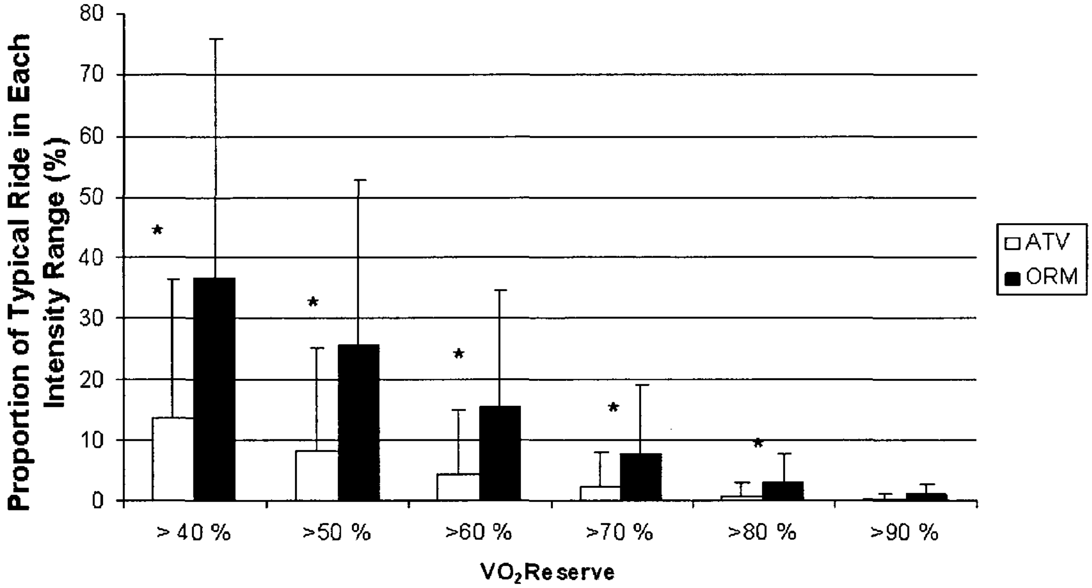

Figure 5.8. The cumulative proportion of a recreational trail ride in each exercise intensity range (%VO_2 Reserve) and by vehicle type. * Significantly different proportion of ride spent at given intensity between ATV and ORM $p<.05$.

Table 5.7. Cumulative time (min) spent in each exercise intensity range (%VO_2 Reserve) above the threshold required for changes in fitness (40 %VO_2 Reserve) during a typical 60-120 min off-road motorcycle (ORM) or 120-180 min all-terrain vehicle (ATV) ride.

Intensity	Cumulative Time (min/ride)	
(%VO_2 Reserve)	ATV	ORM
> 40 %	16.2 - 29.2	22.1 - 26.5
>50 %	9.8 - 17.7	15.4 - 18.5
>60 %	5.4 - 9.7	9.3 - 11.2
>70 %	2.6 - 4.8	4.7 - 5.6
>80 %	1.0 -1.7	1.9 - 2.2
>90 %	0.4 - 0.6	0.7 - 0.8

Anaerobic Involvement

Mean post riding blood lactate was 3.4 ± 2.2 mmol·L with no difference between vehicle types or age groups. Men (4.2 ± 2.9 mmol·L) had a significantly higher post-riding lactate value than women (2.7 ± 1.8 mmol·L, p=.012). Compared to post-exercise test levels, male and female ATV riders were respectively working at 35% (3.8/11.7 mmol·L) and 26% (2.4/9.3 mmol·L) and ORM riders at 39% (4.4/12.8 mmol·L) and 36% (2.9/10.9 mmol·L) of peak lactate levels while riding.

Perceived Exertion

Within vehicle types, all riders rated their perceived exertion similarly with no divergence in RPEavg or RPEmax among age groups or between genders. Considering their ride as a whole, ORM riders reported a higher RPEavg (13.5 ± 2.0 ORM, 11.8 ± 2.7 ATV, *p*=.007) and RPEmax (15.5 ± 2.2 ORM , 13.6 ± 2.9 ATV, *p*=.002) than did ATV riders. RPEavg was similar to their RPE while jogging at 2.2 $m \cdot s^{-1}$ during the graded exercise test. Pre-testing ride time, by quartile, showed no effect on either RPEavg or RPEmax. There was no correlation between riding lactate and RPEavg or RPEmax.

Muscular Strength and Power Involvement

ORM riders showed a decrease in both left (0.7 ± 5.2 kg) and right (1.8 ± 6.6kg) grip strength and ATV riders an increase in left (1.7 ± 5.6 kg) and right (1.8 ± 6.5 kg) strength ($p<.05$) as a result of riding. Changes in hand grip strength in both ORM and ATV did not differ between the left and right hand, nor did right or left hand dominance relate to the increase or decrease in scores. Further, there was no influence of gender or age. Push and pull strength decreased 1.5 ± 13.3 kg and 3.4 ± 11.6 kg respectively in ATV riders and 4.2 ± 17.3 kg and 2.6 ± 9.4 kg in ORM riders ($p<.05$), but did not differ by age, gender or vehicle type. There was a significant difference in the upper body fatigue index score between ORM and ATV as ORM fatigued to a greater extent as a result of riding ($p=.028$), but no differences among age categories or between sexes. There was no fatiguing effect of off-road riding in either jump height or power factor. However, an interaction occurred for ground time between age and sex ($p=.037$) such that riding caused the oldest female riders to increase ground time to a greater extent than the two younger female age groups. No such effect occurred in males.

5.3.4 DISCUSSION

This is the first study to conduct a detailed physiological examination of recreational off-road vehicle riding and consider the potential health and fitness effects that participation in this activity may have on Canadians. In general, off-road riding was found to impose a true physiological demand which would be expected to have beneficial effects on health and fitness according to current PA recommendations (96, 186). These objectively measured demands of off-road vehicle riding can be used to refine previously estimated levels of this type of alternative PA in future studies and in the commonly referenced compendium of PA (4).

Physical Demands Analysis

Aerobic Involvement

ATV and ORM riding elevate oxygen consumption by approximately 3.5 and 6 times resting (metabolic equivalents; METs) respectively. According to current American College of Sports Medicine (ACSM) guidelines (96) these MET levels are considered moderate intensity with ATV and ORM being at the lower and upper ends of the moderate intensity spectrum respectively. Given the variability in the rides, some individual ATV rides would be classified as light intensity activity (<3 METs) and some ORM rides as vigorous activity (>6 METs) (4, 96). Despite possessing a higher VO_2max than ATV riders (43.3±8.3 $ml \cdot kg^{-1} \cdot min^{-1}$ vs. 33.5±7.1 $ml \cdot kg^{-1} \cdot min^{-1}$), ORM riders still work at a higher $\%VO_2max$ while riding. Using HR alone, the demands of riding belong to the category of "hard" exercise (110), but this value is likely inflated due to riding related psycho-emotional responses (136). There was a disproportionate increase in HR compared to VO_2 while riding both an ORM (14 bpm) and ATV (9 bpm). This increase in HR was also likely influenced by repeated isometric contractions of the forearms which have been suggested to increase HR during activities such as rock climbing (209) and motocross riding (135, 136). Although exercising blood pressure was not monitored in the current study, based on both the aerobic and resistance exercise related demands of riding and the established relationship with blood pressure response (6, 141, 151, 152), it seems likely that systolic blood pressure would increase while riding. Combined with the effect of an inflation in HR over the objectively measured metabolic demands, it is possible that the rate pressure product increases dramatically in riders. This has potential to present a problem to those with occult heart disease (197), and is an area for future research.

ORM riders stand for a much larger portion of a typical ride compared to ATV riders. It is commonly believed by riders that standing allows them to travel over rough ground more quickly and easily; however this was not confirmed in the current study as we found no relationship between standing time and speed or VO_2.

Table 5.8. The metabolic demand of common physical activities for comparison with off-road riding.

	Sport	Level of play	Participants (#, age and gender)	Mean relative VO_2 ml.kg-1.min-1 (Absolute VO_2 L/min)	MET	Percentage of VO_2max	Percentage of HRmax	Lactate (mmol/L)	RPE	Net energy Expenditure (k/cal)
Recreational	Off-Road Riding	Recreational (Current Study)	n=128, 43 ± 13, male and female	12.1 ATV, 21.3 ORM (1-1.6)	3.5-6	42.5 ATV, 51.3 ORM	69 ATV, 78 ORM	3.5 ATV, 4.1 ORM	11.8 ATV, 13.5 ORM	218-436 (1hr)
	Golf	Recreational, pulling cart [1]	n=20, 54 ± 7.7 yr, male	14.7† (1.2)	4.2	46	-	-	-	458 (9 holes)
	Alpine Skiing	Recreational, ski instructor guided [2,3]	n=9, 52.6 ± 5.1, 1 female, 8 male / n=10, 22.7 ± 4, female	13.6-18.6 (1-1.4)	4-6	30-60	48-94	0.7-6.0	6-17	215-320 (1hr)
	Active Video Games	Leisure time, dance video game [4]	n=19, 21.8 ± 3.5, male	13.1-25.2 (1.1 – 2)	4-7	23-50	48-80	-	11-14	210-516 (1hr)
	Racquetball	Recreational [5]	n=14, 23.1 ± 2.8, 3 female, 11 male	27.3 (2.2)	8	-	73*	-	12.9	551 (1hr)
	Rock Climbing	Non-competitive (outdoor) [6]	n=8 43 ± 8, male/ n=5, 31 ± 8, female	27.5-28.3 (1.6 -2.0)	8	70-72	84-93	1.6-3.3	-	400-503 (1hr)
		Elite climbers (indoor) [7]	n= 6 male, 3 female, 18.2 ± 5.6	20.1-22.7 (1.3 – 1.4)	6-7	44-50	67-75	-	-	310-372 (1hr)
	Ice Hockey	Recreational [8,9]	n=19, 42.7 ± 6.9, male / Junior and men	32-35 (2.4 – 2.8)	10	-	50-85	-	-	675-713 (1hr)
Competitive	Motocross	Elite and non-elite competitive	n=7 elite 23 ± 4, n= 5 recr. 28 ± 4, male / n=9, 21± 4, male	34-42 (2.6 – 3.2)	10-12	69-94	95-98	4-6	-	624-657 (1hr)
	Mountain Biking	Elite level course, competitive and elite riders [12]	n=5, 21 ± 4 yr, male	63 (4)	18	84	90	30% above 4 mmol/L	-	1105 (1hr)
	Nordic Skiing	National level	n=10, 17.9 ± 1yr, male / n= 5 18 ± 1, female	53-55 (3.8 – 4)	15-16	72	93	5.9-10.5	-	840-1008 (1hr)
	Water polo	Competitive, non elite (5 minute quarters)	n= 8, 25 ± 5.7 yr, male	40-50 (3 - 4.3)	11-14	75-94	85-99	3.8-3.9	-	485-617 (20 min)
	Tennis	Elite	n=20, 26 ± 3.7, male	27.3 - 29.1 (2 – 2.2)	7.8 -8.3	51	60-78	2.1	-	510-534 (1 hr)
	Basketball	Competitive Collegiate level (NCAA)	n=6, 21± 1.0, male / n=6, 20 ± 1.3, female	33.4 - 36.9 (2.2 – 3.4)	9.5-10.5	64.7 – 66.7	88 - 89	3.2 4.2	13 - 14	379 -582 (40 min)
	Soccer	Amateur competitive	n=7, 25.3 ± 1.2, male	34-48 (2.5 – 3.5)	10-14	70-94	82-97	1.9-13.4	2.3-9.1	657-949 (1hr)

Absolute VO_2 values calculated using activity representative participant weight (kg) from published literature. * calculated using estimated HRmax (220-age). †Calculated from MET, healthy adult only. Energy expenditure (k/cal) estimated using MET (minus resting) multiplied by body weight and duration

Comparison of VO_2 while riding an ATV with sub-maximal treadmill VO_2 values revealed the aerobic work of riding an ATV to be less taxing than walking at 1.6 $m \cdot s^{-1}$. Because the habitual ATV riders in the current study were not avid exercisers, reached VO_2max at relatively low treadmill workloads and had perceptibly inefficient gaits, it is likely that the work of walking was exaggerated. This highlights the potential importance of alternative PA such as off-road riding to promote PA in a group that might otherwise forgo exercise altogether. ORM riders, had moderately high aerobic fitness, but were also inefficient at translating the work of running into high speeds on the treadmill when compared to true runners. Thus, the finding that riding an ORM was more taxing than walking and less than a slow jog gives a reasonable reference for this particular group. However, comparison between the physical demands of off-road riding and other common sports is also informative.

Table 5.8 reveals the aerobic demands of off-road riding to be in a similar VO_2 range (12-23 $ml \cdot kg^{-1} \cdot min^{-1}$) as other common self-paced individual activities (i.e. golf (62), rock climbing (192, 209), alpine skiing (203, 205) and active video gaming (207)) whereas intermittent sprint-based team sports (hockey (21, 206), soccer (69), water polo (87), basketball (166) and predominantly aerobic endurance sports (cycling (116) and nordic ski racing (139, 251) tend to have a higher aerobic demand. Although the acute aerobic demand and temporally standardized caloric expenditure of an off-road vehicle ride is lower than sports such as competitive mountain biking, the likelihood of PA adherence and duration are important considerations. If the caloric expenditure of a 60 min cross-country mountain bike ride (1105 kcal at elite race pace) is compared with a typical duration (120 min ORM, 180 min ATV) off-road vehicle ride (654 kcal ATV, 872 kcal ORM) the caloric discrepancy in Table 5.8 greatly decreases.

If performed on "at least 5 days of the week" for a duration of ≥30 min, off-road riding would fit the ACSM's updated PA recommendations as an acceptable form of PA to stimulate changes in health-related fitness and health; however, the typical pattern of long duration and infrequent bouts reported by habitual riders may be less effective considering the ACSM's statement that aerobic endurance training <2 days per week, at <40-50% of VO_2R generally does not provide sufficient stimulus for maintaining fitness in healthy adults (2). Furthermore, given that only 14% of an ATV ride and 38% of an ORM ride is within the intensity range required to stimulate changes in aerobic fitness (Figure 5.8), exercise "training" time, as opposed to simple ride duration, must be considered in PA guideline adherence. In a ride lasting from 120-180 min, an ATV rider only spends 16-30 min above the level required to stimulate changes in aerobic fitness. Similarly, ORM riders are above this level for 22-27 min during a 60-120 min ride. Nevertheless, given the guideline of approximately 450-750 $MET \cdot min \cdot wk^{-1}$ of combined moderate and vigorous intensity PA, habitual riders are accumulating between 420 $MET \cdot min \cdot wk^{-1}$ (3.5 MET x 120 min, ATV) and 720 $MET \cdot min \cdot wk^{-1}$ (6 MET x 120 min, ORM), which approximates this recommended value. It has yet to be determined if infrequent longer bouts summing to the same absolute weekly energy expenditure lead to the same health benefits as shorter duration, frequent exercise. This particular dose-response issue examining the effects of long duration low frequency exercise on health-related fitness outcomes is an area for future research.

Anaerobic Involvement and Perceived Exertion

Lactate levels measured at the end of exercise confirmed that off-road vehicle riding is primarily aerobic exercise (101). We did not have the capacity to measure lactate throughout the duration of a ride. However, assuming that the values observed post-ride were representative of mean riding levels, off-road riding is at an intensity just below the level of uncompensated blood lactate accumulation (4 mmol·L). Based on participants' common reference to "arm-pump", or a rigid contracture of the forearm musculature, which occurs from squeezing the handlebars while riding, we speculate that riders purposely adjust riding speed to maintain their exercise intensity below a level which could impair their ability to safely operate the vehicle due to the arm muscle pain associated with lactate accumulation. Blood lactate accumulation following the graded exercise test was considerably higher than levels recorded while riding, supporting our postulation that riders adjust-down the riding workload to avoid acidosis despite a physiological ability to function at higher anaerobic workloads and blood lactate levels.

Perceived exertion is closely, but not perfectly, related to HR response because it is influenced by many physiological processes and has input signals from the peripheral muscles and joints, cardiovascular and respiratory systems and central nervous system (30). When allowed to self-select a training intensity, both fit and unfit individuals choose an intensity of approximately 60% of VO_2max, or 11-14 RPE (61) and self-adjust their overall power output accordingly to maintain this level. In this study, both ORM and ATV riders selected exercise intensities within this RPE range, with ORM riders choosing a slightly higher RPEavg and RPEmax corresponding to the greater aerobic work they were accomplishing. While jogging on the treadmill within this 11-14 RPE range, both ATV and ORM participants in our study were working at approximately 60-65 %VO_2max as expected; however, while riding at the same RPE, participants were only working at between 43-51 %VO_2max.

Off-road vehicle riders perform considerable physical work using their arms and upper body while riding, evident in the observed fatigue in this study and as documented using electromyographic monitoring (EMG) in an examination of motocross riding (136). Because upper body work involves relatively small muscle groups compared to locomotive work using the legs (i.e. running or cycling), VO_2 is lower and these smaller muscle groups of the upper extremities are pushed toward anaerobic energy pathways. Repeated isometric contractions are also likely to occlude blood flow thus restricting oxidative pathways further. Although the lactic acid production of these smaller muscles does not greatly elevate systemic blood lactate levels, riders likely perceive the local acid build-up as a high level of exertion thus explaining the elevated RPE scores.

Muscular Strength and Power Involvement

Off-road vehicle riding caused fatigue in both the upper and lower body indicating a strength involvement to off-road vehicle riding which corroborates evidence of high EMG muscle activation in motocross riders (136). Unexpectedly, we observed an increase in ATV grip strength from pre to post, potentially explainable as a stimulatory effect of riding. Elite motocross riders have been shown to have elevated urinary catecholamine levels (adrenaline, noradrenalin, dopamine) following a simulated race (136) and there is evidence that forearm strength can be augmented as a result of sympathetic nervous stimulation caused by an unexpected loud noise (115). Although it is unlikely that the moderate intensity off-road riding caused a stimulatory effect itself, it is possible that this effect was driven by the thrill of riding and/or the fear of a fall. This makes the observed decrease in ORM grip strength stronger evidence of fatigue as the effect of riding was powerful enough to overcome any excitatory effect in these riders. Considering previous research comparing the grip strength of habitual recreational off-road riders to the normative Canadian population (Manuscript I) in which there was no improvement in strength (except in older riders), it appears that off-road riding affects muscular endurance more so than strength.

Increases in musculoskeletal fitness are beneficial in attenuating weight gain, preventing obesity and improving insulin sensitivity as well as a host of other risk factors for disease (240, 241). Upper body push and pull strength showed a clear fatiguing effect of riding in both vehicle types signifying an upper body strength requirement to off-road riding which could lead to beneficial training increases in musculoskeletal fitness. An effect of lower body fatigue was only observed in the "ground time" of older female participants, suggesting that lower body musculature may be important in off-road riding in older females, but this effect was not seen in younger female riders or males who may have been more habituated to the activity. EMG measures of motocross riders have shown that the lower body musculature is highly activated during motocross riding. However, similar to hand grip, a fatiguing effect in leg extension was only evident in the less experienced, and less habituated, motocross riders (136). Further examination of both the upper and lower body musculoskeletal demands of riding using quantifiable strength outcomes are required.

5.3.5 CONCLUSION

Off-road vehicle riding is a recreational activity associated with moderate intensity cardiovascular demand and fatigue inducing muscular strength challenges, particularly for upper body musculature. The metabolic demand of off-road riding is at an intensity level associated with health and fitness benefits in accord with the guidelines of both Health Canada and the ACSM. Potential effects on health and fitness may be augmented by the beneficial effect of increased caloric expenditure. In general, off-road vehicle riding is similar in aerobic demand to many other recreational, self-paced, sporting activities such as golf, rock climbing and alpine skiing. This examination of off-road vehicle riding is valuable for understanding the physical demands of this alternative mode of recreational PA in the context of potential health-related fitness outcomes.

Acknowledgements: This study was supported through a research grant provided by the Canadian Off-Highway Vehicles Distributors Council which included funds from both private and government sources.

5.4 Manuscript IV

Fitness and Health Training Adaptations from Off-Road Vehicle Riding

Burr, Jamie F. , Jamnik, Veronica K. , Gledhill, Norman. Fitness and Health Training Adaptations from Off-Road Vehicle Riding. *Manuscript in Preparation*

5.4.1 INTRODUCTION

Cross-sectional examination of the fitness and health of habitual recreational off-road vehicle riders has revealed that off-road riders have physiological profiles slightly healthier than the general population (Manuscript I). These higher levels of fitness and health appear to result from regular off-road riding, which has moderate aerobic intensity and strength requirements (Manuscript III). Despite the findings of a relatively healthy physiological profile in those who habitually ride off-road vehicles and a typical exercise intensity that falls within the guidelines to improve fitness and health, a definitive cause and effect relationship using a longitudinal study design has yet to be established. Establishing the effectiveness of off-road vehicle riding to stimulate meaningful changes in fitness and health is important to determine if this popular recreational activity should be recommended alongside other, more traditional, sport and recreation endeavors known to have positive effects. Because off-road riding is particularly popular in rural communities where traditional exercise opportunities are unavailable and unpopular, off-road riding may represent an attractive alternative to help increase physical activity levels in these communities which are particularly vulnerable to inactivity related morbidity and mortality (148, 180).

The primary purpose of this investigation was to determine the fitness and health effects of a structured program of off-road vehicle riding in non-habituated riders using two different training volumes (typical habitual rider PA volume and population recommended PA volume) and two modes of off-road vehicle riding (all-terrain vehicle;

ATV and off-road motorcycle; ORM). A second purpose was to measure the ambient levels of carbon monoxide (CO) exposure during group rides and to estimate the potential ill-effects of this CO exposure on cardiovascular and respiratory health. We hypothesized that fitness and health changes would occur as a result of off-road vehicle riding, with greater changes occurring in ORM riders than ATV riders and in those who trained using the recommended PA volume as opposed to the typical off-road participation volume.

5.4.2 MATERIALS AND METHODS

5.4.2.1 Participants

Participants were recruited from the university community and across southern Ontario via announcements in undergraduate classes and internet postings. For both the experimental and control conditions we sought participants of both genders who were >16 yr of age and were not actively involved in regular PA. Previous riding experience was unnecessary. A total of 46 experimental and 12 control group participants were recruited and their descriptive characteristics are provided in Table 5.9. Participants were from ethnically diverse backgrounds (self identified: 25% North American, 13.9 % Asian, 22.2 % East Indian, 8.3 % Middle Eastern, 22.2% European, 8.3% African). Experimental group participants were randomly assigned to one of four training modes: **1.** 2 ORM n=12 (riding ORM 2h/d, 2d/wk), **2.** 2 AT, n=11 (riding ATV 2h/d, 2d/wk), **3.** 4 ORM, n= 12 (riding ORM 2h/d, 4d/wk) **4.** 4 ATV, n =11 riding ATV 2h/d, 4 d/wk). Both the 2 ORM and 2 ATV had a study duration of 8wk while 4 ORM and 4 ATV had a duration of 6 wk. Control group volunteers were recruited from the same population pool following recruitment and randomization of experimental groups. After verbal explanation of procedures, written informed consent was provided by all participants, with those 16-18 yr also providing parental consent. This project was approved and conducted in accord with York University Human Ethics Review Board guidelines.

Table 5.9. Descriptive participant characteristics (mean ± SD) of experimental and control groups divided by gender.

Group		n	Age (yr)	Height (cm)	Weight (kg)	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)
Experimental	male	23	26.7 ± 9.9	177.2 ± 6.9	84.5 ± 9.6	37.7 ± 6.2
	Female	23	25.3 ± 9.9	165.2 ± 7.2	67.4 ± 17.2	40.1 ± 7.5
	Combined	46	26 ± 9.9	171.2 ± 7.1	76.0 ± 13.4	38.9 ± 6.8
Control	male	4	21 ± 1.4	180.8 ± 8.2	74.9 ± 7.9	49.1 ± 5.6
	female	9	22.4 ± 2.1	160.8 ± 4.9	58.8 ± 7.7	42.0 ± 6.1
	combined	13	21.7 ± 1.8	170.8 ± 6.6	66.8 ± 7.8	45.5 ± 5.9

5.4.2.2 Assessments

For this investigation, health was operationally defined as the absence of disease and disability (or risk factors) primarily from a physiological/fitness point of view. Given that overall health has physical, social and psychological implications which cannot be captured simply by the absence of disease or disability (47) we also included a measure of health-related quality of life (QOL) using the short-form 36 item health survey questionnaire (SF-36) from the Medical Outcomes Study (249).

We employed an unbalanced repeated measures design (Figure 5.9) involving fitness and health assessments; participants in the 2 ORM, 2 ATV and control groups were tested at baseline, 6 wk and 8 wk, participants in the 4 ATV and 4 ORM were tests at baseline and 6 wk. Each participant in the 4 ATV and 4 ORM groups completed a total of approximately 48 training hr over 6 wk, whereas the 2 ATV and 2 ORM groups completed a total of 32 training hr over 8 wk. All measurements were overseen by the investigators but performed by technicians who were blinded to the group assignments.

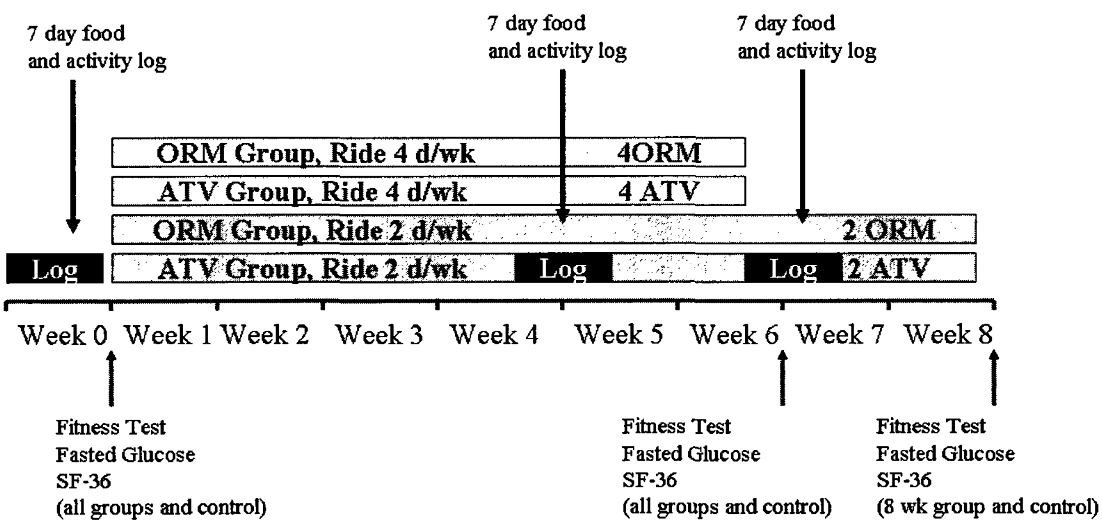

Figure 5.9. Study time line of the four experimental groups who participated in the off-road ride training. Control subjects were tested at all three testing points similar to the 2 ATV and 2 ORM groups but did not participate in training.

Training

All vehicle riding took place under the supervision of instructors at a professional off-road riding school. Within vehicle type and riding volume group divisions, riders were further sub-divided by instructors into smaller training groups of 4-8 riders based on riding ability. As participants improved their riding skills, groups were adjusted so that the speed and difficulty of terrain were maintained throughout the program at a safe and appropriate level for all participants. Daily rides were a mean of 121.7 ± 19.3 min, with ATV riders covering 24.3 ± 7.3 km/ride and ORM riders 28.0 ± 10.6 km/ride. All rides took place within an 11,000 acre woodland which contained approximately 400 km of off-road trails of varying terrain. The intensity of off-road riding was periodically monitored using heart rate (HR) (Suunto Oy, Vantaa, Finland) and VO_2 measures (Cosmed Fitmate, Rome, Italy) which have been described in detail in a related study (41). Measurements were not initiated until the third week of training to control the influence of a learning effect which may have altered riding efficiency. Heart rate, altitude and GPS calculated speed and distance were collected throughout these randomly selected rides. VO_2 measures were taken for a mean of 27.1 ± 8 min during rides with the initiation of data collection occurring at random and cessation occurring after approximately 20 min of collection when the riding group re-assembled before initiating a new trail or stopped for a break. The control group was monitored throughout the study period with meetings at each of the three testing time points as well as through periodic communication via email.

Fitness Measures

Body mass, waist circumference (WC) and body composition were measured to examine whether the riding program sufficiently increased caloric expenditure to alter adiposity. Percent body fat was calculated using the estimation of body density from the sum of 4 skinfold measurements as described by Durnin and Womersly (64). A highly skilled anthropometrist collected all skinfold measures according to the protocol described in the Canadian Physical Activity Fitness and Lifestyle Assessment (CPAFLA) which assures low variability (intra rater reliability .91-.98) between measurements as a result of a systematic method involving multiple measures at each site. Body composition changes were confirmed using bioelectrical impedance measures (not reported). Participants were instructed not to alter their PA during the study. Prior to study onset and two wk before completion, participants logged daily food intake and elective PA for 7 d using online software (The Food Processor, ver. 10.5, ESHA Research, Salem, OR). These measures were to control for the competing effects of diet and PA on health-related fitness and to determine if participants made changes from their regular diet or PA as a result of participation.

Hand grip strength was measured using a dynamometer (Smedley Hand Dynamometer, Stoelting Co, Wood Dale, Ill) adjusted to the second knuckle. Three trials were performed per hand in alternating order and maximal value was recorded. Isometric upper body strength was assessed using a spring resisted dynamometer for both push and pull strength at a standardized elbow joint angle of 110 degrees. Maximal force was recorded from three trials, alternating push and pull. Dynamic upper body strength was assessed using either full (male) or partial push-ups (female) with the hands placed directly below the shoulders. Push-ups were performed to maximum using a metronome pace of 25 per min and participants were stopped when they could not maintain either pace or proper form (straight back and full range of motion). Back health was assessed using the CPAFLA tests of partial curl-ups (maximum at a pace of 50 bpm), sit and reach trunk flexion (2 trials) and the Sorenson back extension (maximal time) with the modification of no ceiling values for performance. These tests are described in detail in the CPAFLA manual (47).

Leg power was assessed with a maximal vertical jump recorded to the nearest 1.3 cm (0.5 inch) using the Vertec jump and reach device (Sports Imports, Hilliard, OH) and a standard long jump. Three trials were given with a visual target provided for each jump. Leg power was calculated from jump height using the Sayers equation (127). Isometric leg endurance was assessed using a wall-sit with the knees bent 90 degrees and back flat against the wall. A stadiometer was used to ensure that participants maintained the starting position and time to the point of failure was recorded. Aerobic fitness was assessed with a progressively ramped treadmill test and analysis of expired gas using open circuit spirometry according to the procedures described in a companion paper (Manuscript III).

Clinical Measures

Blood pressure was measured prior to the fitness assessment in a quiet, temperature controlled room using an automated blood pressure device (SunTech Medical, model 247, Morrisville, NC). Fasted blood samples were collected from a finger tip blood sample and analyzed with the Cholestech LDX system (Cholestech Corporation, Hayward, CA) for blood glucose. The analyzer was calibrated periodically with two known samples (high and low) and optics checks were performed as recommended by the manufacturer.

Health-Related Quality of Life

Quality of Life was assessed using the SF-36 (ver. 1) psychometric assessment. Data collected from participants on the 8 main SF-36 scales were transformed into two summary scales, the physical component scale (PCS) and mental component scale (MCS) which allow a greater power to detect changes and reflect physical function and mental well being respectively (248). This assessment was used to determine if participation is this form of alternative PA had a beneficial effect on mental and physical health-related QOL.

Carbon Monoxide

During group rides ambient CO concentration was measured, rather than the sometimes measured direct emission at the tailpipe, as health risk is best determined using actual lung exposure (74). Measurements were taken using a portable CO meter

(Fluke Corporation, Everett,WA) mounted on the handlebars of an off-road vehicle with the real-time display facing the investigator who monitored average and peak levels which were recorded as ranges. During the ride, measurements were taken from a safe following distance (5-10 m) involving various terrains and speeds. Measurements were randomly taken from assorted positions (front, middle, back) within the group. Due to differences in engine cycles and suspected differences in CO output, both 2-stroke and 4-stroke ORM rides were analyzed, however, 2 stroke ATVs were not included as they are very rare and uncommon for recreational riding. All vehicles were well maintained and less than 1 yr old.

5.4.2.3 Statistical Analyses

Baseline comparisons between the control and experimental groups were performed using one-way ANOVA. Time course changes were analyzed from baseline to 6 wk and to 8 wk separately to account for the unbalanced study design and to allow for inclusion of partial data from subjects who completed training up to 6 wk but withdrew before 8 wk. Experimental group changes from baseline to 6 wk were compared between exercise frequencies using a 2 (baseline and 6 wk measures) x 5 (2 ORM, 2 ATV, 4 ORM, 4 ATV and control) repeated measures ANOVA, which was further decomposed to analyze effects of riders as an overall group. Interaction effects were interpreted from variable plots and confirmed with paired t-tests using a Bonferonni correction for the number of comparisons. Fitness measures from the 2 ATV and 2 ORM riding groups at 8 wk were compared to 6 wk measures using a 3 (2 ATV, 2 ORM and control) x 2 (6 wk and 8 wk) repeated measures ANOVA which was also decomposed to examine riders as a standalone group. The magnitude of physiological fitness and health changes from pre to post measures was assessed using Cohen's d statistic. Using VO_2 as the prime variable of interest and based on an expected change of ≥ 3 $ml \cdot kg^{-1} \cdot min^{-1}$ reported in a previous training study with duration of 6 wk (208), an a priori power calculation revealed an expected power of 85 % given a sub-group size of 10 participants and a standard variance of 2.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Significance for all tests was set a priori at $p < 0.05$. All analyses were performed using SPSS software (version 17.0; SPSS Inc, Chicago IL). All data are presented as mean ± SD unless otherwise noted.

5.4.3 RESULTS

Participant Compliance and Dropouts

A total of 12 participants withdrew before study completion (7 due to time commitments, 1 unrelated shoulder injury, 1 unrelated head injury, 1 unrelated neck injury, 1 study-related bruised shoulder and 1 study-related cracked rib). Participants who withdrew before the 6 wk testing were removed from analyses. Overall, participants had an 88.6 ± 12.3% compliance with training sessions. In a total of approximately 1300 hrs of riding, there was only 1 non-serious (bruised shoulder from tip-over) and 1 serious adverse event (cracked rib from impact with tree stump) that required medical attention and study withdrawal. This indicates a serious adverse event rate of <0.0008 per hour of supervised riding.

Training

Altitude and GPS recordings illustrate that ascending and descending hills each composed 24.5 ± 5.5 % of a typical ride and the remaining 51 ± 10.4 % involved riding trails on flat ground; however this latter proportion also included rest breaks on the trail, thus, most rides likely involved slightly less flat riding than altitude measures indicated. Nevertheless, the composition of a "training" trail ride intentionally approximated the "typical" trail ride described by habitual off-road riders in a related study (41) with regard to terrain types, hills and ride duration. The relative metabolic demand while riding (ATV 10.3 ± 2.3 ORM 15 ± 3.8 $ml \cdot kg^{-1} \cdot min^{-1}$) was similar to values recorded in habitual off-road riders (ATV 12.1± 4.9 and ORM 21.3 ± 7.1 $ml \cdot kg^{-1} \cdot min^{-1}$, (41) (Manuscript III). Group-specific training intensities (HR and VO_2 Reserve) are provided in Figure 5.10.

Fitness Measures

Health and fitness measures at baseline, 6 wk and 8 wk are presented in Table 5.10. At baseline, after removal of dropouts, there were no differences among off-road riding groups or controls on any health or fitness variables. As such, all groups have been collapsed for presentation of this data. At 6 wk there was no effect of riding on body mass in any riding group. However, % body fat at 6 wk decreased in all riders from baseline ($p<0.001$) and WC decreased in the 4 d/wk riders regardless of vehicle type ($p=0.03$). There was a trend toward a greater reduction in body fat in riders who participated 4 d/wk, but this did not reach statistical significance ($p=0.06$). No other group-specific differences existed. Activity and food logs revealed no increase or decrease in elective PA and no changes in caloric intake with the exception of the 4 ORM and 4 ATV groups (p=0.047) who increased average caloric intake by approximately 150 kcal/d from baseline. No change occurred in any fitness variable of the control group from baseline to 6 or 8 wks with the exception of a decrease (162.7 W, p=0.03) in leg power at 6 wks.

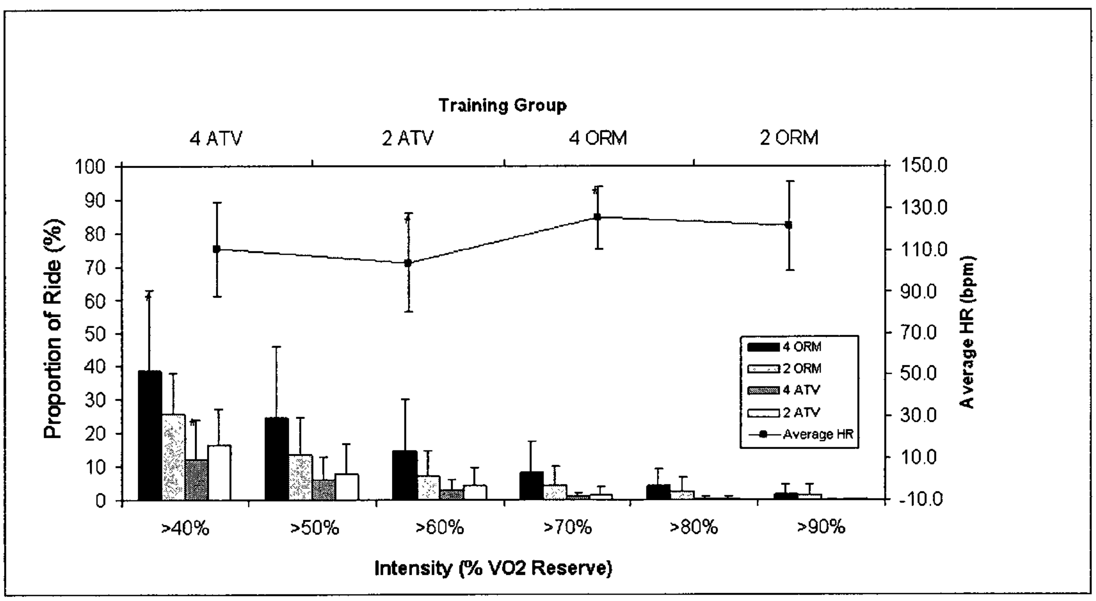

Figure 5.10 Intensity of off-road ride training by experimental group. (Left Axis) Cumulative proportion of off-road riding time by intensity zone. (Right axis) Mean heart rate response of all training rides. * Significant difference between riding modes $p < 0.05$

Table 5.10. Off-road riding group scores (mean ± SD) on fitness and health measures at baseline and following 6 wk and 8 wk of off-road riding.

	All groups combined (2 ATV, 2 ORM, 4 ATV, 4 ORM)			8 wk group only (2 ORM, 2 ATV)		
Variable	Baseline	6 wk		6wk	8 wk	
Pre-exercise heart rate (bpm)	75.4±8.8	74.6±10.9		74.1±12.7	70.4±9.1	
Systolic pressure (mmHg)	121.4±13.0	112±10.3	†	106.1±10.0	109.6±11.5	¶
Diastolic pressure (mmHg)	74.6±9.2	68.9±7.6	†	65.9±7.7	65.7±8.1	
Fasting Glucose (mmol)	5.2±0.8	4.7±0.6	†	4.7±0.6	4.8±0.8	
Weight (kg)	76.0±17.0	75.3±15.6		74.2±15.5	74.6±15.5	
Waist Circumference (cm)	88.5±10.5	87.2±9.4	§	87.3±9.6	87.3±9.8	
Body Fat (%)	28.7±6.8	27.7±6.6	†	27.2±7.6	27.0±7.6	
Push (kg)	76.0±30.5	77.9±33.6		76.0±35.3	73.0±32.5	
Pull (kg)	72.4±25.7	77.6±24.7	*	73.4±25.2	74.5±24.2	
Push-ups (max)	16.2±8.1	16.5±8.7		18.2±9.4	18.4±9.7	
Trunk Flexion (cm)	30.3±6.9	31.7±6.7	§	31.4±8.7	30.4±8.6	
Leg Power (W)	3638±1044	3810±1153	*	3746±1179	3890±961	
Back Extension (sec)	116±44	130±66		113±93	137±93	
Curl-up (max)	34±29	46±36	*	41.3±31.2	47.6±28.6	
Standing Long (cm)	176.5±40.7	183.7±38.8	*	177.3±41.9	175.8±42.4	
Wall Sit (sec)	79±32	105±52	†	103±50	96±36	
VO_2max (ml·kg^{-1}·min^{-1})	39.9±7.8	42.5±7.2	†	39.4±9.9	41.1±10.5	
Combined Grip Strength (kg)	78.2±25.2	77.7±24		75.6±24.4	76.6±23.4	
Caloric Intake (kcal)	1996±981	2060±951	§	-	-	

No Significant differences exist between groups at baseline.

* significant p>0.05, † p>0.01, § interaction p>0.05 with only 4 d/wk groups significantly different from baseline. ¶ interaction p>0.05 only ATV different at 8 wk. **2 ORM** -ride ORM 2h/d, 2d/wk, 8 wk duration; **2 ATV**- ride ATV 2h/d, 2d/wk, 8 wk duration; **4 ORM**- ride ORM 2h/d, 4d/wk, 6 wk duration; **4 ATV** - ride ATV 2h/d, 4d/wk, 8 wk duration.

Off-road riding did not affect maximal hand grip, push-ups or isometric push strength in any group, whereas isometric pull strength increased (Cohen's d (d)=0.42) in all groups. There was no effect of off-road riding evident in lower back endurance, but all participants greatly improved core strength from baseline to 6 wk as evident in curl-up ability (p=0.006, d= 0.55) . There were no further improvements in the 2 d/wk groups at 8 wk. Trunk flexibility (lower back and hamstrings) increased 2.8±2.3 cm (mean ± √ mean square error, p=0.01, d =0.79) in those who rode 4 d/wk. Leg power, calculated using body mass and vertical jump ability, and long jump increased similarly from baseline in all groups (p>0.05, d=0.35). All groups showed an increase in isometric leg endurance at 6 wk (p=0.001, d=0.59) with no further improvement at 8 wk. No changes were observed from baseline in any musculoskeletal fitness measures of the control group with the exception of a decrease in leg power (230 W, p=0.03) at 6 wk, which was no longer evident at 8 wk.

Aerobic power improved similarly in all experimental groups from baseline to 6 wk (p<0.001, d=0.97) with no further increase in the 2d/wk group at 8 wk. Resting HR decreased significantly from baseline to 6 wk in the 4ORM group only (p=0.049). There were no changes in aerobic fitness in controls at any time point and no further changes were observed in any fitness measure in the 2 ATV and 2 ORM groups with an additional 2 weeks of riding between the 6 wk and 8 wk times.

Clinical Measures

No statistically significant change occurred in any health variable of the control group from baseline to 6 or 8 wks. Both systolic and diastolic blood pressure decreased from baseline after 6 wk of training, with no significant differences between vehicle types or riding volume (d=1.28 DBP, 1.3 SBP)). Fasting blood glucose decreased in all groups (p=0.001, d=0.71). The additional 2 wk of riding in the 2 ORM and 2 ATV groups did not affect any clinical variable with the exception of an increase in 2 ATV SBP toward baseline. No changes were observed from baseline in the control group.

Health-Related Quality of Life

There was no significant effect of off-road riding on participant PCS scores in any riding group from baseline to 6 wk or between 6 and 8 wk. However, a significant effect from baseline to study completion (8 wk) was found in those who rode 2 d/wk for both vehicle types (49.4 ± 6.7 to 55.2 ± 3.6, p=0.006). Data for all groups are presented in Figure 5.11. The lack of effect of off-road riding to increase PCS score at 6 wk was attributable to an increase in bodily pain which was reflected in this SF-36 sub-scale (Appendix) which is a major component of the PCS composite score. Upon closer examination of all groups combined, the bodily pain scale revealed a drop from baseline at 6 wk followed by a return to baseline levels at 8 wk.

There was a significant pre-post effect of riding (from baseline to 6 wk) for the MCS scale in participants who rode 2 ORM and 4 ORM (49.6 ± 10.4 baseline to 58.2 ± 5 6 wk, p=0.02). No further changes occurred beyond 6 wk and there were no effects evident for ATV riding at any time point. There were no significant differences in either the PCS or MCS in the control group from baseline to 6 wk or 8 wk.

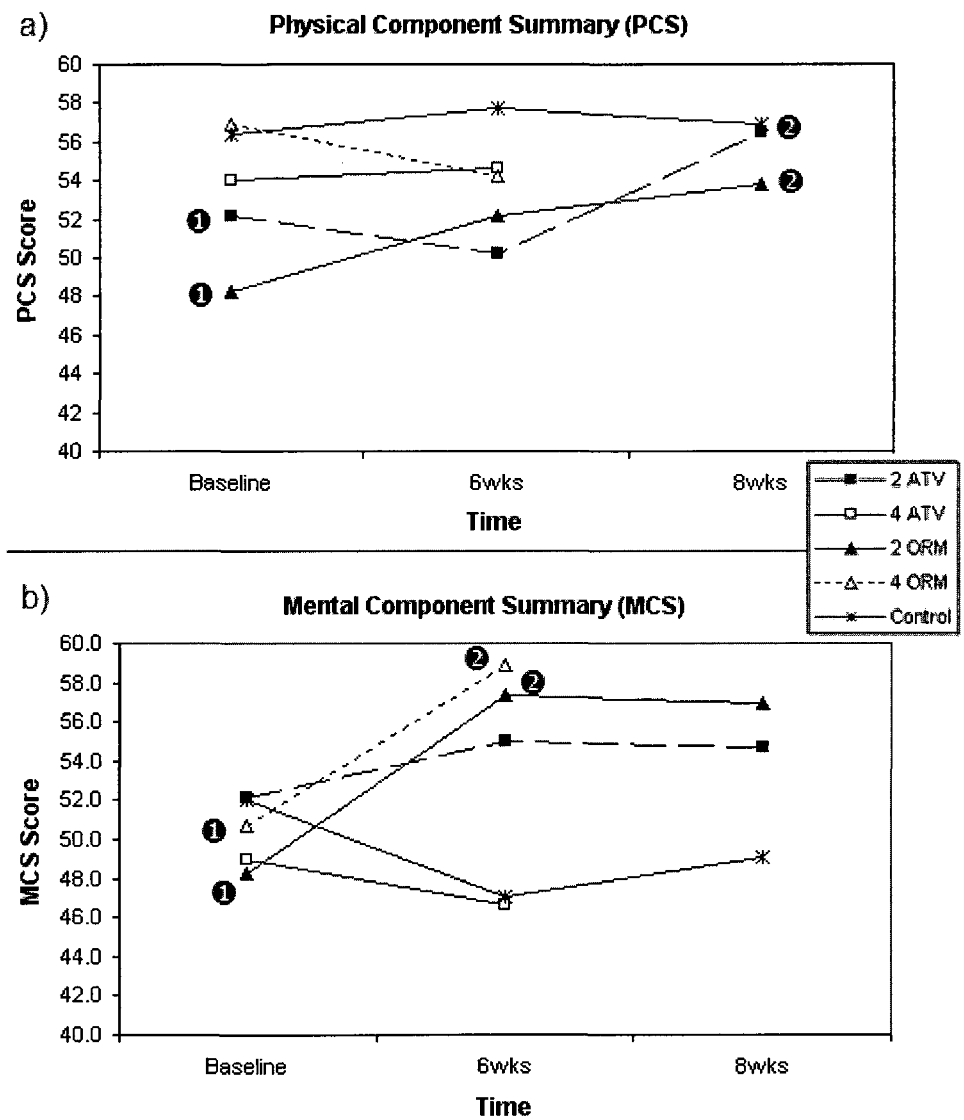

Figure 5.11. SF-36 quality of life summary scales divided by experimental condition at baseline, 6 wk and 8 wk. **a)** physical component summary **b)** and mental component summary. ❶ is significantly different from ❷ $p<0.05$

Carbon Monoxide

Ambient CO levels recorded while trail riding in a sub-group of ORMs (≈ 8 riders) ranged between 0-20 ppm, with little variation outside this range. There was a higher CO level of approximately 85 ppm when vehicles stopped and quickly accelerated. No differences existed between 2-stroke and 4-stroke ORMs. Ambient CO recorded while riding in a group of ATVs (≈ 8 riders) ranged between 10-30 ppm on typical trails, increased to 50-100 ppm while riding slowly (technical trails) and spiked to approximately 150 ppm following acceleration after a stop. The highest observed value (210 ppm) occurred during an ATV hill climb in a wind sheltered ravine. Location within the riding group (front, middle or rear) was had no effect.

5.4.4 DISCUSSION

The observed changes in fitness and health using off-road vehicles were much greater in magnitude than would be expected for other more commonly prescribed exercises at the low end of the exercise intensity spectrum, such as walking. Given that the control group did not show similar alterations in measures from pre-post, it is likely that these changes occurred as a result of the training stimulus and not another influencing factor such as a learning effect or measurement error. As such, the training adaptations observed in this study represent remarkable alterations in fitness over a relatively short time period which could enormously impact health and the economic burden of inactivity. Exact participation rates are difficult to determine because many off-road vehicles remain unregistered, but it has been estimated that over 8 million Americans (55) and approximately 77% of rural Canadian residents (247) have access to off-road vehicles. Given the considerable physiological adaptations that can be achieved by this type of non-traditional PA, and the fact that this type of PA can be used to target higher risk rural communities where exercise opportunities are limited, off-road riding represents an attractive alternate activity to help combat preventable disease and premature mortality and the attendant burden to the health care system.

Fitness Measures

Moderate intensity exercise in the absence of weight loss is associated with reductions in subcutaneous, abdominal and intramuscular adipose, and these reductions are related to improvements in cardiovascular and metabolic health (144, 193). The lack of alteration in body mass following 6 to 8 wk of off-road riding suggests that participants in our study improved their relative lean muscle mass with this activity while decreasing adipose stores. This is confirmed by the decreased % body fat in all riders and a decreased WC in those who rode more frequently. The greater loss of abdominal fat (based on WC) and the trend toward greater subcutaneous fat loss in those who rode 4 d/wk demonstrates that changes occur with increases in PA dose and consequent caloric expenditures.

The strength training effect of off-road riding on musculoskeletal fitness of both upper and lower body musculature has important health implications for those who choose this activity as a means of PA. It has been reported that increased muscular strength, endurance and flexibility protect against premature mortality (123) and functional disability (37). Increased musculoskeletal fitness has also been shown to be associated with a protective effect against significant weight gain (156) and can aid in decreasing cardiovascular risk factors and increase overall health (241).

All experimental groups, regardless of training frequency or vehicle type, showed an improvement in VO_2max, without a concomitant increase in controls, demonstrating that off-road riding has the potential to improve aerobic fitness when participants are engaged habitually. The lack of a differential increase in aerobic fitness between riding volumes and vehicle types, despite a documented difference in exercise intensity (41), is likely due the high variability of individual responses to the training stimulus (34) combined with the relatively short time course for adaptation to occur. As with any study comparing multiple variables, it is also possible that this is simply random chance.

Clinical Measures

The decreases observed in both SBP and DBP were greater than expected based on meta-analysis of literature in normotensive populations which shows typical reduction of 3-4 mmHg for both SBP and DBP (70). Both moderate aerobic (40-60% VO_2max) and dynamic resistance exercise training have been shown to contribute to reductions in blood pressure (17, 70) and there is some evidence that isometric exercise (including hand grip) may also be effective in lowering SBP, possibly owing to an effect of enhanced antioxidant protection (181). All of these stimuli are present in the activity of off-road riding, thus it is difficult to determine the mechanism of greatest effect, or if the reductions in BP were summative in any way. It is possible that the greater than expected decreases in blood pressure were influenced by a "white coat" elevation at baseline which subsided with follow-up visits; however, a similar effect did not occur in controls. Decreases in BP are known the lower the risk of cardiovascular morbidity and mortality (51).

Fasted blood glucose was effectively reduced by participation in off-road riding demonstrating the potential for this mode of alternative PA as an aid in metabolic regulation. The observed change from 5.3 to 4.7 mmol/L is considerable, specifically in the 4 ORM group, as it removes riders from the high risk category of impaired fasting glucose (>5.6 mmol/L) as defined by the American Diabetes Association (9). These effects may have occurred through changes in insulin sensitivity directly, or as a result of improvements in body composition (86). It has also been demonstrated that even small amounts of vibration training have the ability to improve glucose tolerance in type 2 diabetics (25), and it is possible that the vibration of off-road vehicles while riding provides a similar stimulus. Both aerobic and resistance PA are recognized as effective treatment options for diabetes (216) and it is likely that even greater changes in fasting glucose would have been observed in a diseased population.

Health-Related Quality of Life

The SF-36 PCS score reveals that up to a duration of 6 wk, riders did not report any improvement in their physical function as a result of riding, however, by 8 wk the additional exposure in those who rode twice weekly led to a significant change in their physical quality of life regardless of vehicle type. This improvement of 5.8 points is of clinical significance for expected health outcomes as it moves these participants from approximately the 50th percentile wherein physical limitations in work and leisure time are likely, pain is more common and energy levels are low to approximately the 75th percentile in which physical limitations and pain are low, energy is high and health is rated more positively (248). The observed increase in bodily pain at 6 wk, which depressed PCS scores, was likely attributable to muscular fatigue and soreness from off-road riding, as well as the non-serious bumps and bruises riders sustained from participation. This effect was apparent at 6 wk but not 8 wk because riders were improving their riding skill (and progressing to greater challenges of riding) during the first 6 wk while adapting to the physical stresses which led to soreness. Bodily pain scores returned to baseline levels at 8 wk as riders sustained fewer physical insults and were becoming habituated to the stress of riding (Appendix G). Although the 4 d/wk groups had more frequent PA exposure and would be expected to adapt to the PA stress more quickly, it is possible that the more frequent exposure also led to more minor injuries (i.e. bumps, bruises and sprains) compounded by the fact that these riders had less recovery time between rides. PCS results suggest that off-road riding is a beneficial exercise modality for increasing health related physical functioning; however, it is only effective to the point wherein participation causes increases in bodily pain.

The increase in MCS scores of ORM but not ATV riders within the first 6 wk of riding demonstrates that off-road vehicle riding has the potential to change participant's perceptions of their own QOL, but that this effect is vehicle type dependent. The observed change in ORM riders is clinically significant in that riders improved from approximately the 55th percentile in which the risk for depression, distress and life dissatisfaction are considerably elevated (46% depressed, 30.5% stressed and only 31.9% satisfied) to approximately the 78th percentile wherein depression is much less prevalent, stress is lower and life satisfaction is higher (18.4% depressed, 11.5% stressed, 66.3% satisfied) (248). Furthermore, this effect was maintained in the group that continued riding for an additional 2 wk. In a previous study using habituated off-road vehicle riders we have shown that MCS scores did not differ between vehicle types (Manuscript II). However, this study was descriptive in nature and these riders were not randomized by vehicle type thus underlying differences may have existed between ATV and ORM riders. The current study provides evidence that participants new to the sport of off-road riding benefitted more from increased health related QOL if riding an ORM.

The above findings effectively demonstrate that off-road vehicle riding can provide an effective exercise stimulus to bring about positive changes in fitness and health. Although participation rates in this alternative form of PA may be less than that of more traditional (urban) activities such as treadmill running or recreational hockey in absolute numbers, this recreational activity is one which is appealing and readily available to a large proportion of high-risk, rural residents. Off-road vehicle riding represents an opportunity for these community members to increase PA levels and decrease inactivity related morbidity and mortality.

Carbon Monoxide

The ambient CO levels recorded while group riding were generally below the recommended CO exposure guidelines set by the U.S. National Institute of Occupational Safety and Health of <35 ppm for a 8 hr exposure and a ceiling of 200 ppm (170). By comparison, average CO levels inside the cabin of an automobile are as high as 44 ppm (108). Peak CO levels while performing technical riding and starting from a stop temporarily surpassed the recommended exposure level and under certain conditions the ceiling may even be surpassed. Although the large majority of group riding is associated with acceptable exposures levels at rest, the combined effect of high transient peaks during PA may increase the risk of CO exposure as minute ventilation and HR are elevated by exercise and heat stress (233). This may have clinical implications particularly for people with coronary artery disease as CO exposure can result in further increases in HR, myocardial dysfunction and cardiac hypoxia (73), although this is likely of little concern for young healthy riders (3).

The effects of CO on carboxyhemoglobin levels and the potential effects on the health of off-road vehicle riders is an area for further research. Until conclusive evidence is available, it seems prudent to suggest riders leave ample space behind lead vehicles so as to minimize exposure to CO and particulate. This is especially important for older riders, those with diagnosed coronary heart disease and when travelling through areas which are wind-sheltered and pollutants do not dissipate quickly. There is evidence that wearing a simple facemask is effective in abolishing adverse effects of particulate inhalation on blood pressure and heart rate variability in cities with high ambient air pollution (138). The use of an adapted face mask, similar to those used in snowmobile and on-road motorcycle helmets to prevent condensation, may be appropriate for off-road riding.

Limitations

Although the current study did randomize participants to experimental groups, randomization did not include members of the control group. The control group was selected from the same participant pool as the experimental groups after these groups were filled and included participants who could not dedicate the substantial amount of time required of experimental participants. As such, it is possible that due to a lack of randomization, the control group may have been systematically different from the experimental groups in some way. It is possible that this could have made the control group more or less resistant to change in a given variable, but no differences were apparent on any of the measured fitness or health variables considered. A second limitation to the control group was a stronger representation of females versus males, especially following subject drop out. Although these limitations decrease the strength of the control group, the control group still provides some assurance that there were no learning effects or measurement errors overriding training effects. Lastly, the experimental and control groups used in the current investigation are younger, and generally of better health, than the average habitual rider. These participants were recruited in higher numbers than older participants due to the nature of study participation which precluded participants who had full time employment during the typical work day for the duration of the investigation. As such, this limits the generalizability of the current results.

5.4.5 CONCLUSIONS

Consistent participation in off-road riding is an effective mode of alternative PA for decreasing adiposity and increasing muscular strength, endurance, power and flexibility. These changes in musculoskeletal fitness could have implications for future health and weight gain. Off-road riding is also effective for increasing aerobic fitness, which lowers the risk of premature morbidity and mortality. Most adaptations resulting from off-road riding occurred within 6 wk of training and little evidence exists to suggest that riding 4 d/wk (recommended PA prescription) led to better health outcomes than the typical riding frequency of 2 d/wk with the exception of a greater fat loss and improved flexibility in those with increased riding volume. Vehicle type had no effect on musculoskeletal and aerobic fitness training outcomes. Off-road riding is effective for lowering blood pressure and may be a useful PA modality to improve metabolic regulation. Off-road riding increases physical functioning QOL in the absence of riding inflicted bodily pain, and life satisfaction and mental health were increased only in those who rode ORM. CO exposure while riding is generally at an acceptable level and should not pose a serious risk to healthy young riders; however, caution should be exercised in those pre-disposed to coronary artery disease especially when combined with additional physical stressors. The results of this study confirm that off-road riding is a useful alternative PA modality for improving health-related fitness and QOL and could have substantial population health effects and health care savings given the high participation rates in North America. This type of alternative PA may be particularly suited for high-risk rural communities where access to off-road vehicles is widespread and inactivity related morbidity and mortality are prevalent.

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CHAPTER 6
GENERAL DISCUSSION AND SUMMARY

6.1 General Discussion

Recreational off-road vehicle riding is a controversial activity about which many Canadians have strong pre-conceived notions. Proponents of off-road riding believe that this recreational activity is a good form of PA which will lead to improvements in fitness, health and quality of life. Critics of off-road riding believe this recreational endeavor has no positive qualities based on the assumption that the use of a self-propelled vehicle precludes significant PA by the rider and consequently does not provide the rider with any fitness or health benefits.

This is the first investigation to systematically evaluate the physiological fitness and health-related effects of participation in habitual recreational off-road vehicle riding as an alternative form of PA. The findings of this investigation are important and relevant to Canadians because this research: 1) elucidates the health and lifestyle behaviors of this group of Canadians 2) objectively characterizes the physical demands of participation in this recreational activity, 3) demonstrates the likely fitness and health outcomes of habitual participation in those who presently engage in this activity as well as in current non-riders who may participate in the future, and 4) gives insight into carbon monoxide exposure during off-road riding, which is a commonly cited risk of participation.

The results of these studies collectively suggest that off-road vehicle riding is a recreational activity with physical demands similar to other more common recreational sports, and that positive alterations in physiological fitness and cardiometabolic health are likely when coupled with an appropriate volume of riding. Habitual off-road riders in the general population revealed important reductions in cardiovascular risk factors, despite mean participation rates that fell below recommended guidelines for PA. Given that the typical frequency of recreational off-road riding falls short of recommended PA guidelines, most habitual recreational riders should either increase their off-road riding frequency or supplement riding with other modes of moderate intensity PA to meet the minimum PA guidelines. Given our present finding that non-habituated riders, with relatively healthy profiles at baseline, demonstrated important fitness and health-related changes in as few as six weeks of off-road riding, regardless of 2 day or 4 day per week riding participation frequency, it is possible that current habitual riders maintained less than optimal body composition and health in some measures as a result of non-PA related lifestyle choices. Therefore, it is likely that if habitual off-road riders were to maintain their current lifestyle habits (in particular alcohol and caloric intake) and cease to participate in recreational riding, their fitness and health would decline drastically as a result. Given the high mental and physical QOL of off-road riders compared to average Canadians, the increase in physical QOL observed in participants who undertook a 6 week program of off-road riding and the known associations between QOL and physical limitations or health problems, it is likely that the removal of off-road riding from the lives of recreational off-road riders would have detrimental effects on health. At present, there is insufficient evidence to make conclusive statements on this possibility and these suppositions are speculative in nature, however, this represents an interesting possibility for future research.

Although it was not a major focus of the current investigation, there is a compelling body of evidence regarding off-road vehicle riding injuries which cannot be ignored. A search of Pub-med revealed that there were 17 research papers/medical statements/case studies published on off-road riding related injuries in 2009 alone. It is notable that the majority of published studies are specifically related to ATV use, while recreational ORM use has received considerably less attention. Off-road riding related injury is a topic that is also given considerable attention in the popular media. From conversations with our study participants it is apparent that many off-road riding enthusiasts believe that riding-related injuries are given unjust attention due to a general perception held by non-riders that there is no good reason to ever ride an off-road vehicle. An often-cited example is that when an accident occurs on a bicycle, it is commonly accepted that regular bicycle riding has an associated justifiable risk given the consequent increased fitness and positive health outcomes. Bicycle accidents are considered an unfortunate mistake that likely could not have been avoided. However, when an off-road rider is involved in an accident, it is perceived that they were involved in risky behavior, with a foreseeable negative outcome and no consideration is given to the countering positive PA or health-related components of habitual recreational off-road riding. Interestingly, a recently released U.S. health report shows that ATV and bicycle related deaths among adults (2000-2005) were similar in that there was an average of 694 and

666 fatalities respectively (102). However, this does not take into account the absolute hours of exposure for each group.

In the current investigation, we have shown that off-road riding provides a mode of PA of sufficient intensity to be considered a viable form of alternative PA to improve fitness and health, despite the fact that participants are riding an engine-propelled vehicle. We have also demonstrated that, contrary to popular opinion, off-road vehicle riders do not appear to have a disposition toward risky behavior any more than other members of the Canadian population. It is possible, therefore, that perceptions of participation in off-road vehicle riding by policy makers and other non-riding Canadians may begin to change, as resultant improvements in fitness and health indicate that off-road riding does indeed have positive qualities.

Although off-road riding related injuries are a valid concern, and precautions to avoid injuries and reduce injury severity are warranted, in the current investigation it has been shown that in controlled situations, the likelihood of serious injury during recreational off-road vehicle riding was relatively low (serious adverse event rate of <0.0008 per hour of supervised riding). It is important to note, however, that during the present research study all riders wore full-body protective safety gear, riders were instructed on safe vehicle operation and trail etiquette and riders never rode under the influence of alcohol or drugs, all of which have been cited as factors contributing to off-road vehicle accidents, injury and death (93, 215). Because true participation rates in off-road riding are difficult to ascertain given that many off-road vehicles are not registered and patterns of use are unclear (i.e. farm related ATVs), to the best of our knowledge this is the first study to quantify injury risk in recreational off-road riding based on verifiable participation rates. It is recognized that this observation certainly does not conclusively end the debate as to the issue of safety; however, this objectively documented injury rate per unit of participation does offer further evidence for consideration. An important area of future research using the methodology of Katzmarzyk et al. (125) is to examine the estimated economic related savings of inactivity related morbidity and mortality associated with off-road riding participation to the estimated cost of hospital treatment from acute riding-related injuries.

6.2 Overall Conclusions

1) With the exception of body composition profile, persons who habitually ride off-road vehicles have physiological characteristics that are equivalent, or slightly superior, to members of the general population on important fitness and health variables. Despite elevated adiposity and WC, habitual recreational off-road vehicle riders have a lower than normal prevalence of the metabolic syndrome, suggesting that off-road riding is associated with protection against cardiovascular risk factors. Habitual recreational off-road riders appear to be happy, mostly content with their lives and have a high QOL. Compared to average Canadians, riders had a lower prevalence of smoking and a higher prevalence of alcohol consumption, were no more prone to participate in risky behavior and did not consume fast-food excessively. Important differences exist in physiological fitness, cardiometabolic health risks and QOL variables between ORM and ATV riders,

suggesting that riders in these two commonly grouped recreational activities are in fact distinct.

2) Off-road vehicle riding is a recreational activity associated with moderate intensity cardiovascular demand and fatigue-inducing muscular strength challenges, particularly for upper body musculature. Potential effects of recreational off-road vehicle riding on health and fitness may be augmented by the beneficial effect of increased caloric expenditure associated with long duration, moderate intensity rides. Recreational off-road vehicle riding is similar in aerobic demand to many other self-paced recreational activities and the metabolic demand of off-road riding is at an intensity associated with health and fitness benefits in accord with North American PA guidelines.

3) A cause and effect relationships exists between participation in off-road vehicle riding and changes in fitness and health measurements such that habitual participation is effective for decreasing adiposity and increasing aerobic fitness, muscular strength, muscular endurance, muscular power and muscular flexibility. Off-road riding is effective for lowering blood pressure and may be a useful PA modality to improve metabolic disease regulation. Off-road riding increases physical functioning QOL (in the absence of riding inflicted bodily pain) in all riders and both life satisfaction and mental health of those who rode ORM. CO exposure while riding is generally at a commonly encountered safe level and should not pose a serious risk to healthy young riders.

6.3 Limitations and Areas for Future Research

6.3.1 Limitations

As noted in the manuscripts which employed cross-sectional analyses of habitual off-road vehicle riders, a limitation of this type of investigation is the inability to draw cause and effect relationships. Because cross-sectional examination only allows for analysis at one point in time, it is possible that differences between groups could be attributed to factors other than the ones being examined. As such, some of the observed differences between habitual off-road riders and the normative population, younger and older riders, or riders of ATV and ORM vehicles may be the result of sampling bias. Sources of sampling bias could include regional (geographic) differences in the off-road riding Canadians who participated, socioeconomic class differences, or participant driven self-selection factors such that certain off-road riders were more or less likely to participate than others. Although the subsequent training study employed in the current investigation helps to clarify a cause and effect relationship for many of the fitness, health and QOL changes that were observed in habitual riders, conclusions as to the cause-related effects of long-term (lifetime) participation cannot be made.

Another limitation of this research was the accuracy with which we could document anaerobic metabolism and muscular strength/endurance demands. In laboratory-based studies, it is possible to take repeated blood samples to determine the time course of blood lactate accumulation; however, in the current investigation it was not possible to take blood samples until participants had completed their exercise bout. Consequently, it is possible that blood lactate levels (used as a marker of anaerobic metabolism) were influenced by the participant's aerobic fitness and ability to buffer lactate. Although it is possible to estimate the onset of blood lactate accumulation by calculating the point of break-away breathing (ventilatory threshold) using VO_2 and VCO_2, the metabolic computers used in the current investigation did not have the capacity to provide VCO_2, thus this calculation was not possible. Similarly, in the current investigation we used muscular fatigue as a crude indicator of muscular involvement while riding. It is possible that this measurement was influenced by training status such that muscular demands did not manifest as fatigue given the insufficient stimulus from the representative 20 minute ride. In laboratory-based studies, muscular strength and endurance demands are commonly quantified using EMG recordings to determine the intensity and frequency of muscle contractions. Due to the unique challenges, complexity of measurements and safety concerns of the current investigation, EMG measures were not made although they may have offered further insight into the muscular strength and endurance demands of off-road riding.

Lastly, a limitation of the training study was the required use of a non-randomized control group. The control group was recruited after all experimental groups were filled to ensure appropriate gender representation and adequate statistical power to detect changes in these groups. Although control group participants were recruited from the same population pool as the randomized experimental groups, it is possible that the control group was systematically different on some variables due to this lack of randomization. Therefore, it is possible that the control group had a lower potential for changes in aerobic fitness due to an un-measured outside variable. Inclusion of the control group does provide some assurance that the changes observed in the experimental groups resulted directly from participation in off-road vehicle riding, however, the strength of comparison to the control group is weakened as a result of the non-randomization.

6.3.2 Future Research

This investigation is the first to examine habitual off-road vehicle riding as a form of alternative physical activity from the perspective of fitness and health outcomes. In addition to provoking possible future off-road riding studies which may confirm or contradict the current results, there are many other research avenues which have been brought to light through the current investigation that could be explored.

One of the findings of the current investigation was that off-road vehicle riders had a lower prevalence of metabolic syndrome than the general population. It was also determined that 6-8 wk of off-road vehicle riding was effective for improving fasting glucose levels in non-habituated riders who were of relatively good health at baseline. It is possible that these findings were primarily driven by decreases in adipose tissue and increases in lean mass; however, it is also possible that other factors were involved and further research is warranted. Given the recent findings that even small amounts of "vibration" training have the ability to improve glucose tolerance in diabetics (25), further research is required to determine how much of the improvement in blood glucose management (if any) was attributable to the vibration resulting from off-road vehicle riding. The potential beneficial effect of vibration stimulated gains in glucose tolerance need to be weighed against the potential soft tissue damaging effects of both high and low frequency vibration from habitual off-road vehicle use (13, 19).

In the current investigation, there was no apparent association between the metabolic demand of riding and a rider's years of experience (riding efficiency), speed, age or percentage of time spent standing, despite a strong belief by off-road riders that those who are more skilled riders stand more often and drive an off-road vehicle more quickly with less physical demand. It is likely that these effects were not observed in the current investigation because the oscillations in physical demand were lost in a regression toward the mean resulting from the intentional inclusion of varied terrain types (which require differing riding tactics and techniques) to represent a typical ride. To further explore the changing demands of riding based on speed, technique and experience, controlled studies using each of these variables in isolation are required.

Based on ambient CO exposures measured while riding, it was concluded that off-road riders without pre-existing heart conditions are likely not in great danger, as the CO levels from ORM and ATV exhaust while riding are below recommended exposure level ceilings. Comparisons were also drawn between off-road vehicle exposures and the concentrations inside the cabin of an automobile. Further research examining carboxyhemoglobin levels as opposed to ambient CO will be useful to determine if there is an additive effect from repeated exposure while riding, if exercise increases the uptake of CO or if factors such as off-road vehicle transportation (using and automobile with a trailer) increases levels to a point where the additional exposure while riding is of concern. Precise carboxyhemoglobin levels will also allow more specific conclusions as to the potential deleterious mental and physiological effects to be made, as much of the basic science in this field has been quantified using this measurement. Further examination of the effects of other components of exhaust and air pollution (ie. hydrocarbons and fine particulate matter/dust) should be made to determine other potential cardiorespiratory risks including comparisons to other PA with similar exposures (i.e. urban cycling, jogging).

Lastly, as previously mentioned, epidemiological-based research examining the cost-benefit of participation is required from a health policy perspective weighing acute injuries against avoidance of chronic disease. Building on the findings from the current research, an analysis of the expected cost savings versus the treatment costs of traumatic injury would allow objective decisions to be drawn concerning the economic value of participation in off-road vehicle riding.

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APPENDIX A – Exercise Intensities Associated with Fitness and Health Benefits

Table 3: Relative intensities for aerobic exercise prescription (for activities lasting up to 60 minutes)*

Intensity		% HRR	% HR_{max}	15-category RPE scale†	Category-ratio RPE scale†	Breathing rate	Body temperature	Example of activity
Very light effort		< 20	< 35	< 10	< 2	Normal	Normal	Dusting
Light effort	Range required for health	20-39	35-54	10-11	2-3	Slight increase	Start to feel warm	Light gardening
Moderate effort	Range required for health	40-59	55-69	12-13	4-6	Greater increase	Warm	Brisk walking
Vigorous effort	Range required for health	60-84	70-89	14-16	7-8	More out of breath	Quite warm	Jogging
Very hard effort		> 84	> 89	17-19	9	Greater increase	Hot	Running fast
Maximal effort		100	100	20	10	Completely out of breath	Very hot, perspiring heavily	Sprinting all-out

Note: HRR = heart rate reserve, HR_{max} = maximum heart rate, RPE = patient's rating of perceived exertion.
*Created from information provided in the handbook for *Canada's Physical Activity Guide to Healthy Active Living*,[26] and the American College of Sports Medicine's guidelines for exercise testing and prescription.[9]
†See Table 4 for details about the RPE scales.

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APPENDIX B – ETHICS APPROVAL FORM

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Certificate #:	**2007- 135**
2nd Amendment Approved: 03/25/09	
Renewal Approved: 01/05/09	
Amendment Approved: 10/15/07	
Approval Period:	**03/25/09-03/25/10**

Memo

To: Professor Norman Gledhill and Veroncia Jamnik
ngledhil@yorku.ca

From: Alison M. Collins-Mrakas, Manager, Research Ethics

Date: **Wednesday March 25th, 2009**

Re: Ethics Approval
The Fitness and Health Benefits of Recreational Off-Road Vehicle Riding

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With respect to your research project entitled, "The Fitness and Health Benefits of Recreational Off-Road Vehicle Riding", the committee notes that, as there are no substantive changes to either the methodology employed or the risks to participants in and/or any other aspect of the research project, renewal of approval re the proposed amendment to the above project is granted.

Should you have any questions, please feel free to contact me at: 416-736-5914 or via email at: acollins@yorku.ca.

Yours sincerely,

Alison M. Collins-Mrakas M.Sc., LLM

Sr. Manager & Policy Advisor, Research Ethics

APPENDIX C

Off-road Vehicle Training Study – Informed Consent

The purpose of this study is to examine the potential health benefits accrued from consistent participation in the activity of off-road vehicle riding.

Various laboratory measures of anthropometry, flexibility, muscular strength, power and endurance will be taken to determine your baseline fitness before initiating instructional riding sessions at TrailTours Riding School with a professional instructor. We will also be inquiring about your physical activity participation, back fitness and lifestyle habits via a series of questionnaires. A small finger prick blood sample will be taken during the laboratory testing (similar to the way a diabetic tests blood sugar) by a certified phlebotomist for analysis of blood lipids, which are a strong indicator of cardiovascular disease risk. Throughout the course of your instruction, heart rate and oxygen consumption will be periodically measured while you are riding what has been determined to be representative of a typical ride by your fellow riders and subject matter experts. The measurement of heart rate will involve wearing a non-invasive chest strap under your safety equipment, against your skin, and a wrist watch. The occasional measurement of oxygen consumption will require you to wear a mouthpiece within your helmet which is connected to a very small portable computer worn in a backpack. In the weeks following the training, you will be invited back to the fitness assessment laboratory at York University where your fitness will again be assessed. The measurement of aerobic fitness will require you to run on a treadmill to maximal exertion while your expired gases are being collected via a mouthpiece and analyzed by qualified lab personnel. The time commitment required for participation in this study will be approximately 20 days in the month of June at the riding school and 1-2 hrs each for the baseline and follow-up tests in the laboratory.

Along with this document of informed consent, you will also be required to complete a PAR-Q (physical activity readiness questionnaire) form which is a widely used pre-screening tool to prevent exercise induced health problems.

Risks and Benefits:

Participation in adventure activities such as off-road motor sports comes with obvious inherent risks which may include falling off of the vehicle, collision with a natural terrain feature, or collision with another rider and their vehicle. These risks will not increase as a result of participation in our study, nor will the scientific equipment impair your ability to ride; however, every possible precaution to avoid accidents will be taken to ensure a safe riding environment. The measures of heart rate and oxygen consumption while riding should not pose any health risks as they are non-invasive, externally worn devices. The collection of blood for lipid analysis will be performed by a trained professional using sterile equipment to ensure your safety. However, as with any break in the skin, there is the small chance of infection and there may be very mild discomfort. Following the collection of the sample, the researchers will provide you with a band-aid and will sterilize the area to further reduce this risk.

The laboratory assessment of your fitness will not pose any significant risks to your health other than those normally associated with participation in regular physical activity. These risks may include, light headedness, fatigue, nausea, shortness of breath and on extremely rare occasions, cardiac complications. First aid equipment and trained staff will be on site (at both locations) in case of any such event.

As a subject, you may gain the benefits of professional motorcycle or ATV instruction, trail use and will have the benefits of a full laboratory fitness test including: body fat assessment, strength and power measures, lifestyle and health related fitness analyses, and anaerobic and aerobic fitness determination at no cost to yourself. Such information can be useful as a measure of health and training status. You will also be provided with the guidance of a professional riding instructor and food and beverage at no cost to yourself while attending the training portion of the study at the riding school. York University Kinesiology students will receive PKIN credit for participation and non-students will be compensated for expenses at a rate of $40/day.

Participants are free to ask questions of the research team and may withdraw from the study at any time without penalty; financial or otherwise. Your withdrawal will not in any way affect your relations with the researchers, York University, the Riding School or the off-road governing bodies. Furthermore, withdrawal from the study will not affect any previous agreement between you and the aforementioned in regards to your participation in the activity.

All data will be kept confidential and no person other than the researchers will have access to this data in accordance with Canadian law. In any resulting publications or presentations, all subjects will remain anonymous. Following the completion of the study, all un-coded data will be deleted or destroyed.

This research project has been reviewed and approved by the HPRC for compliance with senate ethics policy. If you have questions or concerns beyond the testing day(s) you may contact Jamie at York University at jamieb@yorku.ca or (416) 736-5794. Other questions can be directed to Allison Collins-Mrakas, Manager, Office of Research Ethics

309 York Lanes,York University,4700 Keele Street,Toronto, Ontario,M3J 1P3,(416) 736-5914, (416) 736-5837 (fax), acollins@yorku.ca (email).

______________________________ ______________________________

Signature of Participant (date) Signature of Principal Investigator

APPENDIX D
Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________________

SIGNATURE ______________________________ DATE ______________________

SIGNATURE OF PARENT ______________________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

 Supported by: Health Canada Santé Canada

continued on other side...

APPENDIX E

Questionnaire package given to participants containing the SF-36 (License #R1-111708-38893), CPAFLA Healthy Physical Activity Participation Questionnaire, CPAFLA Fantastic Lifestyle Checklist.

YORK UNIVERSITY – OFF-ROAD HEALTH BENEFITS STUDY

YORK UNIVERSITÉ UNIVERSITY

redefine THE POSSIBLE.

The following package contains a number of surveys designed to determine your views about your own health and fitness. Please answer the questions as honestly as possible; all information will be recorded by computer and kept strictly confidential. Completion of this package will generally take 15-20 minutes, but you may have as much time as is necessary.

Each participant will be assigned a personal ID number. This number (found below) is used to code your data and ensure confidentiality. Only the lead researcher will keep a copy of the names and corresponding numbers to provide anonymity. Following submission of this package, your number will be recorded and the information linking your name and number will be destroyed.

Using an HB pencil record all answers on the red scanner sheet provided. When bubbling answers, completely fill in the bubbles on the answer sheet. If you make a mistake, erase your answer completely before filling in the correct bubble.

Before beginning the Questionnaire, please start by filling in your ID number on the top left of the red scanner sheet. Your number should be written in the column as well as bubbled using the corresponding numbers to the left.

Name: ______________________________

ID Number : ___________________________

SF-36 *Please select only one choice for each item.*

1) My Gender is:

a) Male   b) Female

2) I fall into the following age range:

a) <24 yrs b) 25 – 34 c) 35-44 d) 45-54 e) 55-64 f) 65-74 g)>75 yrs

3) In general, would you say your health is:

a) Excellent b) Very good c) Good d) Fair e) Poor

4) Compared to ONE YEAR AGO, how would you rate your health in general NOW?

a) MUCH BETTER than one year ago.

b) Somewhat BETTER now than one year ago

c) About the SAME as one year ago.

d) Somewhat WORSE now than one year ago.

e) MUCH WORSE now than one year ago.

The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?	**Answer**		
	Yes limited a lot	Yes Limited a little	No, Not limited at all

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?	**Answer**		
5) Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports?	a	b	c
6) Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf?	a	b	c
7) Lifting or carrying groceries?	a	b	c
8) Climbing several flights of stairs?	a	b	c
9) Climbing one flight of stairs?	a	b	c
10) Bending, kneeling or stooping?	a	b	c
11) Walking more than a mile?	a	b	c
12) Walking several blocks?	a	b	c
13) Walking one block?	a	b	c
14) Bathing or dressing yourself?	a	b	c

During the past 4 weeks, have you had any of the following problems with your work or other regular activities as a result of your physical health?	**Answer**	
	Yes	**No**
15) Cut down on the amount of time you spent on work or other activities?	a	b
16) Accomplished less than you would like?	a	b
17) Were limited in the kind of work or other activities?	a	b
18) Had difficulty performing the work or other activities (for example it took extra effort)?	a	b

	Yes	No
19) Cut down on the amount of time you spent on work or other activities?	a	b
20) Accomplished less than you would like?	a	b
21) Didn't do work or other activities as carefully as usual?	a	b

22) During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

a) Not at all b) Slightly c) Moderately d) Quite a bit e) Extremely

23) How much bodily pain have you had during the past 4 weeks?

a) None b) Very mild c) Mild d) Moderate e) Severe f) Very severe

24) During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

a) Not at all b) A little bit c) Moderately d) Quite a bit e) Extremely

These questions are about how you feel and how things have been with you during the ***past 4 weeks****. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks...*	**All Of The Time**	**Most Of The Time**	**A Good Bit Of The Time**	**Some Of The Time**	**A Little Of The Time**	**None Of The Time**
25) Did you feel full of pep?	a	b	c	d	e	f
26) Have you been a very nervous person?	a	b	c	d	e	f

27) Have you felt so down in the dumps that nothing could cheer you up?	a	b	c	d	e	f
28) Have you felt calm and peaceful?	a	b	c	d	e	f
29) Did you have a lot of energy?	a	b	c	d	e	f
30) Have you felt downhearted and blue?	a	b	c	d	e	f
31) Do you feel worn out?	a	b	c	d	e	f
32) Have you been a happy person?	a	b	c	d	e	f
33) Did you feel tired?	a	b	c	d	e	f

34) During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

a) All of the time

b) Most of the time.

c) Some of the time.

d) A little of the time.

e) None of the time.

How TRUE or FALSE is each of the following statements for you?	**Definitely true**	**Mostly true**	**Don't know**	**Mostly false**	**Definitely false**
35) I seem to get sick a little easier than other people?	a	b	c	d	e
36) I am as healthy as anybody I know?	a	b	c	d	e

37) I expect my health to get worse?	a	b	c	d	e
38) My health is excellent?	a	b	c	d	e

For the following Pages – complete the questionnaires first and then only bubble the answer on the bubble sheet as instructed in the box at the top of each page.

Bubble your score from box C (below) in the bubbles next to # 39 on the scanner sheet using the following.

a) *9-11* **b)** *6-8* **c)** *4-5* **d)** *1-3* **e)** *0*

DETERMINING THE HEALTH BENEFITS OF YOUR PHYSICAL ACTIVITY PARTICIPATION IS AS EASY AS A, B, C ...

A. Answer the following questions.

#1 Frequency

Over a typical seven-day period (one week), how many times do you engage in physical activity
that is sufficiently prolonged and intense to cause sweating and a rapid heart beat?

At least three times
Normally once or twice
Rarely or never

#2 Intensity

When you engage in physical activity, do you have the impression that you:

Make an intense effort
Make a moderate effort
Make a light effort

#3 Perceived Fitness

In a general fashion, would you say that your current physical fitness is:

Very Good
Good
Average
Poor
Very Poor

B. Circle your score for each answer and total your scores.

Item	Male	Female	Male	Female	Male	Female
#1 Frequency	Rarely or never		Normally once or twice		At least three time	
	0	0	2	3	3	5
#2 Intensity	Light Effort		Moderate effort		Intense effort	
	0	0	1	2	3	3
#3 Perceived Fitness	Very Poor or Poor		Average		Good or Very Good	
	0	0	3	1	5	3

Total Score = _______________

C. Determine your health benefit rating based on your score from B.
D.

Health Benefit Zone	Total Score
Excellent	9-11
Very Good	6-8
Good	4-5
Fair	1-3
Needs Improvement	0

FANTASTIC LIFESTYLE CHECKLIST (CPAFLA)

FAMILY FRIENDS	I have someone to talk to about things that are important to me	almost never		seldom		some of the time		fairly often		almost always	
	I give and receive affection	almost never		seldom		some of the time		fairly often		almost always	
ACTIVITY	I am vigorously active for at least 30 min. per day eg. running, cycling, etc.	less than once/week		1-2 times/week		3 times/week		4 times/week		5 or more times/week	
	I am moderately active (gardening, climbing stairs, walking, housework)	less than once/week		1-2 times/week		3 times/week		4 times/week		5 or more times/week	
NUTRITION	I eat a balance diet (see explanation)	almost never		seldom		some of the time		fairly often		almost always	
	I often eat excess: 1) sugar, or 2) salt, or 3) animal fats, or 4) junk food	four of these		three of these		two of these		one of these		none of these	
	I am within _____ kg of my healthy weight	not within 8 kg		8 kg (20 lbs)		6 kg (15 lbs)		4 kg (10 lbs)		2 kg (5 lbs)	
TOBACCO TOXICS	I smoke tobacco	more than 10 times/week		1 – 10 times/week		none in the past 6 months		none in the past year		none in the past 5 years	
	I use drugs such as marijuana, cocaine	sometimes								never	
	I overuse prescribed or 'over the counter' drugs	almost daily		fairly often		only occasionally		almost never		never	
	I drink caffeine-containing coffee, tea, or cola	more than 10/day		7-10/day		3-6/day		1-2/day		never	
ALCOHOL	*My average alcohol intake per week is _____* (see explanation)	*more than 20* drinks		13-20 drinks		11-12 drinks		8-10 drinks		0-7 drinks	
	I drink more than four drinks on an occasion	almost daily		fairly often		only occasionally		almost never		never	

	I drive after drinking	sometimes								never	
	I sleep well and feel rested	almost never		seldom		some of the time		fairly often		almost always	
	I use seatbelts	never		seldom		some of the time		most of the time		always	
SLEEP **SEATBELT**	I am able to cope with the stresses in my life	almost never		seldom		some of the time		fairly often		almost always	
STRESS **SAFE SEX**	I relax and enjoy leisure Time	almost never		seldom		some of the time		fairly often		almost always	
	I practice safe sex (see explanation)	almost never		Seldom		some of the time		fairly often		always	
TYPE OF BEHAV-IOUR	I seem to be in a hurry	Almost always		fairly often		some of the time		seldom		almost never	
	I feel angry or hostile	almost always		fairly often		some of the time		seldom		almost never	
	I am a positive or ptimistic thinker	almost never		seldom		some of the time		fairly often		almost always	
INSIGHT	I feel tense or uptight	almost always		fairly often		some of the time		seldom		almost never	
	I feel sad or depressed	almost always		fairly often		some of the time		seldom		almost never	
CAREER	I am satisfied with my job or role	almost never		seldom		some of the time		fairly often		almost always	

APPENDIX F

Sayers equation for the calculation of leg power

Peak Leg Power (W) = [60.7 x jump height (cm)] + [45.3 x body mass (kg)] -2055

Ainsworth Question:

"Considering a 7-day period (a week), how many times on the average do you do strenuous exercise (heart beats rapidly) for more than 15 minutes during your free time?"

______

Follow-up:
Of these sessions, how many are performed using an off-road vehicle?
ALL _____ NONE _____ OTHER _____ (please include number if other)

APPENDIX G

Supplementary Figure

Bodily pain scores of the four off road riding groups (4 ORM, 4 ATV, 2 ORM, 2 ATV) decomposed from the overall PCS composite. Scores decreased from baseline to 6wk, then increased from 6 wk to 8 wk in the 2 ORM and 2 ATV groups who continued to train.