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ORIGINAL ARTICLE

Physiological fitness and health adaptations from purposeful training using off-road vehicles

J. F. Burr · V. K. Jamnik · N. Gledhill

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Abstract The purpose of this study was to evaluate fitness and health adaptations from a training program riding all-terrain vehicles (ATV) and off-road motorcycles (ORM) as the exercise stimulus. Participants ($n = 58$) were randomized to a control group ($n = 12$) or one of four experimental groups; 2 days/week ATV ($n = 11$), 2 days/week ORM ($n = 12$), 4 days/week ATV ($n = 11$), or 4 days/week ORM ($n = 12$). Aerobic fitness, musculoskeletal fitness, body composition, clinical health, and quality of life (QOL) were compared at baseline and following 6 weeks of training. In all riding groups, there were improvements in blood pressure (SBP = 9.4 ± 10.1, DBP = 5.8 ± 6.2 mmHg), fasting glucose (0.5 ± 0.7 mmol/l), subcutaneous adiposity (0.9 ± 1.1%), body mass (0.7 ± 2.7 kg), waist circumference (1.3 ± 2.5 cm), and isometric leg endurance (26 ± 44 s). All changes were of moderate to large magnitude (Cohen's *d* 0.52–0.94) with the exception of a small loss of body mass (Cohen's $d = 0.27$). Although changes occurred in the riding groups for aerobic power (2.9 ± 4.6 ml kg^{-1} min^{-1}), leg power (172 ± 486 w), and curl-ups (13.2 ± 22.7), these changes were not significantly different from the control group. No significant alterations occurred in resting heart rate, trunk flexibility, back endurance, hand grip strength, long jump, pull/push strength, or push-up ability as a result of training. Physical domain QOL increased in all 2 days/week riders but mental domain QOL increased in all ORM, but not ATV riders regardless of volume. Ambient carbon monoxide levels while riding (<30 ppm) were within safe exposure guidelines. Positive adaptations can be gained from a training program using off-road vehicle riding as the exercise stimulus.

Keywords Motorcycle · ATV · Health-related fitness · Cardiovascular · Metabolic · Aerobic

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J. F. Burr · V. K. Jamnik · N. Gledhill
Physical Activity and Chronic Disease Unit,
School of Kinesiology and Health Science,
Faculty of Health, York University, Toronto, ON, Canada

J. F. Burr (✉)
Rm 354 Bethune College, 4700 Keele St,
Toronto, ON 1P3 M3J, Canada
e-mail: j.burr@physicalactivityline.com

Introduction

Off-road vehicle riding is an increasingly popular recreational activity in North America and around the world, and much debate exists as to the impact of off-road riding on participant fitness and health. Cross-sectional examination of the fitness and health of habitual recreational off-road vehicle riders has revealed that off-road riders reveal some positive alterations in fitness and health (Burr et al. 2010a). As a group, these include a higher aerobic fitness, healthier blood lipid profiles, and a lower prevalence of the metabolic syndrome compared to the general population; however, important differences exist among riders in association with the type of vehicle they use (Burr et al. 2010a). These higher levels of fitness and health appear to result from regular off-road riding, which has moderate aerobic intensity and strength requirements that differ slightly according to the vehicle type used (Burr et al. 2010c). Despite the findings of both a healthier physiological profile in those who habitually ride off-road vehicles and a typical exercise intensity that falls within recommended guidelines to improve fitness and health, a

Table 1 Descriptive participant characteristics (mean ± SD) of experimental and control groups

Group	n (m/f)	Age (year)	Height (cm)	Weight (kg)	VO_2max (ml kg^{-1} min^{-1})
2 ATV	8 (3/5)	22 ± 3	170 ± 13	78.3 ± 12.8	43.9 ± 5.6
2 ORM	8 (4/4)	31 ± 13	173 ± 4	67.5 ± 14.2	41.0 ± 9.2
4 ATV	7 (3/4)	23 ± 10	168 ± 9	78.9 ± 14.0	35.5 ± 7.8
4 ORM	11 (7/4)	26 ± 8	173 ± 9	76.1 ± 19.4	38.9 ± 7.2
Control	10 (2/8)	22 ± 2	165 ± 10	63.8 ± 13.1	41.8 ± 6.3

This table includes only data from participants who completed the training study, with dropouts excluded

definitive cause and effect relationship using a longitudinal study design has yet to be established. Ascertaining 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 (Liu et al. 2006; Peach and Bath 1999).

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 all-terrain vehicles (ATV) and off-road motorcycles (ORM). A second purpose was to determine if differences would occur in the training response by vehicle type or riding frequency. The final purpose was to measure the ambient levels of carbon monoxide exposure during group rides and to discuss the potential ill-effects of this carbon monoxide exposure on cardiovascular and respiratory health. It was 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 physical activity volume as opposed to the typical off-road participation volume.

Methods

Participants

Participants were recruited from the university community and across the province of Ontario via announcements in undergraduate classes and internet postings. For both the experimental and control conditions, the authors sought participants of both genders who were >16 year of age and were not actively involved in regular physical activity. 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 1. Participants were from ethnically diverse backgrounds. Ten volunteers were randomly picked as controls and 40 volunteers were randomly assigned to one of four training modes: (1) riding ORM 2 days/week (2 ORM, $n = 12$), (2) riding ATV 2 days/week (2 ATV, $n = 11$), (3) riding ORM 4 days/week (4 ORM, $n = 12$), and (4) riding ATV 4 days/week (4 ATV, $n = 11$). All training sessions were for a duration of 2 h/day and the study duration was 6 weeks. After verbal explanation of procedures, written informed consent was provided by all participants, with those of 16–18 years also providing parental consent. This project was approved and conducted in accord with York University Human Ethics Review Board guidelines.

Assessments

For this investigation, health was operationally defined as the absence of disease and disability, or risk factors for chronic disease, 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 (Canadian Society for Exercise Physiology 2004) the authors 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 (Ware and Sherbourne 1992).

The authors employed a repeated measures design involving fitness and health assessments with all participants and controls tested at baseline and following 6 weeks of training. An additional 2 weeks of training was performed by the 2 ORM and 2 ATV groups for a follow-up analysis in an attempt to equilibrate total training hours, despite different frequencies of participation. This follow-up was included in case the 2 ATV and 2 ORM groups required a longer training duration before manifesting possible changes in fitness and health. Each participant in the 4 ATV and 4 ORM groups completed a total of approximately 48 training hours over 6 weeks, whereas the

2 ATV and 2 ORM groups completed a total of 32 training hours over 8 weeks. All measurements were overseen by the investigators but performed by technicians who were blinded to the group assignments.

Training

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 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 the off-road riding program was monitored using heart rate (Suunto Oy, Vantaa, Finland) and ambulatory VO_2 measures (Cosmed Fitmate, Rome, Italy). In brief, participants periodically wore a portable metabolic computer, with an adapted helmet to allow the collection of expired gas without restricting movement of the rider. In addition, heart rate, altitude, and GPS calculated speed and distance were collected throughout other training rides, with all riders completing both HR and VO_2 measures at least twice in the course of training to ensure that the training was of an appropriate intensity. VO_2 measures were collected for 25–30 min during a ride with a mean of 27.1 ± 8 min. During rides, the initiation of data collection was randomized to include samples at the beginning, middle, and end of training. HR and GPS measures were collected for the full duration of the ride.

Fitness measures

Body mass, waist circumference, 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 Womersley (1974). Participants were instructed not to alter their regular physical activity during the study. Prior to study onset and 2 weeks before completion, participants logged daily food intake and elective physical activity for 7 days 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 physical activity on health-related fitness and to determine if subjects made changes from their regular diet or physical activity as a result of participation.

Grip strength was measured using a dynamometer (Smedley Hand Dynamometer, Stoelting Co, Wood Dale, Ill) adjusted to the second knuckle of the hand. Three trials were performed per hand in an alternating sequence 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°. Maximal force was recorded from three trials, alternating push and pull. Dynamic upper body strength was assessed using either full (male) or partial (female) push-ups with the hands placed directly below the shoulders and elbows kept tight to the body. 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, which included a straight back and full range of motion. Core musculature was assessed using the Canadian Physical Activity Fitness and Lifestyle Assessment (CPAFLA) tests of partial curl-ups (modified sit-ups, with a movement range of 10 cm to maximum at a pace of 50 bpm), two trials of sit and reach trunk flexion and the Sorenson back extension (maximal time with the lower back muscles supporting the upper body at horizontal) with the modification of no ceiling values for performance. These tests are described in specific detail in the CPAFLA manual (Canadian Society for Exercise Physiology 2004).

Leg power was assessed with a maximal vertical jump recorded to the nearest 1.3 cm (0.5 in.) 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 in watts was calculated from jump height using the Sayers equation (Keir et al. 2003). Isometric leg endurance was assessed using a wall-sit with the knees bent 90° and back flat against the wall. A wall mounted 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 with analysis of expired gas (S-3A/II oxygen, CD-3A carbon dioxide; AEI Technologies, Pittsburgh, PA) using open circuit spirometry. Participants began walking (3.5 mph, 0% elevation), 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. All participants were encouraged to continue until a super-maximal value was obtained (i.e., a true plateau and/or drop in VO_2 was observed). If participants were unable to continue to this point, VO_2 peak is reported.

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 eight 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 (Ware and Kosinski 2007). This assessment was used to determine if participation in this form of alternative physical activity had a beneficial effect on mental and physical health-related QOL.

Carbon monoxide

During group rides, carbon monoxide concentration was measured in ambient air, as opposed to directly from the tailpipe, as health risk is best determined using actual lung exposure (Flachsbart 1999). Measurements were taken using a portable carbon monoxide 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 at the front, middle, and back of the group. All vehicles were well maintained and less than 1 year old.

Statistical analyses

Baseline comparisons between control and experimental groups were performed using one-way ANOVA for each individual measure. Using VO_2 as the prime variable of interest an a priori power calculation revealed an expected power of 85% given a sub-group size of ten participants and a standard variance of 2.5 ml kg^{-1} min^{-1}. Training related changes from baseline to 6 weeks were compared between exercise frequencies and vehicle types using a 2 (baseline and post-training measures) × 5 (2 ORM, 2 ATV, 4 ORM, 4 ATV and control) repeated measures ANOVA with post hoc Bonferroni comparisons. Owing to a lack of differentiation by riding subgroup, a follow-up 2 (riders and controls) × 2 (baseline and post-training) repeated measures ANOVA was performed to establish significant main effects of training in all riding groups combined versus the control group. Delta scores were calculated to express changes from pre to post as a mean ± SD. The magnitude of physiological fitness and health adaptations were assessed using Cohen's d statistic. All analyses were performed using SPSS software (version 17.0; SPSS Inc, Chicago IL).

Results

Participant compliance and dropouts

A total of 2 control and 12 experimental participants withdrew before study completion (9 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 weeks testing were removed from analyses. Overall, participants had an 88.6 ± 12.3% compliance with training sessions. In a total of approximately 1300 h of riding, there was only one non-serious (bruised shoulder) and one 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 hills 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. The composition of a "training" trail ride intentionally approximated the "typical" trail ride described by habitual off-road riders in a related study (Burr et al. 2010c) 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 kg^{-1} min^{-1}) was similar to values recorded using habitual off-road riders (ATV 12.1 ± 4.9 and ORM 21.3 ± 7.1 ml kg^{-1} min^{-1}) (Burr et al. 2010c). Group-specific training intensities are provided in Fig. 1.

Fitness measures

Health and fitness data from baseline to 6 weeks is presented in Table 2. At baseline there were no significant differences

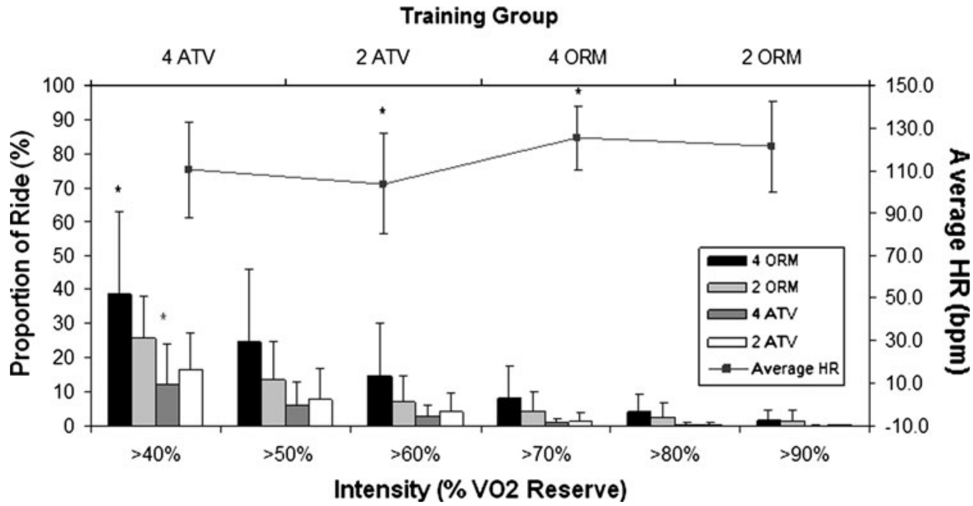

Fig. 1 Intensity of off-road ride training by experimental group. *Left axis* Cumulative proportion of off-road riding spent by aerobic exercise intensity, considering only exercise intensities sufficient to stimulate changes in fitness (>40% VO_2 reserve). *Right axis* Mean heart rate response of all training rides. *Significant difference between riding modes $P < 0.05$

among off-road riding groups and controls on any health or fitness variables. With the exception of percentage of body fat, in which those who rode 4 ORM had significantly greater improvements compared to controls by decreasing body fat by 1.5% ($P = 0.01$), significant differences did not exist on fitness measures according to vehicle type and riding frequency classifications. Given this lack of training group differentiation, main effects were considered across the combined group of riders versus controls which increased statistical power. At 6 weeks, there were significant changes toward a healthier state of considerable magnitude (mean change ± SD, Cohen's *d*) in body mass (0.7 ± 2.7 kg, $d = 0.27$), waist circumference (1.3 ± 2.5 cm, $d = 0.52$), percentage of body fat (0.9 ± 1.1%, $d = 0.85$), and wall sit time or isometric leg endurance (26.1 ± 44 s, $d = 0.59$). Standing long jump and leg power scores

Table 2 Health and fitness changes in off-road vehicle (off-road motorcycle and all terrain vehicle) trained groups and controls at baseline and following 6 weeks of training

	Control		Off-road riding training groups combined		Main effect	Change
	Baseline	6 weeks	Baseline	6 weeks		*P*
Pre-exercise heart rate (bpm)	78.5 ± 13.7	74 ± 8.6	75.4 ± 8.8	74.6 ± 10.9	↔	0.33
Systolic blood pressure (mmHg)	119.9 ± 11.5	120.3 ± 14.8	121.4 ± 13.0	112 ± 10.3	↓	0.01
Diastolic blood pressure (mmHg)	75.4 ± 10.4	73.7 ± 9.0	74.6 ± 9.2	68.9 ± 7.6	↓	0.001
Fasting glucose (mmol)	4.7 ± 0.5	4.6 ± 0.5	5.2 ± 0.8	4.7 ± 0.6	↓	0.004
Body mass (kg)	62.5 ± 13.1	63.8 ± 13.1	76.0 ± 17.0	75.3 ± 15.6	↓	0.05
Waist circumference (cm)	79.0 ± 6.1	80.0 ± 8.1	88.5 ± 10.5	87.2 ± 9.4	↓	0.02
Body fat (%)	28.9 ± 7.3	28.9 ± 7.6	28.7 ± 6.8	27.7 ± 6.6	↓	0.01
Isometric wall sit (s)	102 ± 64	94 ± 36	79 ± 32	105 ± 52	↑	0.04
Isometric push strength (kg)	63.2 ± 29.1	63.4 ± 25.5	76.0 ± 30.5	77.9 ± 33.6	↔	0.68
Isometric pull strength (kg)	68.1 ± 23.6	65.9 ± 29.5	72.4 ± 25.7	77.6 ± 24.7	↔	0.09
Push-ups (max)	21.9 ± 8.5	18.8 ± 9.8	16.2 ± 8.1	16.5 ± 8.7	↔	0.18
Combined grip strength (kg)	60.8 ± 21.1	63.2 ± 26.8	79.0 ± 26	78.5 ± 24.4	↔	0.33
Trunk flexion (cm)	34.3 ± 6.6	35.2 ± 4.8	30.3 ± 6.9	31.7 ± 6.7	↔	0.67
Leg power (W)	2956 ± 962	3119 ± 916	3638 ± 1044	3810 ± 1153	↔	0.08
Back extension (s)	126 ± 52	125 ± 51	116 ± 40	130 ± 66	↔	0.36
Standing long jump (cm)	172 ± 43	171 ± 45	176.5 ± 40.7	183.7 ± 38.8	↔	0.06
Curl-up (max)	30.5 ± 12.4	38.1 ± 20.5	34 ± 29	46 ± 36	↔	0.57
VO_2max (ml kg^{-1} min^{-1})	41.8 ± 6.3	43.0 ± 8.1	39.3 ± 6.8	42.2 ± 7.0	↔	0.29
Caloric intake (kcal)	1997 ± 682	1872 ± 683	1996 ± 981	2060 ± 951	↔	0.26

Data presented as mean ± SD

↑ Increased from baseline, ↔ No statistically significant change from baseline, ↓ Decreased from baseline revealed a trend toward improvement, but did not reach statistical significance. A temporally significant improvement was evident in leg power, partial curl-ups, and aerobic power from baseline, however, due to a concomitant change in the scores of control group participants, the authors cannot conclusively state that these changes were the result of participation in the off-road ride training as no significant difference existed between the change scores of experimental and control group participants. Activity and food logs revealed no increase or decrease in elective physical activity and no changes in caloric intake in any group. The additional 2 weeks of follow-up riding in the 2 ATV and 2 ORM groups led to no additional significant changes in fitness measures.

Clinical measures

Large magnitude changes toward a healthier state were observed in both systolic blood pressure (9.4 ± 10.1 mmHg, $d = 0.93$) and diastolic blood pressure (5.8 ± 6.2 mmHg, $d = 0.94$). Fasting glucose decreased (0.5 ± .0.7 mmol, $d = 0.71$), in all off-road riding groups combined.

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 weeks. However, a significant effect from baseline to follow-up completion (8 weeks) was found in 2 ORM and 2 ATV riders (49.4 ± 6.7 to 55.2 ± 3.6, $P = 0.006$) with no change in controls. Data for all groups are presented in Fig. 2. The lack of effect of off-road riding to increase PCS score at 6 weeks was attributable to an increase in the "bodily pain" SF-36 sub-scale (data not shown) which is a major component of the PCS composite score. The bodily pain scale revealed an increase in pain from baseline at 6 weeks followed by a return to baseline levels at 8 weeks.

Six weeks of off-road riding led to an improvement in MCS score for participants who rode 2 ORM and 4 ORM (49.6 ± 10.4 baseline to 58.2 ± 5 6 weeks, $P = 0.02$). These changes were maintained beyond 6 weeks and there were no effect evident for ATV riding or controls at any time point.

Carbon monoxide

Ambient carbon monoxide levels recorded while trail riding with approximately 8 ORMs ranged between 0 and 20 ppm, with little variation outside this range. There was a higher carbon monoxide level of approximately 85 ppm when vehicles stopped and quickly accelerated. No differences existed between 2-stroke and 4-stroke ORMs. Ambient carbon monoxide recorded while riding with approximately 8 ATVs ranged between 10 and 30 ppm on typical trails, increased to 50–100 ppm while riding slowly on 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) had no effect.

Discussion

The observed changes in some markers of fitness and health, such as blood pressure, 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 (Warburton et al. 2006). Exact participation rates in off-road riding are difficult to determine because many off-road vehicles remain unregistered, but it has been estimated that over 8 million Americans (Cordell et al. 2008) and approximately 77% of rural Canadian residents (Warda et al. 1998) have access to off-road vehicles. Given the important physiological adaptations that can be achieved by this type of non-traditional physical activity, and the fact that this type of physical activity can be used to target higher risk rural communities where exercise opportunities are limited, off-road riding represents an attractive unconventional physical 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 (Lee et al. 2005; Ross et al. 2000). Participants in this study decreased both subcutaneous adiposity (% body fat) and visceral adiposity (waist circumference), while only realizing a small magnitude decrease in body mass. This suggests that 6 weeks of off-road riding not only leads to healthy changes in adipose stores but also increases lean muscle mass to offset the weight loss associated with adipose reductions. These improvements in body composition are important health-related fitness improvements which reduce the risk of cardiovascular disease (Thompson et al. 2003) and can aid in proper metabolic function to help prevent metabolic disease or the progression of diabetes (Burr et al. 2010d).

The strength training effect of off-road riding on musculoskeletal fitness was significant only in lower body

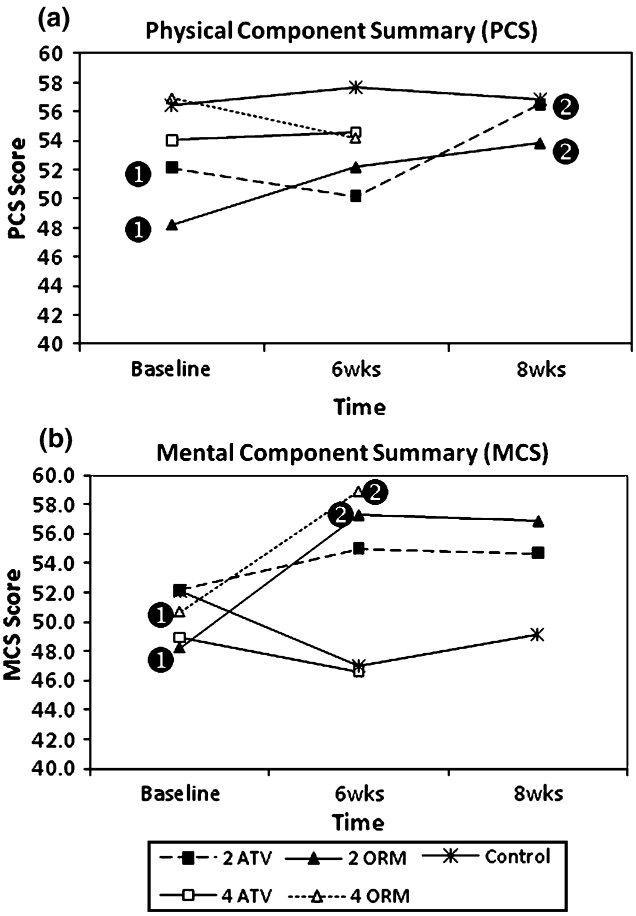

Fig. 2 SF-36 quality of life summary scales divided by experimental condition at baseline, 6 weeks and 8 weeks. **a** Physical component summary and **b** mental component summary. *1* is significantly different from *2* $P < 0.05$

muscular endurance, but showed trends toward changes in other measures and could have important health implications for those who choose this recreational pursuit as a means of physical activity. It has been reported that increased muscular strength and endurance protect against premature mortality (Katzmarzyk and Craig 2002) and functional disability (Brill et al. 2000). Increased musculoskeletal fitness has also been shown to be associated with a protective effect against significant weight gain (Mason et al. 2007) and can aid in decreasing cardiovascular risk factors while increasing overall health (Warburton et al. 2001). Despite indications from related studies that off-road riding is associated with upper body muscular strength (Burr et al. 2010c), no upper body training effects were evident in this study. This may have been related to the relatively short time course for adaptation or, more likely, the fact that the riding population was young and already possessed relatively high levels of upper body muscular strength.

A significant improvement in VO_2max (as well as leg power and core endurance) was evident from baseline to study completion in all groups, including the controls. Because the control group increased similar to the experimental groups, it is possible that the observed differences were as a result of measurement error, learning effects, or other non-study related participant factors thus it cannot be concluded that this was necessarily a training related effect. However, it is also possible that significant differences were not detected in the change scores between the individual experimental groups and the control due to a lack of power on some variables as a result of small effect sizes, relatively large variability in mean change scores and lower than anticipated sub-group size following drop out. These particular measures require further investigation using a larger sample size (65–70 participants) and a longer training duration to conclusively determine whether or not these apparent, but non-significant, changes represent a true training effect or simply measurement artifact.

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 (Fagard 2006). Both moderate aerobic (40–60% VO_2max) and dynamic resistance exercise training have been shown to contribute to reductions in blood pressure (Arroll and Beaglehole 1992; Fagard 2006) and there is evidence that isometric exercise may also be effective in lowering SBP (Peters et al. 2006). 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 (Chobanian et al. 2003).

Fasted blood glucose was effectively reduced by participation in off-road riding demonstrating the potential for this mode of alternative physical activity as an aid in metabolic regulation. The observed combined group mean change from 5.2 to 4.7 mmol/l is considerable, specifically in the 4 ORM group, as it removed group members from the high risk category of impaired fasting glucose (>5.6 mmol/l) as defined by the American Diabetes Association (American Diabetes Association 2009). These effects may have occurred through changes in insulin sensitivity directly, or as a result of improvements in body composition (Goodpaster et al. 1999). It has also been demonstrated that even small amounts of vibration training have the ability to improve glucose tolerance in type 2 diabetics (Baum et al. 2007), and it is possible that the vibration of off-road vehicles provides a similar stimulus. Both aerobic and resistance physical activity are recognized as effective treatment options for diabetes (Sigal et al. 2006) and it is likely that even greater changes in fasting glucose would have occurred in a diseased population.

Health-related quality of life

The SF-36 PCS score reveals that up to a duration of 6 weeks, riders did not report any improvement in their physical function as a result of riding, however, by 8 weeks 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 (Ware and Kosinski 2007). The observed increase in bodily pain at 6 weeks, 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. It was speculated that this effect was apparent at 6 weeks but not 8 weeks because riders were improving their riding skill (and progressing to greater challenges of riding) during the first 6 weeks while adapting to the physical stresses which led to soreness. Bodily pain scores returned to baseline levels at 8 weeks as riders sustained fewer physical insults and were becoming habituated to the stress of riding. Although the 4 days/week groups had more frequent physical activity exposure and would be expected to adapt to the physical activity stress more quickly, it is possible that the more frequent exposure also led to more minor injuries and 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 weeks 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, and 66.3% satisfied) (Ware and Kosinski 2007). Furthermore, this effect was maintained in the group that continued riding for an additional 2 weeks. In a previous study, using habituated off-road vehicle riders it has been shown that MCS scores did not differ between vehicle types (Burr et al. 2010b). 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. This study provides evidence that participants new to the sport of off-road riding benefitted more from increased health related QOL if riding an ORM, however, after pooling across vehicle types, a small but significant effect existed for age (with ORM being slightly older) which could have potentially affected this result.

The above findings 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 physical activity 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 physical activity levels and decrease inactivity related morbidity and mortality.

Carbon monoxide

The ambient carbon monoxide levels recorded while group riding were generally below the recommended carbon monoxide exposure guidelines of $<$35 ppm for a 8 h exposure or a ceiling of 200 ppm set by the U.S. National Institute of Occupational Safety and Health (NIOSH 1992). By comparison, average carbon monoxide levels inside the cabin of an automobile are as high as 44 ppm (Horner 1998). Although the large majority of group riding is associated with acceptable exposures levels at rest, the combined effect of high transient peaks during physical activity may increase the risk of carbon monoxide exposure as minute ventilation and heart rate are elevated by exercise and heat stress (Walker et al. 2001). This may have clinical implications particularly for people with coronary artery disease as carbon monoxide exposure can result in further increases in heart rate, myocardial dysfunction, and cardiac hypoxia (Favory et al. 2006), although this is likely of little concern for young healthy riders (Adir et al. 1999). The effects of carbon monoxide 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 carbon monoxide and particulate.

Conclusions

Consistent participation in off-road riding is an effective mode of alternative physical activity for decreasing adiposity, increasing muscle mass, and improving endurance in the lower body. Off-road riding is effective for lowering blood pressure and may be a useful physical activity modality to improve metabolic regulation. This study did not provide evidence to suggest that riding 4 days/week (recommended physical activity prescription) led to better health outcomes than the typical riding frequency of 2 days/week or that vehicle type had any effect on musculoskeletal and aerobic fitness training outcomes. Off-road riding increased 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. Carbon monoxide exposure while riding is generally at an acceptable level and should not pose a serious risk to healthy young riders; however, caution should likely 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 physical activity 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 physical activity 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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