This article was downloaded by: *[Buhel, Oksana]*
On: *22 October 2010*
Access details: *Access Details: [subscription number 928512912]*
Publisher *Routledge*
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713721847

A cross-sectional examination of the physical fitness and selected health attributes of recreational all-terrain vehicle riders and off-road motorcyclists

Jamie F. Burr[a]; Veronica Jamnik[b]; Norman Gledhill[a]
[a] Physical Activity and Chronic Disease Unit, [b] School of Kinesiology and Health Science, York University, Toronto, Ontario, Canada

First published on: 14 September 2010

To cite this Article Burr, Jamie F. , Jamnik, Veronica and Gledhill, Norman(2010) 'A cross-sectional examination of the physical fitness and selected health attributes of recreational all-terrain vehicle riders and off-road motorcyclists', Journal of Sports Sciences,, First published on: 14 September 2010 (iFirst)
To link to this Article: DOI: 10.1080/02640414.2010.510847
URL: http://dx.doi.org/10.1080/02640414.2010.510847

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Journal of Sports Sciences, 2010; 1–11, i*First* article

Routledge
Taylor & Francis Group

A cross-sectional examination of the physical fitness and selected health attributes of recreational all-terrain vehicle riders and off-road motorcyclists

JAMIE F. BURR[1], VERONICA JAMNIK[2], & NORMAN GLEDHILL[1]

[1]*Physical Activity and Chronic Disease Unit and* [2]*School of Kinesiology and Health Science, York University, Toronto, Ontario, Canada*

(Accepted 21 July 2010)

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

Abstract

The aims of this study were: (1) to characterize selected fitness and health attributes of two types of habitual recreational off-road vehicle riders – off-road motorcyclists and all-terrain vehicle riders; (2) to explore differences among riders in terms of vehicle type, age, and gender; and (3) to compare the fitness and health of riders to population norms and clinical health standards. Canadian off-road riders ($n = 141$) of both sexes aged 16 years and over were recruited through local and national off-road riding organizations. Anthropometry, fitness, and health measures of off-road motorcycle and all-terrain vehicle riders were compared with population norms, health standards, and physical activity guidelines. Off-road motorcycle riders had above average aerobic fitness (79th percentile), while all-terrain vehicle riders were lower than average (40th percentile). All riders had a healthy blood lipid profile and a low incidence of the metabolic syndrome (12.9%) compared with members of the general population. Off-road motorcycle riders had healthier body composition and fitness than all-terrain vehicle riders; however, the body composition of off-road motorcycle riders was no healthier than that of the general population and all-terrain vehicle riders were worse than the general population. Off-road motorcycle riders had healthier anthropometry and fitness than all-terrain vehicle riders and thus fewer health risk factors for future disease, demonstrating that the physiological profiles of off-road riders are dependent on vehicle type.

Keywords: *Motorcycle, all-terrain vehicle, alternative exercise, health-related, physical activity*

Introduction

Physical activity 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 (Canadian Society for Exercise Physiology, 2004). Recreational off-road vehicle riding is an increasingly popular non-traditional recreational activity around the world. 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 and off-road motorcycles that are intended for non-racing recreational use. These vehicles are also commonly referred to as "quad cycles" and "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" (Gobbi, Francisco, Tuy, & Kvitne, 2005), "motocross" (Ascensao et al., 2007; Gobbi et al., 2005; Konttinen, Hakkinen, & Kyrolainen 2007; Konttinen, Kyrolainen, & Hakkinen 2008), and "desert rally" (Gobbi et al., 2005) racing suggests that top-level off-road motorcycle riders have aerobic capacities (45–58 $ml \cdot kg^{-1} \cdot min^{-1}$) and body compositions (13–17% body fat) comparable to

Correspondence: J. F. Burr, Physical Activity and Chronic Disease Unit, York University, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada. E-mail: jamieb@yorku.ca

ISSN 0264-0414 print/ISSN 1466-447X online © 2010 Taylor & Francis
DOI: 10.1080/02640414.2010.510847

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

other high-profile North American athletes such as hockey players (Burr et al., 2008). However, this body of literature only considers high-level off-road motorcycle racers and the assumption that non-competitive, recreational riders share the same attributes as elite athletes is not supported by the evidence. To date, off-road vehicle rider fitness research has exclusively examined motorcycles, and the differences that may exist in off-road riding between two-wheeled motorcycles and four-wheeled all-terrain vehicles 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 (Warburton, Nicol, & Bredin 2006). 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 that cannot be captured simply by the absence of disease or disability (Canadian Society for Exercise Physiology, 2004) and these related dimensions are considered in an adjunct paper (Burr, Jamnik, Shaw, & Gledhill 2010).

There were three purposes to this cross-sectional observational study: (1) to characterize selected fitness and health attributes of two types of habitual recreational off-road vehicle riders – off-road motorcyclists and all-terrain 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.

Methods

Participants

Canadian off-road riders ($n = 141$) of both sexes aged 16 years and over 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 individuals who considered themselves a habitual rider. The researchers contacted clubs from the provinces of Ontario and Quebec to gather the volunteers together for pre-arranged group testing in their local area. The research team controlled the recruitment and selection of participants, thus avoiding selection bias from outside governing bodies. Exclusion criteria eliminated those taking medication that affected the health variables being considered and those who did not ride habitually, which was operationally defined as an average riding frequency of approximately once per week. Descriptive participant statistics are provided in Table I. After verbal explanation of the procedures, the participants provided written informed consent, with those under 18 years also received 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 participants' scores. This project was approved and conducted in accord with York University Human Ethics Review Board guidelines.

Assessments

Heart rate, blood pressure, height, weight, body composition, and waist circumference were measured before exercise. Riders reported physical activity participation using the Canadian Physical Activity Fitness and Lifestyle Appraisal form (Canadian Society for Exercise Physiology, 2004) and weekly frequency was calculated from information collected with the Ainsworth questionnaire (Ainsworth, Richardson, Jacobs, & Leon, 1993) for estimating aerobic fitness. This questionnaire was selected for consistency with data previously collected on the normative Canadian population

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

		Vehicle type		Age (years)			Years of experience			
	No. of riders (%)	ORM	ATV	16–30	31–49	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 (19.0)	42 (30.0)
Males	107 (75.9)	59 (75.6)	48 (76.2)	19 (65.5)	48 (71.6)	40 (88.9)	29 (67.4)	20 (69.0)	21 (77.8)	37 (88.1)
Females	34 (24.1)	19 (24.4)	15 (23.8)	10 (34.5)	19 (28.4)	5 (11.1)	14 (32.6)	9 (31.0)	6 (22.2)	5 (11.9)

Note: Combined values are expressed as number of riders (percentage of overall group); gender specific values are expressed as number of riders (percentage of gender split within group). ORM = off-road motorcycle riders; ATV = all-terrain vehicle riders.

(Payne, Gledhill, Katzmarzyk, Jamnik, & Keir, 2000). Weekly physical activity data were collected to document the amount of physical activity this subgroup 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 I) and weekly riding frequency.

Upper body strength was assessed using an isometric spring resisted dynamometer that allowed for quantification of both push and pull strength at an elbow joint angle of 110°. Push strength involved the isolated use of chest and elbow extensor muscles, while pull strength involved muscles of the upper back and elbow flexors. A Smedley analog handgrip 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 Canadian Physical Activity Fitness and Lifestyle Appraisal partial curl-up and the Sorenson back extension protocol (Canadian Society for Exercise Physiology. 2004). 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 (Keir, Jamnik, & Gledhill 2003).

Most participants ($n = 98$) underwent an assessment of aerobic power using 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 ($n = 22$) that they were not required to provide in accord with the 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 participants 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 ($\dot{V}O_2$) did not increase at least 150 ml $\cdot$ min^{-1} with an increase in workload, when the respiratory exchange ratio was greater than 1.15, when heart rate did not increase with increases in exercise intensity, or when the participant reached volitional fatigue and had a rating of perceived exertion greater than 17 on the Borg 6–20 scale (Heyward, 2002). All participants were encouraged to continue until a super-maximal value was obtained. If participants were unable to continue to this point, $\dot{V}O_{2peak}$ is reported.

Normative population anthropometric, health, and fitness data were used as a standard reference for the participants' specific Canadian Physical Activity Fitness and Lifestyle Appraisal measures (Payne et al., 2000). Comparisons between riders and these norms were possible for all variables listed in Table II. For the sub-set of participants whose aerobic fitness was measured directly, comparisons were made to norms specific to age and gender (Cooper Institute for Aerobics Research, 2009). 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 analysed using the Cholestech LDX system (Cholestech Corporation, Hayward, CA) collected from a randomly selected sub-sample ($n = 61$) of our participants. A sub-sample of participants was used to allow sufficient representation of all groups, while keeping costs at a minimum. This sub-population had representation from all groups as follows: 37.5% (18/48) of male and 71.4% (10/14) of female all-terrain vehicle riders; and 38.9% (23/59) of male and 52.6% (10/19) of female off-road motorcycle riders. This system has been evaluated with reference to National Cholesterol Education Program standards and is accurate for general classification of results into blood lipid ranges associated with known health outcomes (Bard, Kaminsky, Whaley, & Zajakowski, 1997).

Statistical analyses

Anthropometric, health, fitness, and clinical measurements were compared with normative data by gender, vehicle type, and age categories using a 3 (norm, all-terrain vehicle, and off-road motorcycle) × 2 (male and female) × 3 (age tertiles) factorial analysis of variance (ANOVA) with *post-hoc* Bonferroni comparisons. Interaction effects with normative aggregate data (mean $\pm$ s) were verified using the *post-hoc* Simple Effects method with a Bonferroni correction for the number of comparisons under the guidance of an expert statistical advisor. Where appropriate, measures were compared with 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 with the normative data set, which was more equally represented. Due to variable participation in some tests and a low female

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

Table II. Anthropometric and health-related fitness measures (mean ± *s*) for population norms, all-terrain vehicle riders, and off-road motorcycle riders divided by gender and age categories.

		Age (years)	*n*	Weight (kg)	Height (cm)	BMI	SO5S (mm)	WC (cm)	Push (kg)	Pull (kg)	Handgrip (kg)	Curl-ups	VJ (cm)	Leg power (w)	Sorenson (s)
Males	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
Females	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

Note: ATV = all-terrain vehicle riders, ORM = off-road motorcycle riders, BMI = body mass index, SO5S = sum of 5 skinfolds, WC = waist circumference, VJ = vertical jump height.

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 set 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).

Results

The frequency of weekly off-road riding was consistent across age groups and between the sexes (1.5 ± 1.7) but differed between all-terrain vehicle (1.0 ± 1.4) and off-road motorcycle (1.8 ± 1.9) riders ($P < 0.001$). Examination of all weekly physical activity (including other sports, work, fitness activities, and riding) revealed a gender × vehicle interaction, with male all-terrain vehicle (3.7 ± 2.1) and off-road motorcycle (3.8 ± 1.8) riders reporting a similar frequency, but female all-terrain vehicle riders (3.3 ± 1.9) reporting being less active than female off-road motorcycle riders (4.5 ± 2.2; $P = 0.021$).

Anthropometry

Descriptive anthropometric and fitness data are presented in Table II. Relative to population norms, male riders were taller ($P < 0.001$), heavier ($P < 0.001$), and had a greater waist circumference ($P < 0.001$). The mean waist circumference of all male riders combined was above the population norm owing primarily to the considerably higher waist circumferences of all-terrain vehicle riders ($P < 0.001$), although off-road motorcycle riders were also elevated above the norm, but by a smaller margin. In male off-road motorcycle riders, similar to population norms, measures of waist circumference were higher among older groups; however, the average waist circumference of male all-terrain vehicle participants peaked in middle-aged riders and then did not increase when comparing middle-aged with the oldest aged category. All-terrain vehicle riders of both sexes were heavier than off-road motorcycle riders, had a greater waist circumference, and a greater body mass index (BMI) (all significant, $P < 0.001$). Off-road motorcycle riders were heavier than the corresponding population norms ($P < 0.001$) but had a similar BMI. Both male all-terrain vehicle and off-road motorcycle riders had a higher sum of five skinfolds than average normative males ($P < 0.001$). However, unlike the population norms wherein the oldest aged group had larger sum of five skinfold values, 30- to 49-year-old riders had a lower sum of five skinfolds compared with those riders over 50. This was apparent for both vehicle types. Nevertheless, adiposity was greater among all-terrain vehicle and off-road motorcycle riders at all ages compared with population norms. Using the Canadian Physical Activity Fitness and Lifestyle Appraisal healthy body composition composite scoring system (0–4, scaled from "needs improvement" to "excellent"; combined group mean 2.5 ± 1.5), all-terrain vehicle riders had a mean score of (1.76 ± 1.51), which was significantly lower than the off-road motorcycle mean of 3.11 ± 1.26 ($P = 0.024$).

Fitness

Combined handgrip strength revealed a vehicle type $\times$ age interaction ($P = 0.013$) such that a decrease in grip strength from the youngest to the oldest age groups was evident in all-terrain vehicle riders and norms, but not in off-road motorcycle 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 oldest off-road motorcycle age group did not reveal a decreased curl-up ($P < 0.001$) or back extension ($P < 0.001$) ability compared with younger age groups, whereas both the normative population and all-terrain vehicle riders did.

Similarly, the upper body push ($P = 0.021$) and pull ($P = 0.013$) strength 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. Vertical jump testing revealed all-terrain vehicle and off-road motorcycle riders to have higher leg power than population norms ($P < 0.001$), which 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 III. The fitness of off-road motorcycle riders (43.3 ± 8.3 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}) was considerably higher than that of all-terrain vehicle riders (33.5 ± 7.1 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}; $P < 0.001$). Similar to population norms, male riders had higher aerobic fitness than female riders ($P = 0.017$) and the normative pattern of decreasing aerobic fitness with increasing age group was

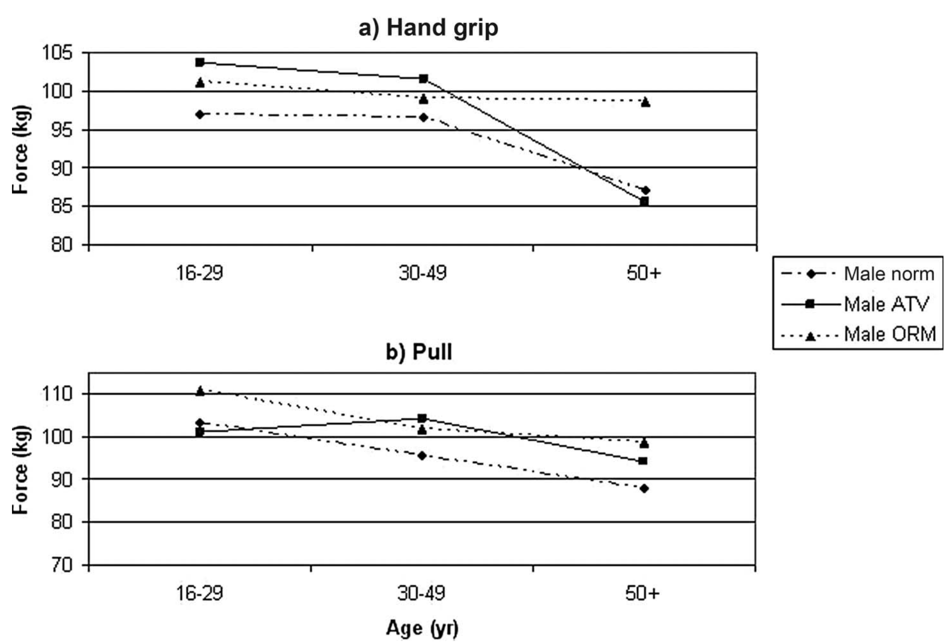

Figure 1. Strength, power, and endurance of male off-road motorcycle riders (ORM), all-terrain vehicle riders (ATV), and population norms according to age. (a) Handgrip strength of population norms and all-terrain vehicle riders declines from the youngest to oldest age groups ($P < 0.05$), whereas off-road motorcycle 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 all-terrain vehicle nor off-road motorcycle riders showed significant differences in pull strength with increasing age. The same pattern was apparent for push strength.

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

apparent ($P = 0.005$). Mean group percentile rankings for all-terrain vehicle and off-road motorcycle riders place them at the 40th and 79th percentile respectively, with females (all-terrain vehicle = 44th, off-road motorcycle = 88th) ranking higher than males (all-terrain vehicle = 36th, off-road motorcycle = 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, which was unexpected and is considered more fully in the Discussion.

Clinical measures

Pre-exercise mean arterial pressure of all-terrain vehicle (99.6 ± 9.0 mmHg) and off-road motorcycle (91.2 ± 14.0 mmHg) riders was significantly different ($P = 0.01$), primarily as a result of an elevated systolic pressure in all-terrain vehicle riders (all-terrain vehicle: systolic = 130.7 ± 12.5 mmHg, diastolic = 84.1 ± 9.1 mmHg; off-road motorcycle: systolic = 121.1 ± 10.7 mmHg, diastolic = 78.4 ± 9.3 mmHg). Pre-exercise heart rate, which is often used as an indicator of fitness, differed between off-road motorcycle (72.5 ± 11.1 beats · min^{-1}) and all-terrain vehicle (79.5 ± 10.6 beats · min^{-1}) riders ($P = 0.001$).

Mean blood lipid concentrations for all riding groups combined were 112.0 ± 64.4 mg · dl^{-1} for triglycerides, 175.4 ± 50.8 mg · dl^{-1} for total cholesterol, 49.2 ± 13.2 mg · dl^{-1} for high-density lipoprotein (HDL), and 98.0 ± 38.3 mg · dl^{-1} for low-density lipoprotein (LDL). Fasting blood glucose

Table III. Peak oxygen consumption (group mean ± *s*) of habitual off-road riders by gender, age category, and vehicle type referenced to the Cooper database by percentile rank and descriptive rating.

	Age (years)	Vehicle type	$\dot{V}O_{2peak}$ (ml · kg^{-1} · min^{-1})	Participants (*n*)	Percentile rank	Descriptiverating[a]
Males	16–29	ATV	42.8 ± 5.1	3	43	F
		ORM	51.8 ± 5.0	7	82	E
	30–39	ATV	38.9 ± 9.2	6	32	P
		ORM	48.7 ± 5.9	5	79	G
	40–49	ATV	34.4 ± 4.5	10	18	VP
		ORM	43.4 ± 9.0	15	63	G
	50–59	ATV	29.7 ± 4.2	8	15	VP
		ORM	38.0 ± 8.2	16	55	F
	60–69	ATV	32.4 ± 2.7	2	46	F
		ORM	38.4 ± 3.2	2	76	G
	70–79	ATV	32.2 ± 0	1	65	G
		ORM	N.A.	N.A.	N.A.	N.A.
Females	16–29	ATV	25.5 ± 6.9	2	4	VP
		ORM	44.0 ± 1.5	3	80	E
	30–39	ATV	42.6 ± 0	1	85	E
		ORM	44.9 ± 7.3	6	91	S
	40–49	ATV	34.1 ± 1.8	4	56	F
		ORM	40.0 ± 3.1	2	85	E
	50–59	ATV	19.7 ± 3.3	2	2	VP
		ORM	43.8 ± 7.6	2	97	S
	60–69	ATV	31.0 ± 0	1	75	G
		ORM	N.A.	N.A.	N.A.	N.A.

[a]VP = very poor, P = poor, F = fair, G = good, E = excellent, S = superior.

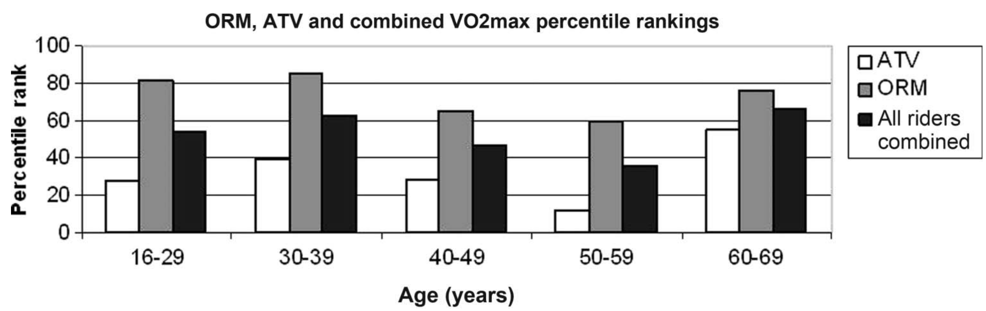

Figure 2. Mean percentile rank of off-road motorcycle (ORM), all-terrain vehicle (ATV), and combined riders referenced to age-matched normative $\dot{V}O_{2max}$ data from the Cooper database. Off-road motorcycle riders have significantly higher aerobic power than all-terrain vehicle riders ($P < 0.001$).

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

was 89.4 ± 11.7 mg · dl^{-1}. Females had elevated HDL compared with males ($P = 0.001$) and also a lower total cholesterol/high-density lipoprotein ratio ($P = 0.039$). There were no significant differences in blood lipids between all-terrain vehicle and off-road motorcycle riders. An age effect was evident for total cholesterol and LDL, with the youngest age tertile having the lowest total cholesterol (148.1 ± 22.7 mg · dl^{-1}) and LDL (74.5 ± 29.8 mg · dl^{-1}). Concentrations were higher in middle age (total cholesterol: 194.7 ± 61.4 mg · dl^{-1}; LDL: 110.7 ± 35.3 mg · dl^{-1}) but were lower than the middle-aged group beyond 50 years of age (total cholesterol: 169.7 ± 40.8 mg · dl^{-1}; LDL: 100 ± 40.8 mg · dl^{-1}; $P < 0.05$). There was no vehicle, gender or age difference for other lipid measures or fasting glucose.

Using National Cholesterol Education Program ATP III classification guidelines, 12.9% of the combined riding sub-population presented with three or more risk factors indicating the presence of the metabolic syndrome. Metabolic syndrome was present in the riding sub-groups as follows: three male all-terrain vehicle riders (17%), three male off-road motorcycle riders (13%), one female all-terrain vehicle rider (10%), and one female off-road motorcycle rider (10%).

Discussion

Our results show that the habitual recreational riders of off-road vehicles in the present study collectively have physiological profiles that are slightly healthier than that of the general population. As summarized in Table IV, persons who ride off-road vehicles typically have increased waist circumference, excess adiposity, and an elevated BMI based on current clinical health recommendations. On average, however, the off-road motorcycle riders in this study had higher aerobic fitness compared with the general population, and all-terrain vehicle and off-road motorcycle riders combined had healthy metabolic profiles both based on clinical standards and compared with population norms. The older off-road riders in this study had lower mean levels of adiposity and increased strength and power compared with population norms. It is impossible to determine whether this difference from "normal" ageing reflects a beneficial effect of participation in off-road riding or if other biasing factors are influencing the results, thus further investigation is warranted. In our discussion we have attempted to highlight potential sources of bias specific to each measure while presenting explanatory hypotheses.

Anthropometry

The greater weight, BMI, and body fat of all-terrain vehicle versus off-road motorcycle riders in our

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

		Fitness measures									Anthropometric and clinical measures						
		Participation in physical activity	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							
Males	ATV	↓	↓	↔	↔	↔	↔	↑	↔	↔	↑	↑	↑	↑	↔	↑	↓
	ORM	↓	↑	↓	↔	↑	↔	↑	↔	↑	↑	↑	↔	↔	↔	↔	
Females	ATV	↓	↓	↔	↔	–	↔	–	↔	–	↑	↑	↑	↑	↔	↔	↓ or ↔
	ORM	↓	↑	↓	↔	–	↔	–	↔	–	↔	↔	↔	↔	↔	↔	

Note: Health-related fitness measures are compared with 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. ORM = off-road motorcycle riders; ATV = all-terrain vehicle riders; BMI = body mass index; WC = waist circumference; BP = blood pressure.

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

population suggest vehicle type differences that emphasize the need to consider riders as belonging to two distinct groups. The greater waist circumference of all-terrain vehicle riders has meaningful significance in that the waist circumference of both male and female all-terrain vehicle riders was above the health-related risk cut-points of 102 cm for men and 88 cm for women (Canadian Society for Exercise Physiology, 2004), whereas both male and female off-road motorcycle means fell below these cut-offs. Accumulation of adipose tissue, especially visceral fat, is associated with increased risk of cardiovascular and metabolic disease (Ardern et al., 2004; Church et al., 2006). The greater sum of five skinfolds of all-terrain vehicle riders, combined with their greater waist circumference, 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 that affected representation within the current sample of off-road riders.

As a result of a similar height but greater weight, all-terrain vehicle 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 off-road motorcycle riders fell just above (0.5 kg $\cdot$ m^{-2}) the cut-off between normal and overweight (BMI > 25 kg $\cdot$ m^{-2}). Individuals with a high BMI are at increased risk for health problems including hypertension, hypercholesteraemia, asthma, arthritis, and poor general health (Mokdad et al., 2003). Although male off-road motorcycle riders 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 (Gobbi et al., 2005; Kinosian, Glick, & Garland, 1994; Konttinen et al., 2007, 2008), and supports previously published literature examining on-road motorcyclists that also found riders to be taller than the general population (Robertson & Minter, 1996). The greater height of riders was suggested to be the result of a selection factor for ridiers, since a high inseam allows comfortable sitting while straddling a motorcycle.

Fitness

Interestingly, off-road motorcycle riders showed no muscular fitness differences across increasing age categories, whereas the normal population revealed declines in muscular strength, endurance, and power. All-terrain vehicle riders showed declines in older compared with younger aged riders, similar to population norms in all variables except leg power, push and pull force. The reasons for greater handgrip strength and core endurance in older off-road motorcycle versus all-terrain vehicle riders is unclear, but may relate to the demands of riding two-wheel versus four-wheel vehicles and warrants further investigation. The significant elevation in leg power of all-terrain vehicle and off-road motorcycle riders compared with population norms may indicate 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 examination 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 (Katzmarzyk, Church, & Blair 2004; Noland et al., 2007; Wei et al., 1999; Wisloff et al., 2005). The differences in aerobic fitness between riders of the two vehicle types in our study population may result from an unequal physical activity 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 physical activity (which was highest in female off-road motorcyclists), excess fat weight (which was higher in all-terrain vehicle riders), and inherent group differences if a selection factor is at work such that less aerobically fit individuals gravitate towards riding four-wheel vehicles. It is plausible that four-wheel vehicles appeal to those with lower aerobic fitness and physical activity levels because they appear more stable or that more highly fit adventure-seekers are drawn to two-wheel vehicles. A final possibility is that unmeasured socioeconomic factors affect vehicle selection, as individuals with higher socioeconomic status typically have higher aerobic fitness (Shishehbor, Gordon-Larsen, Kiefe, & Litaker, 2008).

Logically, if off-road vehicle riding leads to changes in aerobic fitness, one would expect riding frequency to be positively correlated with $\dot{V}O_{2max}$. After controlling for the potential confounding factors of age, gender, and non-riding physical activity, no such relationship was found. This lack of a relationship suggests that recreational off-road riding as undertaken by the average habitual participant does not provide a sufficient physical activity dose to achieve improvements in aerobic fitness;

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

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 once or twice a week is an insufficient physical activity stimulus to cause aerobic adaptation as a result of a low frequency of exercise (American College of Sports Medicine, 1998) 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 (Ainsworth et al., 2000). However, as explicated by Bouchard and Rankinen (2001), 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 physical activity 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 $\dot{V}O_2$) is available to determine the physical activity dose of this type of activity. This is another important area for future study.

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

Clinical measures

The pre-exercise blood pressure measured in both all-terrain vehicle and off-road motorcycle riders was below the widely accepted definition of hypertension of 140 mmHg systolic and 90 mmHg diastolic (Canadian Hypertension Education Program, 2008; Canadian Society for Exercise Physiology, 2004). Off-road motorcycle riders were at near optimal levels of 120 mmHg systolic and 80 mmHg diastolic, whereas all-terrain vehicle riders fell within the high-normal or pre-hypertensive category (Canadian Society for Exercise Physiology, 2004). 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'', which would underestimate the health of off-road riders. However, we did not observe extreme blood pressures and comparison between groups was not compromised, as all groups would have been affected equally.

Blood lipid profiles of habitual off-road riders were at healthy levels, with no difference between all-terrain vehicle and off-road motorcycle 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 findings 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. Total cholesterol and LDL showed an age effect such that they were highest in the middle age group, 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 total cholesterol and LDL 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 risks associated with high cholesterol concentrations and is directly involved in atherosclerotic propagation (Fuster, Gotto, Libby, Loscalzo, & McGill,1996; Leon et al., 2000). Analysis of long-term athletic involvement has shown improvements in the total cholesterol/HDL ratio, of which LDL typically makes up about 70% of total cholesterol (Criqui & Golomb, 1998; Seals et al., 1984), and a reduction in hypercholesteraemia with increased physical activity dose or intensity (Williams, 2009). Thus, it is possible that those in the oldest age category are showing these benefits as a result of lifetime involvement, although objective participation rates need to be verified for confirmation. Importantly, the mean LDL concentrations of off-road riders classify them in an optimal category of $<100 \text{ mg} \cdot \text{dl}^{-1}$ (National Institutes of Health, National Heart, Lung and Blood Institute, 2001).

In our sub-population of riders, 12.9% exhibited three or more risk factors for the metabolic syndrome. Using the same National Cholesterol Education Program criteria, recent US estimates predict 34% of men and 35% of women have at least three risk factors (Ford, 2005), with Canadian estimates at 17% for males and 13% for females (Ardern, Katzmarzyk, Janssen, & Ross, 2003). The rate observed for all riders, as well as gender-specific incidence rates for both vehicle types were at or below the normal population incidence rate. Assuming our population of riders is representative of the average habitual rider, it is possible that off-road riding plays a role in the avoidance of the metabolic syndrome. Given that off-road riders in this study, especially all-terrain vehicle riders, presented with high waist circumferences and body fat percentages (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 that 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, although there is currently no other data with which to confirm or deny this possibility. Participants 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, although no such systematic reason for withdrawal was apparent to the research team. Lastly, information regarding exclusion criteria between our population and referent populations was unavailable, so comparisons of representativeness were not possible.

Conclusions

With the exception of body composition, our sample of habitual off-road vehicle riders had physiological characteristics that were equivalent, or slightly superior, to members of the general population on important fitness and health variables. In this population, there was evidence to suggest a possible beneficial effect of riding on muscular fitness in older riders. Notably, off-road motorcycle riders had healthier anthropometry and fitness characteristics than all-terrain vehicle riders and thus fewer health risk factors for future disease. This was particularly evident in measures of blood pressure, BMI, body composition, and waist circumference, wherein all-terrain vehicle riders were classified in unhealthy ranges. The finding of a lower than normal prevalence of the metabolic syndrome in both all-terrain vehicle and off-road motorcycle 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 waist circumference. If these changes do indeed reflect the effects of habitual off-road riding, this may constitute an alternative physical activity that has the capacity to cause health and fitness changes in the absence of significant changes in body composition or aerobic fitness. Although there is an increasing recognition that health changes can occur in the absence of changes in fitness, as evidenced by the evolving health-related exercise recommendations of the ACSM and Health Canada (Haskell et al., 2007; Warburton et al., 2006; Warburton, Katzmarzyk, Rhodes, & Shephard, 2007), it is still accepted that the risk reductions of many disease states are generally stronger when accompanied by reductions in fat stores (Ross et al., 2000; Thompson et al., 2003), especially in the visceral area (Despres et al., 1990), and there is no evidence from the current study to suggest that riders' health would not be further improved with such changes. Further research is needed to elucidate the acute physical demands of off-road vehicle riding from an intensity and duration perspective. This 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

This study was supported by a research grant provided by the Canadian Off-Highway Vehicles Distributors Council. Funds for this grant were provided through both government and private sources.

References

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J. et al. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise*, *32* (suppl.), S498–S504.

Ainsworth, B. E., Richardson, R. T., Jacobs, D. R., & Leon, A. S. (1993). Prediction of cardiorespiratory fitness using physical activity questionnaire data. *Medicine, Exercise, Nutrition and Health*, *24*, 75–82.

American College of Sports Medicine (1998). ACSM Position Stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Medicine and Science in Sports and Exercise*, *30*, 975–991.

Ardern, C. I., Katzmarzyk, P. T., Janssen, I., Leon, A. S., Wilmore, J. H., Skinner, J. S. et al. (2004). Race and sex similarities in exercise-induced changes in blood lipids and fatness. *Medicine and Science in Sports and Exercise*, *36*, 1610–1615.

Ardern, C. I., Katzmarzyk, P. T., Janssen, I., & Ross, R. (2003). Discrimination of health risk by combined body mass index and waist circumference. *Obesity Research*, *11*, 135–142.

Ascensao, A., Ferreira, R., Marques, F., Oliveira, E., Azevedo, V., Soares, J. et al. (2007). Effect of off-road competitive motocross race on plasma oxidative stress and damage markers. *British Journal of Sports Medicine*, *41*, 101–105.

Bard, R. L., Kaminsky, L. A., Whaley, M. H., & Zajakowski, S. (1997). Evaluation of lipid profile measurements obtained from the Cholestech L.D.X analyzer. *Journal of Cardiopulmonary Rehabilitation*, *17*, 413–418.

Bouchard, C., & Rankinen, T. (2001). Individual differences in response to regular physical activity. *Medicine and Science in Sports and Exercise*, *33* (suppl.), S446–S451; discussion S452–S453.

Burr, J. F., Jamnik, R. K., Baker, J., Macpherson, A., Gledhill, N., & McGuire, E. J. (2008). Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. *Journal of Strength and Conditioning Research*, *22*, 1535–1543.

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

Downloaded By: [Buhel, Oksana] At: 16:14 22 October 2010

Burr, J. F., Jamnik, V. K., Shaw, J. A., & Gledhill, N. (2010). Physiological demands of off-road vehicle riding. *Medicine and Science in Sports and Exercise*, *42*, 1345–1354.

Canadian Hypertension Education Program (2008). 2008 Canadian Hypertension Education Program recommendations: An annual update. *Canadian Family Physician*, *54*, 1539–1542.

Canadian Society for Exercise Physiology (2004). *The Canadian physical activity, fitness and lifestyle approach* (3rd edn. pp. 1–57). Ottawa, Ontario: CSEP H&FP.

Church, T. S., Kuk, J. L., Ross, R., Priest, E. L., Biltoft, E., & Blair, S. N. (2006). Association of cardiorespiratory fitness, body mass index, and waist circumference to nonalcoholic fatty liver disease. *Gastroenterology*, *130*, 2023–2030.

Cooper Institute for Aerobics Research (2009). *Fitness assessments and norms.* Dallas, TX: Cooper Institute.

Criqui, M. H., & Golomb, B. A. (1998). Epidemiologic aspects of lipid abnormalities. *American Journal of Medicine*, *105*, 48S–57S.

Despres, J. P., Moorjani, S., Lupien, P. J., Tremblay, A., Nadeau, A., & Bouchard, C. (1990). Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arteriosclerosis (Dallas, Texas)*, *10*, 497–511.

Ford, E. S. (2005). Prevalence of the metabolic syndrome defined by the International Diabetes Federation among adults in the U.S. *Diabetes Care*, *28*, 2745–2749.

Fuster, V., Gotto, A. M., Libby, P., Loscalzo, J., & McGill, H. C. (1996). 27th Bethesda Conference: Matching the intensity of risk factor management with the hazard for coronary disease events. Task Force 1. Pathogenesis of coronary disease: The biologic role of risk factors. *Journal of the American College of Cardiology*, *27*, 964–976.

Gobbi, A. W., Francisco, R. A., Tuy, B., & Kvitne, R. S. (2005). Physiological characteristics of top level off-road motorcyclists. *British Journal of Sports Medicine*, *39*, 927–931; discussion 931.

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A. et al. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, *39*, 1423–1434.

Heyward, V. H. (2002). *Advanced fitness assessment and exercise prescription* (4th edn.). Champaign, IL: Human Kinetics.

Katzmarzyk, P. T., Church, T. S., & Blair, S. N. (2004). Cardiorespiratory fitness attenuates the effects of the metabolic syndrome on all-cause and cardiovascular disease mortality in men. *Archives of Internal Medicine*, *164*, 1092–1097.

Keir, P. J., Jamnik, V. K., & Gledhill, N. (2003). Technical-methodological report: A nomogram for peak leg power output in the vertical jump. *Journal of Strength and Conditioning Research*, *17*, 701–703.

Kinosian, B., Glick, H., & Garland, G. (1994). Cholesterol and coronary heart disease: Predicting risks by levels and ratios. *Annals of Internal Medicine*, *121*, 641–647.

Konttinen, T., Hakkinen, K., & Kyrolainen, H. (2007). Cardiopulmonary loading in motocross riding. *Journal of Sports Sciences*, *25*, 995–999.

Konttinen, T., Kyrolainen, H., & Hakkinen, K. (2008). Cardiorespiratory and neuromuscular responses to motocross riding. *Journal of Strength and Conditioning Research*, *22*, 202–209.

Leon, A. S., Rice, T., Mandel, S., Despres, J. P., Bergeron, J., Gagnon, J. et al. (2000). Blood lipid response to 20 weeks of supervised exercise in a large biracial population: The HERITAGE Family Study. *Metabolism: Clinical and Experimental*, *49*, 513–520.

Mokdad, A. H., Ford, E. S., Bowman, B. A., Dietz, W. H., Vinicor, F., Bales, V. S. et al. (2003). Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *Journal of the American Medical Association*, *289*, 76–79.

National Institutes of Health, National Heart, Lung and Blood Institute (2001). *Third Report of the National Cholesterol Education Program Expert Panel (NCEP) on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)*. Bethesda, MD: NIH.

Noland, R. C., Thyfault, J. P., Henes, S. T., Whitfield, B. R., Woodlief, T. L., Evans, J. R. et al. (2007). Artificial selection for high-capacity endurance running is protective against high-fat diet-induced insulin resistance. *American Journal of Physiology: Endocrinology and Metabolism*, *293*, E31–E41.

Payne, N., Gledhill, N., Katzmarzyk, P. T., Jamnik, V. K., & Keir, P. J. (2000). Canadian musculoskeletal fitness norms. *Canadian Journal of Applied Physiology*, *25*, 430–442.

Robertson, S. A., & Minter, A. (1996). A study of some anthropometric characteristics of motorcycle riders. *Applied Ergonomics*, *27*, 223–229.

Ross, R., Dagnone, D., Jones, P. J., Smith, H., Paddags, A., Hudson, R. et al. (2000). Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men: A randomized, controlled trial. *Annals of Internal Medicine*, *133*, 92–103.

Seals, D. R., Allen, W. K., Hurley, B. F., Dalsky, G. P., Ehsani, A. A., & Hagberg, J. M. (1984). Elevated high-density lipoprotein cholesterol levels in older endurance athletes. *American Journal of Cardiology*, *54*, 390–393.

Shishehbor, M. H., Gordon-Larsen, P., Kiefe, C. I., & Litaker, D. (2008). Association of neighborhood socioeconomic status with physical fitness in healthy young adults: The Coronary Artery Risk Development in Young Adults (CARDIA) study. *American Heart Journal*, *155*, 699–705.

Thompson, P. D., Buchner, D., Pina, I. L., Balady, G. J., Williams, M. A., Marcus, B. H. et al. (2003). Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: A statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*, *107*, 3109–3116.

Warburton, D. E., Katzmarzyk, P. T., Rhodes, R. E., & Shephard, R. J. (2007). Evidence-informed physical activity guidelines for Canadian adults. *Canadian Journal of Public Health*, *98* (suppl. 2), S16–S68.

Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal*, *174*, 801–809.

Wei, M., Kampert, J. B., Barlow, C. E., Nichaman, M. Z., Gibbons, L. W., Paffenbarger, R. S., Jr. et al. (1999). Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. *Journal of the American Medical Association*, *282*, 1547–1553.

Williams, P. T. (2009). Incident hypercholesterolemia in relation to changes in vigorous physical activity. *Medicine and Science in Sports and Exercise*, *41*, 74–80.

Wisloff, U., Najjar, S. M., Ellingsen, O., Haram, P. M., Swoap, S., Al-Share, Q. et al. (2005). Cardiovascular risk factors emerge after artificial selection for low aerobic capacity. *Science*, *307* (5708), 418–420.