Adventure Science – Scientific background for the run.

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1. Oxygen consumption/VO_{2max} – What is that all about?

If an athlete were to run this race non-stop they could probably average 50% of their maximal aerobic capacity (VO_{2max}) over the course of the run. In relay fashion each athlete will have a rest period of 12 to 18 h between runs to recover and will likely be able to run at an average pace of 70 to 75% of VO_{2max}. VO_{2max} is the maximum of oxygen that the body can consume per unit time. This is usually expressed as L/min or mL/kg/min. For weight supported activities such as cycling on a flat road, it is the absolute value (L/min) that is a more important determinant of performance; whereas, for a cyclist climbing or a runner who has to carry the weight of their body, VO_{2max} expressed relative to body weight (mL/kg/min) is the more important determinant of performance. To put this into context, while reading this article, you are consuming about 3.5 mL/kg/min. To get up and go to the washroom this would increase to between 7 and 9 mL/kg/min. The average young sedentary person in North America has a VO_{2max} of between 25 - 35 mL/kg/min and the top endurance athletes in the world are approximately 90 mL/kg/min. We will be measuring VO_{2max} for each member of the two teams and these will be reported on the website. VO_{2max} is a rough predictor of performance, but there are many other factors that will determine success in endurance sports including biomechanical efficiency, body composition, years of training, method of training including tapering, and nutritional strategies. VO_{2max} inevitably declines with age even with continued training. For example, Drs. Waddington and Tarnopolsky had their VO_{2max} measured multiple times when they were in their young 20's ranging from 83 to 86 ml/kg/min. You can see how their VO_{2max} has declined with the aging process, yet until major injuries two years ago their performance was as good, if not better, than they were in their early 20's in trail racing (Tarnopolsky) and orienteering (Waddington). One interesting component of this study will be to determine the average VO_{2max} of each team and see whether that has any bearing on the performance.

When measuring the VO_{2max} (see the video on this site) we also will be recording heart rate and the volume of carbon dioxide ($VC0_2$) produced. During the run, we will have heart rate monitors on each individual and each individual will have their own plot of heart rate verses VO_2. Consequently, from the heart rate data we will be able to predict the VO_2 during a given running segment and calculate the total caloric cost (1 L oxygen consumption = 4.85 kilocalories of energy expenditure). Consequently, we will be able to calculate the number of calories per leg and the total number of calories required to run the Bruce trail for each team. From the $VC0_2$ data we will be able to calculate the carbon foot-print for a runner completing the Bruce trail run (kilograms of carbon dioxide produced) and we will be comparing this to the amount of carbon dioxide

produced if one were to drive a compact car, SUV, bus or transport truck the entire distance. The readers will no doubt see the vastly lower carbon footprint produced by a runner as compared to a motorized vehicle!

2. How does body composition come into all this – why are endurance athletes so lean?

Although the relative VO_{2max} (mL/kg/minute) is an important determinant of performance, body composition is also very important. For example, if an individual were 30% body fat verses another who is 10% body fat the energy cost of carrying that extra weight would reduce performance. In general, women are 6 to 7% higher body fat than men and the endurance athlete has a much lower percent body fat than a sedentary individual. The prevalence of obesity is increasing dramatically in North America and a greater proportion of children and adults are overweight and obese. For population studies, something called the body mass is used (weight and kilograms divided by height and meter square) but this provides only a rough estimate of the percent body fat. Percent body fat is really much more important for an individual could be endowed a fairly large muscle mass but have very little body fat and the body mass index would tend to be higher when in reality their body fat could be quite low. There are a number of ways of measuring body fat including skin fold (pinch an inch) where equations have compared the sum of various skin folds to total body fat determined by a more definitive methods. A newer technology called dual energy x-ray absorptiometry (DEXA scan) uses low energy x-rays which are attenuated much more when they go through dense tissues such as bone and muscle as compared to less dense tissue such as fat. Consequently, DEXA has become very convenient and an accurate way of determining percent body fat. In the current study each of the athletes will have their percent body fat determined by DEXA and we will see whether body fat changes after each individual after they run this race. We will also see which team has the lower percent body fat and whether that predicts ultimate success in the race.

3. So what types of fuels are being used during the race?

Even though women have a slightly higher percent body fat they also have an inherently higher capacity to oxidize lipid which long duration activity may be advantageous. For example, in a 10 km run the vast majority of the energy to fuel such a run comes from carbohydrate predominately in the form of muscle glycogen (starch within muscle). Muscle glycogen stores can provide the majority of the energy for approximately two hours of exercise between 50 and 75% of VO_2max, however, for longer duration activity or if individuals are going at a lower intensity a greater proportion of fat is oxidized. One of the ways to increase carbohydrate content and muscle is to increase dietary intake of carbohydrates through a procedure called "glycogen loading" or "carbohydrate loading". The original method involved a period of high intensity training with low carbohydrate meals to deplete the muscle glycogen stores followed by 3 to 4 days of low carbohydrate intake followed then by 3 to 4 days of very high carbohydrate intake. More recent studies have shown that increasing the proportion of carbohydrates in the diet for 3 to 4 days prior to an event can increase muscle glycogen

stores and this can improve performance. Women can glycogen load but they require a much higher proportion of carbohydrate or a slight increase in energy intake to achieve the same level of carbohydrate loading as men. The athletes will be consuming various sports drinks and carbohydrate containing juices, gels and other foods during exercise to provide what is called an "exogenous" source of energy. We will be recording all of the food and fluid intake for each individual during the study and it will be of interest to calculate the total amount of energy that is required to run the entire Bruce trail and to determine the total amount of energy that can be consumed during such a run and calculate the caloric deficit (given that it is impossible to consume calories at a rate equivalent to the amount that are expended during a race).

4. Will a race like this damage the muscles and what can be done to prevent the muscle damage?

In addition to the energy cost of running the Bruce trail, there is also a physical cost during prolonged exercise especially when running downhill there can be some damage to muscle. When running downhill the force of contraction can actually be stronger (eccentric or lengthening contractions) and can lead to an increase in muscle pain termed "delayed onset muscle soreness". There is still a bit of controversy as to what causes delayed onset muscle soreness; however, muscle biopsies do show that there is some alteration in the fine ultrastructure of muscle called z-band streaming (figure 1) and we and others have found inflammation (figure 2) in muscle. In general, women have slightly less muscle damage than men for any given amount of activity. One way of measuring muscle damage is to measure the change in enzyme activity in the blood from an enzyme that is contained within muscle. For example, creatine kinase (CK) is an enzyme found in muscle and when there is muscle damage the CK leaks out of muscle and will increase in the blood. A rough indicator of muscle damage is the change in CK activity and we will be recording this before and after the run for each individual and we would expect that the CK rise will be less than the women verses the men and it will be of interest to see whether those with the highest CK increases experience the most discomfort in their muscle and whether the CK rise has any bearing on the ultimate outcome of the race.

In addition to direct damage to and inflammation in muscle, there is also an associated oxidative stress (free radical generation) that occurs with an acute bout of exercise. With endurance exercise <u>training</u> the total amount of oxidative stress for a given amount of exercise is lower and athletes in maintenance training will have lower markers of oxidative stress. Nevertheless, when there is extreme exercise such as in the current stage race, there will definitely be some oxidative stress. We will be measuring oxidative stress markers in the urine before and after the race and we would expect that they would increase substantially. Again, we will be determining whether the increase in oxidative stress is related to the increase in CK activity and/or related to the increase in muscle pain and discomfort that each athlete experiences. Here too we expect that women will have less oxidative stress as compared to men and we will also be measuring the dietary consumption of antioxidants prior to and during the race to see if those with higher antioxidant intakes will show less oxidative stress. Although a lot of supplement

companies and many other individuals advocate antioxidant supplements for athletes, it is important to note that with exercise training alone the bodies endogenous antioxidant enzymes within muscle and other tissues increases in response to exercise itself and ultimately oxidative stress is lower per unit of exercise in trained vs untrained people. However, athletes can still cause oxidative stress during an extreme event such as the one that we are participating in where they push their bodies far beyond what would normally be expected during training. It is very controversial whether exogenous antioxidant supplements are of any benefit to endurance adaptation or performance. There is a body of literature that suggests that taking antioxidants during the training period may inhibit the body's natural endogenous up-regulation of antioxidants and this could be deleterious. This requires further investigation which is being undertaken in my laboratory. During an extreme event such as this one where there will be an acute increase in oxidative stress, the adaptation phase is of no immediate relevance. Since high levels of oxidative stress can actually inhibit muscle contraction, the consumption of antioxidants during an acute severe bout of exercise may be beneficial. Again, this is controversial, but we will evaluate whether antioxidant consumption before and during exercise will attenuate markers of muscle damage and/or the markers of oxidative stress and/or have any benefit on performance. One study found that Tour de France riders had less evidence of muscle damage when they were taking a drug that inhibits the production of free radicals.

There is no question that the most effective way to prevent muscle damage is to actually train! Studies have clearly shown that even after the first bout of exercise, the delayed onset muscle soreness is less after a second identical bout even month later (second bout effect). We will be recording the training history of each athlete in the months before the race and it would be expected that those who "log the most miles" will show the lowest markers of muscle damage and oxidative stress.

5. Are there any psychological factors?

After all of the scientific aspects are said and done, there are certainly a number of intangible factors which can influence the outcome of a race including; accidents such as twisting ankles, broken bones, cuts, heat exhaustion, etc. Finally, there is still an intangible aspect to performance locally termed as tenacity or "guts". Old guys such as myself would like to think that over the years we have developed the tenacity to push through pain of running or perhaps this ability has allowed us to stay in the sport while others have dropped out! Team Mitochondria certainly has a higher average age and although the young wiper snipers think that they will be faster on paper, the old guys would like to think that their years of experience will ultimately prevail. We will have to wait and see.

6. How do the charities relate to the athletes?

Team Mitochondria: these individuals are running to raise funds for the United Mitochondrial Disease Foundation (UMDF, http://www.umdf.org). Although most of

you will not have heard of mitochondrial disease, it affects at least 1 in 6,000 individuals. While many of the readers will have heard of amyotrophic lateral sclerosis (ALS, Loou Gherig's disease), ALS only affects 1 in 50,000 individuals. In fact, to some extent all of us have a mitochondrial disease given that mitochondrial dysfunction is a major component of the aging process! The best way to slow down the age-associated loss of mitochondrial function is to exercise. Even older adults who start exercise programs show improvements in mitochondrial function. There are well over 200 types of mitochondrial disorders that can range from death in the first few days of life to droopy eyelids and hearing loss in 50 and 60 year olds. As we learn more and more about diagnosis, we are finding that the number of conditions attributed to primary or secondary mitochondrial dysfunction is increasing dramatically. In fact, diseases such as Parkinson's disease, Alzheimer's, obesity and type II diabetes do have a link to mitochondrial dysfunction. The UMDF supports research and provides education and sports services for children and adults afflicted with mitochondrial disease.

For adults with mitochondrial disease exercise intolerance is a major component of their disease. The mitochondria is the "power house" of the cell where the oxygen we breathe and the food that we eat are combined to form energy. The athletes in this study have some of the best mitochondria in the world that is roughly correlated with VO_{2max}. As you will recall above, the VO_2 just to walk to the bathroom is close to 10 mL/kg/min and yet many of our patients have VO_{2max} levels in this range. You can see how just performing daily activities can be very difficult for these individuals. Since mitochondria are present in every cell of our body, except for red blood cells, one can see how mitochondrial dysfunction can have a host of clinical presentation including strokes, seizures, droopy eyelids, blindness, hearing loss, extreme muscle fatigue, muscle weakness, heart thickening, liver failure, renal failure and peripheral nerve damage. It is of interest that exercise training does improve function in patients with mitochondrial disease and it is really the only therapy that has ever been shown to improve VO_{2max} or enzyme capacity in muscle to date. Team mitochondria have some of the best mitochondria in the world running for those whose mitochondrial impairment can even threaten their lives!

Team Muscle: Team muscle is running to race funds for the Muscular Dystrophy Association of Canada (MDAC, http://muscle.ca/). Muscular dystrophy is a genetic disorder that affects approximately 1:1,000 individuals. There are many different types of muscular dystrophy (greater than 50) with the most common being; Duchenne/Becker's muscular dystrophy, limb girdle muscular dystrophy, myotonic muscular dystrophy, fascioscapulohumeral muscular dystrophy and ocular pharyngeal muscular dystrophy. These conditions are due to a genetic mutation that makes a dysfunctional protein that is part of the muscle contraction process. As a consequence, these patients have weakness of muscles that is usually progressive. As with the mitochondrial disease these conditions are partially treatable but by no means curable. As patients muscles get weaker and weaker it is more and more difficult for them to perform activities of daily living such as running, walking, shopping, lifting and eventually progressing to the point where it is difficult to perform such basic tasks as eating, brushing their teeth and eventually breathing. The rate of progression and

severity is highly different between the different conditions with one of the most severe being Duchenne muscular dystrophy where boys are in a wheelchair by age 12 and usually die in their 20's from respiratory failure.

As part of this study, we will be measuring leg strength in each of the athletes and, although leg strength is not a determinant of endurance exercise performance, it will be of interest to see which team has the highest cumulative strength. You will see that each individual has leg strength greater than 150 Nm and patients with muscular dystrophy end up in a wheelchair usually when their knee extension strength gets below 20 Nm.

The Muscular Dystrophy Association of Canada provides advocacy for patients with muscular dystrophy and has support programs to help to fund assistive devices such as wheelchairs, walkers, canes, etc. It is truly unfortunate that in a supposed universal health care system such as we have in Canada all of my patients with muscular dystrophy are required to contribute something towards their different assistive devices. Even though some subsidies provide 75% of the funs (Ontario program), patients still have to contribute several thousands of dollars for a motorized wheelchair. With disability pensions of 800.00 – 1,2000/month, this is far beyond their capacity. Groups like the MDAC help to bridge this gap and through increased awareness and advocacy hopefully all of the unfortunate patients afflicted with these genetic conditions will have the support they need.