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THE EFFECTS OF TIRE PRESSURE ON WHEELING EFFICIENCY

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INTRODUCTION

This research project was undertaken to give clinicians information that will allow them to help clients select the most appropriate wheelchair tire for their needs. The benefits and drawbacks of pneumatic tires are well known. Some initial studies that we conducted gave us information about the rolling resistance of various tires on flat hard terrain. High-pressure 24 x 1" pneumatic tires had a clear advantage, rolling about 30% further than conventional 24 x $1^3/_8$" tires, which in turn rolled about 30% further than solid urethane tires.

A review of the literature showed one study which looked at tire deflation in ten able-bodied individuals during manual wheelchair propulsion with tire pressures of 45, 30, 15 and 5 psi (Henriksen et al, 1994). They found a significant difference of energy expenditure, only between tire pressures of 45 and 5 psi. However, they studied able-bodied individuals and used pressures that did not reach our accepted standard tire pressure of 65 psi for standard tires or 100 psi.

Over the years, returning clients have consistently shown up at our centre with very low tire pressures. Only realizing how low, when we pumped up the tires and the chair rose 1/2 an inch. One of the questions for this research project was; At what pressure are the benefits of pneumatic tires lost to the wheeler. Our other question was; Does heart rate correlate to energy expenditure? The hope being that we would be able to use heart rate as a simple, reliable, clinically applicable tool to assess the energy required to wheel over a variety of terrain

Energy expenditure or oxygen cost is defined as the amount of oxygen consumed (ml) per kilogram of body weight per distance traveled (ml/kg/m). This method is commonly used to measure the

physiological cost of walking in individuals with physical impairments (Bowen, et al., 1998; Corry, et al., 1996; Duffy, et al., 1997; Findley, et al., 1988). This type of analysis requires that the subject reach a steady state of exercise (constant velocity and constant oxygen consumption level), be it slow or fast. The use of heart rate to predict energy expenditure has been well described in the literature with correlations of 0.90 in adults (Luke et al., 1997) to 0.86 and 0.89. for paediatric gait (Butler et al, 1984; Nene et al, 1993; Rose et al, 1990). However, Boyd et al (1999) found too much within subject variability for heart rate to be a reliable measure in predicting energy expenditure. To date there have been no studies examining the relationship between energy cost and heart rate during wheelchair propulsion at a self-selected wheeling pace.

Research Hypotheses

1. There will be a positive linear relationship between heart rate and oxygen consumption among wheelchair users wheeling over a flat hard surface.

2. There will be a significant difference in at least one of the condition trials between oxygen cost and pneumatic wheelchair tire pressure among wheelchair users.

METHODS

Individuals will be included in the study if they i) have a diagnosis of paraplegia due to a spinal cord lesion, either traumatic or congenital in nature, at the T2 level or lower; ii) are between the age of 9 and 50 years of age; iii) have been using a wheelchair for at least six months and their current chair for at least two months.

Four sets of PR1MO V-TRAK 1" tires were mounted to Sunrim SW6000 wheels. Tires were pre-inflated to 25,50,75,100 psi. This arrangement allows the tires to be pre-inflated so the subjects were blinded to the tire pressure. The quick release mechanisms of wheelchair wheels allow the wheels and varying tire pressures to be easily interchanged without the subject needing to transfer in and out of the chair. The starting and subsequent tire inflation pressures (conditions) are determined using block randomization and set just prior to the first trial. A total of four trials (one for each condition) will be conducted allowing for a full 10-minute rest break between trials. A Cosmed O_2 analyser was fitted to the adults to measure oxygen consumption as well as a heart rate monitor to measure heart rate. The children only used the heart rate monitor by which the oxygen consumption was predicted.

During each trial the subject are instructed to maintain constant self-selected wheeling velocity for eight minutes on a level linoleum surface hallway. The following variables are collected during each trial: i) expired air samples will be measured using the oxygen analyser; ii) heart rate using the Heart Rate Monitor; iii) velocity and distance traveled.

A Pearson product moment correlation coefficient was derived to determine if a positive relationship exists between heart rate and oxygen consumption (hypothesis 1). A single factor repeated measures

ANOVA of the oxygen cost (oxygen consumption / body weight / distance travelled in meters (ml/kg/m) calculated for each of the four conditions) was used to address Hypothesis 2. Scheffe?s post hoc analysis was performed to assess differences between the conditions. Data was stratified for age comparing adult and paediatric populations (ages 9-17 and ages 18-50).

RESULTS

Fifteen subjects have been tested, 9 children, 6 adults. Mean age for adults was 30.7 yrs and 12.2 yrs for the children. There was a significant positive correlation between the predicted energy cost using heart rate and measured energy cost using oxygen consumption (r=0.73; p<.0001) (Fig.1). Also, there was a significant increase in one of the tire conditions. The 25 psi significantly increased the amount of energy required to wheel for both adults and children (p <.0001; power >.99) (Fig 2). There was a significant difference between the adults and the children for wheeling velocity and energy cost . The adults wheeled at a mean velocity of 2.2 m/sec and the children 1.7 m/sec.

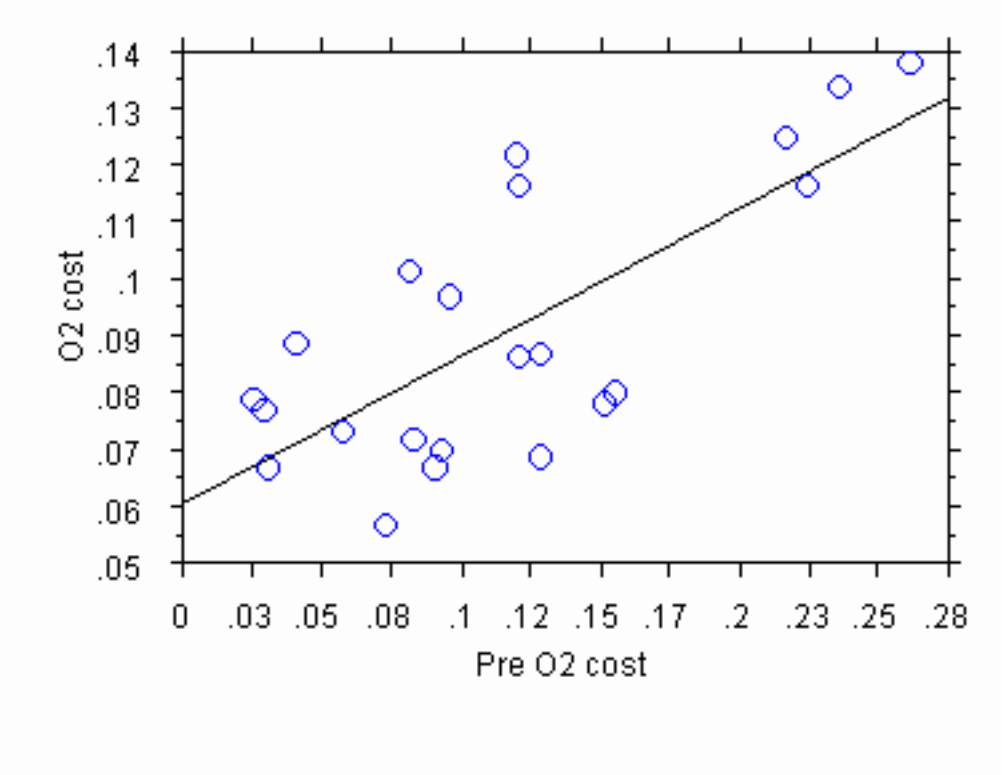

Figure 1. Correlation between predicted energy cost using heart rate and energy cost as measured with oxygen consumption.

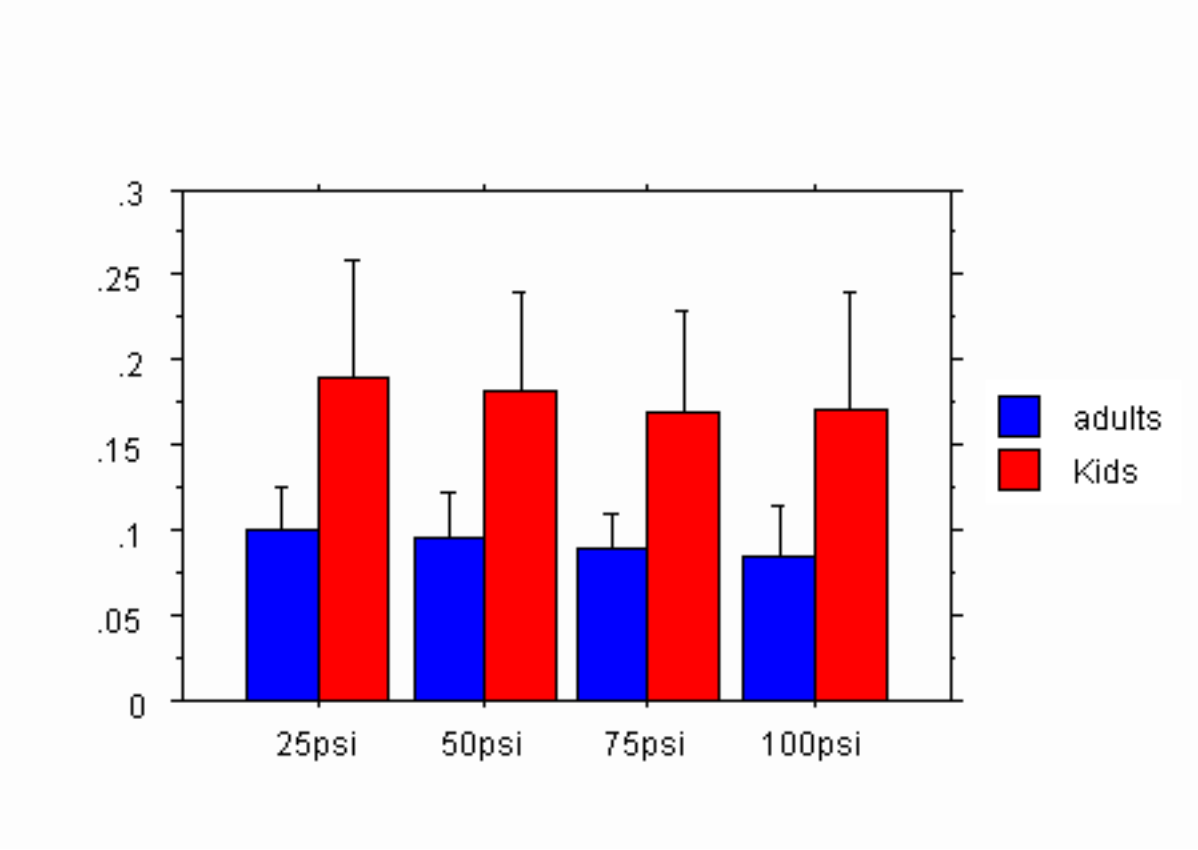

Figure 2. Energy cost (ml/kg/m) for adults and children with 25,50,75,100psi tire pressure.

DISCUSSION:

While the research process answered our questions we do have to caution that the information be used wisely. For instance, our conclusions are only valid for the 24 x 1" PR1MO V-TRAK smooth. We had originally selected PR1MO Xtreme 24 x 13/8 tires to use as our test tire but had to discontinue early in the pilot phase because the difference in the tires performance at the selected pressures was too small. Further investigation revealed that the Xtreme tire had Kevlar woven into the carcass resulting in a stiffer sidewall. The footprint of the tire was larger than the V trak at 100 psi, but smaller at 25psi. The Xtreme had inferior rolling resistance at 100 psi but superior below 50psi. These characteristics make it a more suitable tire choice for people unable to fill their tires regularly.

While the highest pressure may offer the lowest rolling resistance on a level linoleum floor, there are a number of clinical factors that may warrant a client using less than maximum tire pressures, these include:

1) A tire inflated to it?s maximum pressure may not provide a grippy enough surface for the hands to push on, some of our clients with limited grip strength report that they keep their tires under-inflated to allow adequate hand to wheel friction.

2) A slightly softer tire acts as a shock absorber and smooths out the ride on surfaces with irregularities.

3) Reducing tire pressure when negotiating softer terrain or if there is snow on the ground increases the footprint of the tire enabling it to "float" on the surface rather than dig in.

SUMMARY

In summary, this study shows physiological evidence for individuals who use wheelchairs to keep their tire pressure up higher than 50 psi in order to conserve energy. Given that many people are wheeling at sub maximal levels for a variety of reasons, it is comforting to know that the perceived benefits of slightly softer tires are not received at an extravagant cost in terms of energy expenditure.

All of our testers were able to detect tire pressure by how they rolled when testing, yet some rolled into the facility with pressures too low to register on the gauge, apparently unaware of the insidious nature of air loss from their tires. Similarly repetitive strain disorders also have an insidious nature, the damage being done long before the victim is aware of any trauma.

If rolling resistance is the only factor in determining optimal tire pressure higher is clearly better. Statistically, the significant increase in energy cost occurs at 50psi. However in order to offset the early onset of RSI of the shoulder we recommend that wheelchair users using Primo V Trak tires keep their pressures as high as possible and reinflate their tires every two weeks.

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