THE USE OF RATING OF PERCEIVED EXERTION
FOR EXERCISE PRESCRIPTION IN WHEELCHAIR-BOUND CHILDREN AND
YOUNG ADULTS

RESEARCH REPORT TO THE ONTARIO MINISTRY OF TOURISM AND
RECREATION

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BACKGROUND AND RATIONALE

Certain subgroups within the population, such as the physically handicapped who are wheelchair-bound, suffer considerably due to their hypoactivity. These people are generally unfit due to their habitual inactivity (Glaser, 1985; and Zwiren and Bar-Or, 1975). They typically become trapped in a vicious cycle in which their sedentary lifestyle leads to lower levels of fitness which, in turn, makes them even more sedentary. Also of concern are the emotional or psycho-social problems that are present in such groups. A negative self-image and low self-esteem are some of the problems which may result from being labelled "handicapped" by their peers.

Presently, there are some 10,000 wheelchair-bound people under the age of 22 living in Ontario. Most of these children and young adults are insufficiently active to maintain an adequate level of fitness. This particular subgroup would benefit greatly from an adapted exercise prescription in order to increase their involvement in physical activity.

When prescribing exercise one must consider the following components:

(a) Mode of Exercise (eg: cycling, walking, jogging, wheeling, swimming, etc.).
(b) Duration; how long each bout of exercise will last (eg.: 20-30 min.).
(c) Frequency; how often one will perform bouts of exercise (eg.: 3-4 times per week).
(d) Intensity; how hard one will exercise during the workout (eg.: at a certain % of maximal heart rate [HR]).

The first three of the above components are objective and can be easily quantified. Intensity, however, is harder to quantify, especially when dealing with non-athletic children. Monitoring exercise intensity during physical activity is necessary to assure that the exercise being performed is neither too hard, nor too easy for the participant. Usually intensity is measured by self-assessment of post exercise HR. This involves palpation of either radial or
carotid pulse and accurate counting of the pulse rate. Most children are not proficient enough at these skills in order to obtain an accurate measurement of HR.

Recently (Birk and Birk, 1987), the Borg 6-20 category scale of rating of perceived exertion (RPE) (Borg, 1970) was suggested as an alternative prescriptive tool for the self-monitoring of exercise intensity. Few attempts have been made to apply the RPE concept for exercise prescription and most of these have been with adults (Chow and Wilmore, 1984; Gutmann et al., 1982; Pollock et al., 1986; Smutok, 1980). Overall, authors have concluded that RPE may be fairly useful for exercise prescription for adults.

If the RPE scale (Figure 1) could be learned and used by children to gauge exercise intensity, physical educators would have a more accurate method of prescribing intensity. This psychophysical method of rating perceived exertion has several advantages over the traditional HR method. For one, it does not depend on the skill of the subject in taking a manual HR. Also, it can be used during, rather than after, the exercise bout.

The problem which remains to be answered is, can wheelchair-bound children effectively use the RPE scale to reproduce a given exercise intensity. Research at the Wingate Institute in Israel (Bar-Or, 1977) suggested that healthy children can rate their intensity of exertion just as accurately as adults. The RPE scale has also been applied to a clinic population of obese children, aged 13 to 17. These children were as accurate in perceiving their levels of exercise intensity as their peers of normal weight (Ward et al., 1986). Another recent study (Bar-Or and Reed, 1986), determined that children with severe neuromuscular disorders could accurately gauge their work intensity. When values of percent peak mechanical power were plotted against RPE, the correlation coefficients were similar to those found among healthy children.

Most currently, an investigation by Ward and Bar-Or (in press) attempted to assess the ability of overweight children to reproduce exercise intensities, prescribed to them as numbers on the Borg 6-20 RPE scale. Results indicated that these children could discriminate among intensities of several cycling or
walking/running tasks that were prescribed as 7, 10, 13 and 16 on the RPE scale. However, they were less successful at reproducing prescribed intensities, as judged by both HR-on-RPE regressions and by differences in observed vs. expected HR.

No data are available in the literature regarding the ability of wheelchair-bound people (children or adults) to use the RPE scale as a means of prescription of exercise intensity.

OBJECTIVES

Primary Objective:

Can both wheelchair-bound adults and children, sedentary or engaged in athletic activities, accurately pace themselves while wheeling around a track, when prescribed an intensity from the pre-learned RPE scale?

Secondary Objectives:

a) Can learning the RPE scale and then practicing it by "anchoring" its extremes during arm cranking in the laboratory be utilized for prescribed wheeling intensities on the track?

b) How do physically disabled children differ from adults in their ability to use the RPE scale as a tool to pace their wheeling on the track?

c) How do physically disabled athletes differ from non-athletes in their ability to use the RPE scale?

d) Is there any long-term retention of the ability to pace one's wheeling by using the RPE scale?
METHODOLOGY

a) Subjects

Subjects were recruited from Variety Village Sport Centre in Toronto, from patient lists at Chedoke-McMaster Hospital in Hamilton, through advertisements in local Hamilton newspapers, and from local recreation centres. Out of twenty-three people who volunteered, only twenty completed all four sessions. The following will therefore be related to n = 20. These were divided into two groups on the basis of age. The "youth" group contained 6 boys and 4 girls, ages 11-15 years. The "adult" group included 4 males and 6 females, ages 23-33 years. All subjects were afflicted with disabilities requiring them to use a wheelchair. These included spina bifida, cerebral palsy (diplegia - main disability in the legs), traumatic paraplegia and other disabilities which impair leg movement (Table 1). The level of spinal lesion was of no consequence to subject selection as long as the subject was able to wheel his or her own chair.

Subjects were given an activity questionnaire in order to assess their level of physical activity. Based on this information, they were assigned to either "athletic" or "non-athletic" category. The former included individuals engaged in training and/or competitions in wheelchair sports. Subjects who neglected to return activity questionnaires were assigned to either category by the judgement of the coach and the experimenter. The athletic group contained 6 children and 5 adults, while the non-athletic group had 4 children and 5 adults.

b) Design and Protocols
Each subject was tested on four separate occasions. The first three visits were spaced one week apart, while the last session was a one-month follow-up test. Most of the testing took place at the Variety Village sports facility in Scarborough, Ontario, with some being conducted at Chedoke McMaster Hospital and the McMaster University running track, both in Hamilton, Ontario.

Session 1 - Orientation and Baseline

Upon arrival, arm span, weight, and skinfold thickness were determined for each subject. Since the subjects could not stand erect for the purpose of measuring standing height, an arm span measurement was taken instead. This was done using a measuring tape, permanently affixed to a length of wood.

Skinfold thickness was measured with Harpenden skinfold calipers, and values were rounded off to the nearest 0.1 mm. Measurements were taken at four sites; bicep, tricep, subscapular, and suprailliac. From these values and a set of standardized tables (Durnin and Womersley, 1973), a percentage of body fat was calculated. We are cognizant of the limitations of calculating % body fat from skinfold thickness, particularly in disabled individuals whose body proportions and, possibly, fat distribution may be abnormal. The % fat values in Table 2 are therefore presented as an approximation only. Weight was measured with a Mott electronic scale, model # UMC 1000 AAAA. accurate to 10 g.

Following the anthropometric measurements (Table 2) the RPE 6 to 20 scale (Figure 1) was introduced and taught to the subjects in a standardized manner, as outlined by Figure 2. Lastly, subjects were asked to perform a progressive, continuous (two-min. stages), maximal arm ergometer test (Bar-Or and Zwiren. 1975). This test was performed using either Fleisch or Monark arm ergometer. Subjects were also instructed to crank at a constant speed of 50 r.p.m. During this all-out test, HR was monitored by using a bipolar electrocardiograph or the Sports Tester PE 3000, a transmitter-receiver device. HR and RPE rating were determined at the end of each two-minute power load. Peak mechanical power was calculated. Also, RPE vs. HR and RPE vs. Power regression lines were constructed for each subject, using the Statpack statistics program. These
individual regression equations were then used to calculate the theoretical power outputs at RPE 7 and RPE 19 at which the practice of these were to be anchored in Session 2.

Session 2 - Practicing the RPE

This was the "anchoring" or learning phase during which the subject would get a feeling for the range of intensities of the Borg scale. This visit involved six bouts of exercise, each lasting three minutes. Three of these bouts were set at a power which corresponded to a rating of RPE 19 and three at RPE 7, as calculated in Session #1. The order of loads for each subject was at RPE 7, 19, 19, 7, 7, and 19, with sufficiently long rest periods in between, to allow the subject's HR to recover to below 100 b.p.m. At the one-, two- and three-min marks of each bout the subject was "anchored" (Figure 3) by being told to associate either a number 7 or 19 with the subjective, bodily feelings of exertion he or she experienced. The subject was also asked following each bout to give feedback on his or her perceived exertion, by being asked "Does the exercise feel like a 7/19 on the RPE scale?" Any discrepancies between the predicted and the actual RPE rating, given by the subject, were noted on the Session #2 test form. HR was also recorded at one-minute intervals, again using an E.C.G. or the Sports Tester.

Session 3 - Prescription

Testing was conducted at the Variety Village 200-m indoor track and the McMaster University 400 m outdoor track. Subjects performed four separate wheeling tasks, each at a different RPE intensity, as prescribed by the investigator. The prescribed intensities were RPE 7, 10, 13, and 16. Each task had to be maintained over a distance of 400 m. RPE 7 was always prescribed first to give the subject a chance to warm up and avoid injury. The subsequent 3 intensities were assigned randomly. The Sports Tester was employed to sample the subjects' HR at fifteen second intervals throughout wheeling and during recovery. These HRs were later recalled from the monitor's memory and recorded. A digital stop watch, accurate to 1/100 of a second, was used to record split times
at 100 m intervals. Total time was later used to calculate the average speed of wheeling while split times revealed how consistent the speed of wheeling was over the 400 m distance. As in Session #2, rest breaks between exercise bouts were about 5-min. long, or until HR had recovered to below 100 b.p.m. Subjects were also offered cold water during rest periods in order to replenish body fluids.

Session 4 - Retention

This final session was conducted one month following Session #3. It was designed to assess the long-term retention of using the previously learned RPE scale to gauge wheeling intensity. Its protocol was identical to that used in Session #3.

DATA ANALYSIS

HR on RPE Regressions. To calculate the relationship between HR and RPE, individual regression lines were calculated for the criterion session (C) and for the two subsequent prescription sessions (P1, P2). Based on these lines, group means were developed for the intercept and for the slope of the HR-on-RPE regressions. The regression line of session C became the criterion against which the success of the subjects to execute the prescribed tasks of session P1, P2 was compared. Inter-session comparisons were then made, using a group (athletes vs. non-athletes or children vs. adults) by treatment (C, P1, P2) 2X3 ANOVA. Stuart-Neuman-Keules post-hoc tests were used to determine the source of the variance.

HR, % Power and Wheeling Velocity. HR, % power and wheeling velocity were compared at each of the four prescription levels (RPE = 7, 10, 13, 16), using both a two-way and a three-way ANOVA with repeated measures. The effect of athletic status was assessed by way of groups (A. NA) by level (7, 10, 13, 16) ANOVA. The effect of age group was assessed likewise. Athletic status-age interaction was compared using a group (AA. NAA, AY. NAY) by condition (C, P1, P2) by level (RPE 7, 10, 13, 16). Tukey post-hoc tests were used to
compare differences in level. Orthogonal contrasts were used to determine age/athletic status interaction.

RESULTS

The results will be presented in three major sections: athletic (AT) VS non-athletic (NAT), youth (Y) VS adults (AD) and the interaction of athletic status and age.

Athletes vs Non-Athletes. A comparison of the HR-on-RPE regression lines for the three sessions is given in Figure 4. In both groups, the regression lines of the two prescription tasks were significantly different from the criterion line (p<0.01), with HRs at any given RPE being higher in P1 and P2 than in C. However, there were no inter-group difference in these lines. It is also noteworthy that, in both groups, there was no difference between the P1 and the P2 regression lines, suggesting that the one-month period between the two prescription tasks did not modify the subjects’ ability to execute the prescriptions.

The wheeling velocities chosen by the two groups in each of the prescribed RPE tasks are summarized in Figure 5. Both groups were able to discriminate among the prescribed tasks in both sessions, by progressively choosing higher speeds with increasing RPE numbers (p<0.0001). One exception was found in session P2, when the non-athletes did not discriminate between prescriptions RPE=13 and RPE=16. The athletes, as expected, wheeled their chair at a higher speed than the non-athletes (p<0.001), at each of the prescribed tasks in both sessions. There were no significant differences in either group between the velocities that they chose in session P1 and those of P2. The ability to replicate the performance following a month's interval was particularly apparent at RPE 7 and 10 for both groups and at RPE 16 for the athletes.
The subjects' ability to discriminate among the four prescribed tasks can also be judged from their heart rates, as summarized in Figure 6. In both groups, HR increased consistently with increasing RPE numbers. However, the differences between prescriptions RPE 13 and RPE 16 were not significant. There were neither inter-group nor inter-session differences in HR at each of the prescribed tasks.

Youth vs Adults. Because of the lack of differences in HR-to-RPE relationship between the athletic and non-athletic groups (Figures 4,6), we decided to combine all youth subjects (n=10) into one group, irrespective of their athletic status. Likewise, we combined all adults (n=10) into another group. Figure 7 is a summary of the group HR-on-RPE regression lines in sessions C, P1 and P2. In each group, the lines in the two prescription sessions were different from those of the criterion session. In addition, there were differences between the groups for slope and intercept and a group-by-session interaction for the slope. In general, for both groups, the HR during the two prescription sessions was higher than in the criterion session.

The wheeling velocities chosen at the two prescription sessions by the youth and the adult groups are summarized in Figure 8. In both groups, there was a general pattern in which a higher velocity was chosen whenever the RPE prescription was higher, suggesting a good ability by the subjects to discriminate among prescribed tasks. One exception was RPE 13 in session P2 which yielded a lower velocity than the RPE 10 prescription. Combining both sessions, ANOVA (p<0.0001) and the post-hoc test showed that the chosen velocities all differed from each other. However, there was no difference due to group. The range of chosen velocities (at RPE 16 minus RPE 7) was identical (0.5 m/s) between the youth and the adults. Inter-session comparison between the velocities chosen by the subjects showed no differences, suggesting their ability to replicate the prescribed task one month apart.

The HRs of both age groups at each of the prescription level are compared in Figure 9. In both groups, there was a distinct (p<0.0001) increase in HR with
the increase in the RPE prescription, again suggesting the subjects' ability to discriminate among prescribed intensities. The youth had significantly higher HRs than the adults at RPE 7 and RPE 10. inter-session comparison shows that the children replicated their HRs extremely well at each, prescription level. The adults, on the other hand, had somewhat lower HRs in session P2, particularly at RPE 7.

Interaction of Athletic Status and Age. All sub-groups, irrespective of athletic status or age, had different HR-on RPE regression lines between the criterion session on the one hand and the two prescription sessions on the other (HR being higher in the two prescription sessions than in the criterion session). The only consistent difference between the sub-groups was in their chosen velocities during the prescribed tasks, as shown in Figure 10. The athletic adults chose significantly higher velocities than did the other three sub-groups. The athletic youth wheeled faster than the two non-athletic groups, which did not differ from each other. It is noteworthy that the range of velocities used by both groups of athletes was higher than that used by the non-athletes.

DISCUSSION

The main finding of this study is that wheelchair-bound people, teenagers and adults alike, can discriminate among wheeling intensities as prescribed to them by the Borg category scale. Such ability does not seem to depend on the nature of the disability, age, or athletic status of the individual. Furthermore, subjects have displayed an excellent retention of this ability, for at least one month.

There is little research available on one's ability to execute exercise intensities as prescribed using the RPE scale. G. Borg was the first to indicate (Borg, 1970) that his category scale could be used for prescribing appropriate exercise intensities. The implied assumption was that one's ability to reproduce a prescribed intensity using the RPE concept is related to the psychophysical process of rating one's perceived exertion. Noble (1982), however, disputed this
assumption. He suggested that the psychophysical process by which one rates the perceived intensity of exercise may be different from that used in order to perform a certain intensity when prescribed as a number on the RPE scale.

As discussed in the introduction to this report, RPE has been found quite useful as a means for prescription of exercise intensity to adults. The ability of teen-agers, in this study and the study by Ward & Bar-Or (in press), to discriminate among prescribed intensities is particularly impressive, bearing in mind that the mode of exercise during practice (arm cranking in this study; cycling in Ward and Bar-Or's study) was different from the one used for prescription (wheeling and running, respectively). Such a difference in exercise modality may be the cause for the children's (and the adults') exaggeration in their choice of the lighter intensities.

Individuals who train in such athletic events as distance running, cycling, skating or wheeling are usually able to gauge their velocity, a common practice in sport training is to describe a certain velocity as a percentage of one's maximal velocity. It was therefore surprising that the "athletes" in this study - children and adults alike - did not show any advantage over the non-athletes in the accuracy of producing the prescribed tasks. One reason may be the difference in exercise modality between the practice and the prescription sessions. Another may be that the particular "athletes" who took Dart in this study were not using fractions of their maximal speed as a means of gauging their wheeling velocity during training or competition. No data are available to us on the ability of healthy athletes to use the RPE as a means of prescription of intensity.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be derived from the above findings:

1. Adults and teenagers, who are confined to a wheelchair as their major means of transportation, can be prescribed wheeling intensities, using the Borg category RPE scale.
2. When taught the notion of the scale during an arm cranking exercise, as done in this study, these people select wheeling velocities that are higher than expected, based on their HR-on-RPE regression lines. However, because such an overestimate is consistent, one can adjust one's prescription such that the required HR will be reached.

3. One's ability to execute a prescribed intensity does not depend on age nor on athletic status. However, athletes (of either age group) seem to utilize a greater range of exercise intensities than do the non-athletes.

4. Such an ability is retained by all subjects, irrespective of age or athletic status, for at least one month after the original prescription.

5. At any RPE level, trained individuals chose wheeling velocities that are higher than those chosen by the untrained. However, the HR at each prescribed RPE does not depend on one's athletic status.

6. At RPEs 7 and 10, the teenager's HR is higher than the respective HR of the adults. These differences diminish at RPEs 13 and 16.
Based on this study we recommend the following:

1. Teachers in adapted physical education and coaches of wheelchair sports should be made aware of the findings of this study and taught how to use RPE as a tool for prescription of exercise intensity.

2. Because such professionals do not have easy accessibility to arm cranking ergometers, they should attempt to teach the RPE scale during wheeling on a track and then use it as a tool for prescription. We anticipate that, with that approach, the carry-over from teaching to prescribing may even be better than when teaching is done on an ergometer and the prescription is executed on a track.

3. Future research is recommended to ascertain the following:
   a. What is the youngest age at which a child – healthy or physically challenged - can grasp the notion of the RPE scale?
   b. What is the youngest age at which a child can benefit from the RPE scale as a tool for prescription of exercise intensity?
   c. Can alternative methods (e.g. pictures, cartoons, analog scales) be used with young children who cannot grasp the notion of a numerical scale?
REFERENCES


Table 1.: Number of Subjects by Athletic Status*, Age Group and Diagnosis.

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<tr>
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<th>Cerebral Palsy</th>
<th>Spina Bifida</th>
<th>Spinal Cord Injury (T2-L5)</th>
<th>Other</th>
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<td>A.Y.</td>
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<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>A.A.</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>N.A.Y.</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>N.A.A.</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>-</td>
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A.Y. - athletic youth
A.A. - athletic adult
N.A.Y. - non-athletic youth
N.A.A. - non-athletic adult

* - athletic status determined by coach and experimenter
Table 2: Subject Anthropometric Characteristics, by Groups. 

Means ± 1SD

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<th></th>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>Arm span (cm)</th>
<th>Sum of 4 Skinfolds (mm)</th>
<th>% fat</th>
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<td>49.8</td>
<td>159.2</td>
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<td>55.1</td>
<td>161.6</td>
<td>46.8</td>
<td>23.7</td>
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LEGEND FOR FIGURES:

Fig. 1  Borg's Category RPE scale.
Fig. 2  Standard instructions given to the subject as an introduction to the 
RPE scale.
Fig. 3  Standard instructions given to the subject during the "anchoring"
practice in Session 2.
Fig. 4  HR-on-RPE regression lines for the criterion session (C) and the 
two prescription sessions (P1, P2). Comparing the athletic (AT)
and non-athletic (NAT) groups. ATC=○, ATP1=●. ATP2
=▲, NATC=▲. NATP1=▪ NATP2=□.
Fig. 5  Wheeling speed at each of four RPE prescriptions.
Comparing athletes (AT) and non-athletes (NAT) in sessions 
P1 and P2. ATP1=○, ATP2=●, NATP1=▲ NATP2=▲.
Fig. 6  HR at each of four RPE prescriptions. Comparing athletes
(AT) and non-athletes (NAT) in sessions P1 and P2. Symbols
as in Fig 5.
Fig. 7  HR-on-RPE regression lines for the criterion session (C) and the 
two prescription sessions (P1, P2). Comparing youth (Y) and 
adults (AD). ADC=▲, ADP1=□, ADP2=■, YC=○,
YP1=●, YP2=▲.
Fig. 8  Wheeling speed at each of four RPE prescriptions in session P1 and P2.
Comparing youth (Y) and adults (AD). P1=○, YP2=●, ADPl=▲,
ADP2=▲.
Fig. 9  HR at each of four prescriptions in sessions P1 and P2.
Comparing youth (Y) and adults (AD). Symbols as in Fig 8.
Fig. 10  Velocities at each RPE prescription level in session P1,
as chosen by the athletic youth (○), athletic adults (□),
non-athletic youth (●), and non-athletic adults (■).
Figure 1.

6

7  VERY, VERY LIGHT

8

9  VERY LIGHT 10

11  FAIRLY LIGHT 12

13  SOMewhat HARD 14

15  HARD 16

17  VERY HARD 18

19  VERY, VERY HARD

20
INSTRUCTIONS FOR RATING THE PERCEIVED EXERTION

a) During your arm cranking test you may feel the exercise to change in difficulty.

b) During the test you will be asked how hard the exercise is.

c) This scale is from 6 to 20. 6 is the easiest exercise possible. There is no 5 or 4, nothing is easier than 6. 20 is the hardest exercise possible. There is no 21 or 22, nothing is harder than 20.

d) When you are asked how hard the exercise feels, please answer by saving the number that best describes how hard you are exercising at that moment.

e) You may use the words opposite the numbers to remind you of what the numbers mean, but always answer by giving a number and not a word.

f) Your answer may be any number between 6 and 20, and not just those opposite words.

g) There is no right or wrong answer. We just want to know how hard you feel you are working.
INSTRUCTIONS FOR PRACTICING THE RPE RANGES, USING THE "ANCHORING" METHOD

"Think about the feeling of exertion in your body, your arms, your breathing and your heart, and assign these feelings a number 7 on the RPE scale - very, very light... (number 19 on the RPE scale - very, very hard)."
WHEELING SPEED, m·s⁻¹
WHEELING SPEED, m.s⁻¹

![Graph ofWheeling Speed vs. RPE](http://www.lin.ca)