Perceived and Measured Levels of Exertion of Patients With Chronic Back Pain Exercising in a Hydrotherapy Pool

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ABSTRACT. Barker KL, Dawes H, Hansford P, Shamley D. Perceived and measured levels of exertion of patients with chronic back pain exercising in a hydrotherapy pool. Arch Phys Med Rehabil 2003;84:1319-23.

Objective: To investigate the efficacy of using ratings of perceived exertion (RPEs) to regulate exercise intensity for patients with chronic back pain while they undergo hydrotherapy.

Design: Experimental study.

Setting: Hydrotherapy pool in the United Kingdom.

Participants: Twenty-six patients (16 women, 10 men) with chronic low back pain of more than 12 months in duration. All were referred for hydrotherapy after attending a back pain triage clinic.

Interventions: Not applicable.

Main Outcome Measures: Borg Ratings of Perceived Exertion Scale; heart rate expressed as a percentage of age-predicted maximum heart rate, computed from readings using heart rate monitors; Oswestry Disability Questionnaire; and pain score from a visual analog scale.

Results: At workloads below 55% of age-predicted maximum heart rate, great variability was found in the relation between RPE and exercise intensity. However, for workloads between 55% and 85% of age-predicted maximum heart rate, RPE had a strong correlation with relative exercise intensity during hydrotherapy.

Conclusions: At workloads sufficient to induce an aerobic training response, and yet be safe for patients with chronic back pain, RPE was an accurate predictor of exercise intensity. At lower intensities, back and leg pain may exert a mediating influence. Further investigation is needed to determine the exact relation between back pain, exercise type, and RPE at low exercise intensities.

Key Words: Exertion; Heart rate; Hydrotherapy; Low back pain; Rehabilitation.

BETWEEN 60% AND 70% of the UK population will experience at least 1 incident of back pain during their lifetime, with 90% recovering spontaneously from the first acute episode. However, many will experience recurrences and become increasingly physically and functionally disabled.[1] Many different modes of physiotherapy are used to treat these patients, including hydrotherapy, which is advocated as an appropriate method to decrease pain and restore function.[2-4] Hydrotherapy has face validity as the ideal environment in which to train for endurance, power, flexibility, and general mobility, but until recently there has been little research into either the physiologic responses to or the clinical outcomes of hydrotherapy. Some evidence does support positive clinical outcomes after patients with chronic back pain have completed hydrotherapy programs.[2,5,6] Moreover, research has provided a greater understanding of the physiologic response to exercise in water.[7-11]

The hydrostatic forces experienced when healthy subjects are immersed in water produce the physiologic response of centralization of blood flow. Blood is redistributed from the lower extremities and abdomen to the thorax, which results in increased venous return to the heart and intrapulmonary blood flow.[7,8] This increased heart volume produces increased heart contractile forces and subsequent increases in stroke volume and cardiac output, with accompanying reflex bradycardia.[2] Consequently, heart rates of healthy subjects who are either at rest or who are exercising while immersed in water (at 35°C), are lower than those recorded for the same subjects at rest or when they are exercising on land.[9-11]

The linear relationships that exist between submaximal workloads, heart rate, and volume of oxygen consumed during exercise on land remain when submaximal exercise is performed in the water. They are reported to be higher when people exercise while immersed in water than when the same exercises are performed on land.[10,11] Consequently, healthy individuals exercising at a given heart rate while immersed in water may actually be exercising at a higher physiologic workload than they would if they were exercising at the same heart rate on land. Knowledge of these physiologic responses can help clinicians regulate patients' exercise intensity and prescribe safe and effective hydrotherapy programs.[10]

After back injury, patients may have reduced cardiorespiratory endurance as a result of detraining from reduced activity levels and impaired motor skills. Thus, simple functional activities such as walking may now require more effort, within a framework of reduced capacity. This may affect overall fatigue levels and tolerance of physical activity, considering that most people tend to engage in activities of daily living at intensities of approximately 40% of their peak oxygen uptake or exercise capacity.[12] Thus, it is potentially beneficial to improve patients' overall fitness while implementing a program that is aimed at decreasing the disability resulting from their low back pain (LBP).

To increase cardiovascular endurance in a hydrotherapy pool, individuals need to exercise at an intensity sufficient to induce a training effect, but not so intense as to increase pain or affect compliance. The use of heart rate or oxygen consumption to monitor exercise intensity during hydrotherapy would be expensive and impractical for group sessions in clinical settings. Thus, for individuals with chronic back pain to gain

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Table 1: Patient Characteristics and Scores

	Mean ± SD	Range
Age (y)	54±11.74	25–72
Duration of back pain (y)	4.5±5.2	1–22
Average heart rate at baseline	86±16.3	57–101
Average heart rate after 20min exercise	161±17.23	76–195
% APMHR at baseline	50.7±11.3	44–84
% APMHR after 20min exercise	63.9±10.2	42–80
RPE at baseline	2.07±1.32	1–6
RPE at end of 20min exercise	14.8±3.36	9–19
VAS at rest	47.65±12.64	29–84
VAS after 20min exercise	43.42±14.41	20–92
ODQ	46.76±9.40	36–64

Abbreviations: % APMHR, age-predicted maximum heart rate; SD, standard deviation.

maximum benefits from hydrotherapy, clinicians need a reliable, valid, and practical measure of physiologic work.

Ratings of perceived exertion (RPE) scales[13] are a recognized, practical, reliable tool with which to monitor and evaluate physiologic work because they provide an association between subjective and objective measurements of physical stress.[14] However, it is important to recognize that research into the relation between RPE and the exercise intensity of nonswimming water-based exercise is limited.[15-18] Comparatively little research has focused on clinical groups.[16,19,20]

In this study, we investigated the relation between RPE and heart rate in individuals with chronic back pain who were participating in a hydrotherapy exercise class. Factors that may influence exercise intensity and the perceptions of exercise intensity were explored.

METHODS

Participants

Twenty-six subjects (16 women, 10 men) with a diagnosis of chronic, nonspecific, LBP, defined as lasting for more than 12 months, were recruited. All patients had been referred to a back triage clinic by their family physician. At the initial visit, patients were screened in accordance with the guidelines in the Clinical Standards Advisory Group's *Report on Back Pain*[21] to ensure that no potential serious pathology existed. After the triage visit, subjects were referred to the physiotherapy department for treatment. Patients were individually assessed by a musculoskeletal physiotherapist specialist who, at his/her discretion, referred them to the hydrotherapy rehabilitation class. Patients were referred if, in the physiotherapist's opinion, they would benefit from a group exercise approach, but that they were too chronic to benefit from the department's more active land-based class.

All patients attended the 1-hour hydrotherapy rehabilitation class, which consist of 4 sessions. Their biometric characteristics are presented in table 1.

Ethics Approval

The study was approved by the local research ethics committee, and patients gave informed consent to participate in accordance with the Royal College of Physicians guidelines.

Measures

Heart rate. Heart rate was continuously measured with Polar Accurex Plus™ heart rate monitors.[a] Readings were taken every 5 seconds, following a standardized protocol with the patients standing while immersed in the water. Minute heart rate was calculated as the mean of the readings taken over 60-second periods.

Ratings of perceived exertion. The Borg Rating of Perceived Exertion (Borg RPE) Scale was used because it is believed to be the most appropriate scale when clinical observation and perceptual responses are used together to regulate exercise.[14,15] Our instructions on how to use the scale followed the recommendations of Borg.[13]

Level of disability. The level of disability experienced by the subjects was measured with the Oswestry Disability Questionnaire (ODQ), which was completed before the hydrotherapy testing. Results are reported as a percentage; the higher the score, the greater the disability (table 1). The ODQ is a valid and reliable measure of disability caused by back pain.[22]

Pain. The intensity of pain at rest and during exercise was recorded using a 10-cm visual analog scale (VAS), with anchors at "no pain" and "extreme pain."[23] Measurements were taken before exercise and at 4-minute intervals during the exercise.

Temperature. Air and water temperatures were measured with an ETI LCD Digital Portable Multi-Stem Thermometer.[b] Temperatures reported are means calculated from readings taken before and after each group's testing.

Procedures

Subjects were tested in small groups of 4 to 5 participants, all of the same sex. The ambient air temperature and the water temperature were constant throughout the testing. Subjects were assessed during the last of 4 exercise sessions to ensure that they were familiar with the exercises they were asked to perform. They were instructed to exercise at a level high enough to become out of breath, but not to provoke their pain. The same instructor supervised all group testing sessions. Each session began with a reading of the standardized directions for using the Borg RPE Scale and a familiarization session in its use. Heart rate measurement then began and the participants were asked to maintain a relaxed stance for at least 3 minutes. Resting minute heart rates were calculated from the readings collected in the 60 seconds immediately before exercise commenced.

Subjects determined for themselves the intensity at which they completed the exercises, following the same program they had completed in previous sessions. All exercises were performed while in an upright position in water 106cm deep. The subjects exercised as a group, completing the same exercises in the same sequence; RPE and heart rates were recorded during exercise.

The session included a 4-minute warm-up, a 16-minute exercise period, and a 4-minute cool down. General exercises included walking forward, backward, and sideways, and jogging in the water. Other exercises were aimed at improving trunk range of movement and improving the strength, mobility, and endurance of the lower limbs and trunk. The exercises were progressed gradually and selected on the basis of the likelihood of improving symptoms without aggravating the patients' pain.[6] Data collection began after the warm-up period, when a steady heart rate had been attained. Subjects indicated their perceived exertion to the poolside investigator at the end of every fourth minute. The corresponding minute heart rates were calculated from the readings taken over the preceding 60 seconds. Relative exercise intensity was calculated as a percentage of the subject's age-predicted maximum heart rate or 220 minus the subject's age.[24] The rating of pain intensity was recorded at rest before the warm-up session and during the 4-minute exercise periods.

Analysis

All data analysis was performed with the SPSS, version 10.0, statistical software package.[c] Normal plots and boxplots, together with Shapiro-Wilks tests, were used to determine the normality of all data sets. Independent *t* tests were used to compare biometric characteristics between the genders. Multiple linear regression (incorporating Pearson correlation coefficients) was used to determine the associations between RPE and: (1) relative exercise intensity (percentage of age-predicted maximum heart rate) over the full range of exercise intensities recorded in this study; and (2) relative exercise intensities between 55% and 85% of age-predicted maximum heart rate–the range, suggested by the American College of Sports Medicine[25] (ACSM) as safe and sufficient to induce an aerobic training response.

RESULTS

The baseline characteristics and variation in scores are detailed in table 1.

Hydrotherapy

Water temperature during hydrotherapy testing ranged from between 33.9° and 34.4°C (mean ± standard error, 34.1°±0.2°C). Poolside air temperature ranged from 28.5° to 28.7°C (mean, 28.5°±0.1°C). The temperatures remained constant throughout each testing session, but varied slightly between sessions.

Reliability of Heart Rate Measurements

Between-day test-retest resting heart rate responses in water were assessed in 12 healthy volunteers. Intraclass correlation coefficients of .852 and .802, respectively, were recorded.

Age, height, level of disability (ODQ), and pain intensity at rest and during exercise (VAS) did not differ significantly between men and women.

Over the full range of exercise workloads that were recorded, the age-predicted maximum heart rate and RPE correlated well ($r=.66$, $R^2=.44$, $P<.001$) (fig 1).

The greatest variability in RPE occurred during lower exercise intensities.

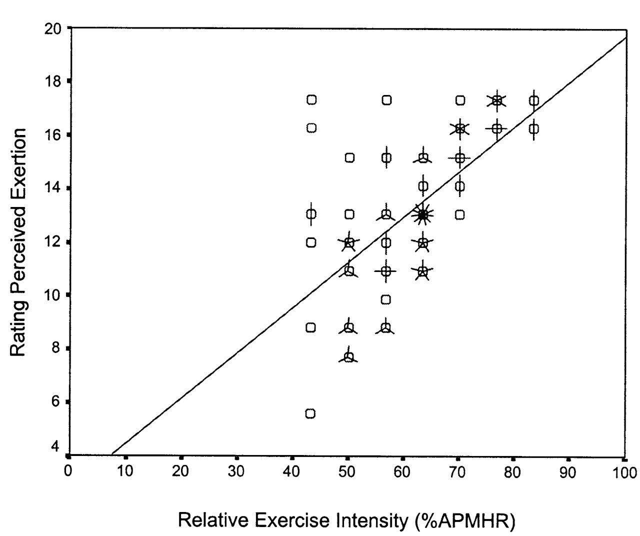

Fig 1. RPE and relative exercise intensities during hydrotherapy (N=26, 4 data points per subject).

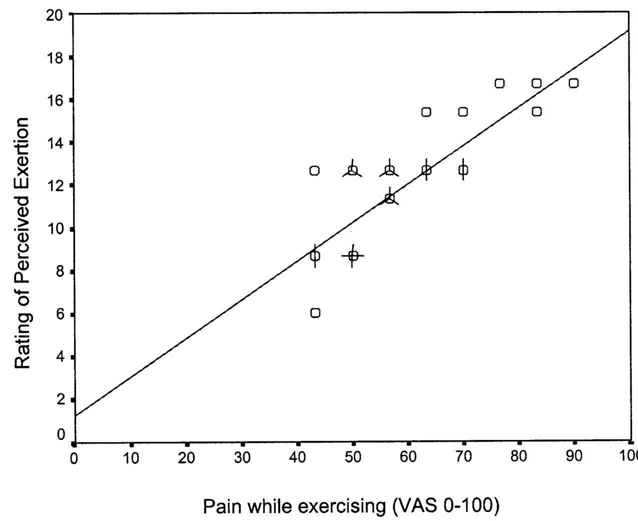

Fig 2. Association between RPE and pain intensity during exercise (VAS) at exercise intensities of below 55% of age-predicted maximum heart rate (n=7, 4 data points per subject).

In the patients who were able to exercise at an intensity of 55% of age-predicted maximum heart rate or above, the RPE was strongly influenced by the exercise intensity ($r=.84$, $R^2=.71$, $P<.001$).

Thirty percent of the patients did not reach an exercise intensity of 55% of age-predicted maximum heart rate. Stepwise multiple regression analysis was performed with these patients to assess the influence of pain and disability on exercise intensity and perceived exertion.

The greatest predictor of a high RPE was the VAS rating of pain during exercise. This accounted for 85.9% of the variation in the analysis ($r=.927$, $R^2=.85$, $P<.001$) (fig 2).

There was no association between the degree of disability as measured with the ODQ and the RPE.

DISCUSSION

Other researchers[26] have recommended the Borg RPE Scale as an appropriate tool for regulating exercise intensity during fitness classes for patients with chronic back pain. However, there is a paucity of research examining the use of RPE in other clinical groups. Furthermore, we found no studies that documented the physiologic response of exercising in water in clinical groups; the studies we did find focused on clinical or psychologic benefits.[1,2,6,16]

Cassady and Nielsen[10] studied the cardiorespiratory responses to exercising in water as compared with exercising on land in healthy subjects. They concluded that subjects who exercised in water had heart rate and percentage of age-predicted maximum heart rate responses that were sufficient to elicit aerobic training changes, yet were within the acceptable ranges for exercise for stable patients in cardiac rehabilitation programs. They recognized the need for a measure that would allow clinicians to assess workload indirectly, but that would use cadence as an indirect measure of heart rate, rather than RPE, as used in this study.

We found that relative exercise intensity was only moderately associated with RPE. In contrast, Nakanishi et al[27] found a strong association between heart rate and RPE, and Brown et al[28] found a high correlation between the percentage of age-predicted maximum heart rate and RPE during immersed exercise. However, these researchers only examined the relation between RPE and exercise intensity for workloads above 55% of age-predicted maximum heart rate. The greatest variability in RPE that we report occurred at the lowest exercise intensities, which is in agreement with the results of studies with healthy controls.[13,29]

When the patients who failed to exercise at a workload of between 55% and 85% of age-predicted maximum heart rate were excluded from analysis, the strength of association improved markedly. In this range, our patients had a correlation similar to that reported by Nakanishi et al[27] (r=.85 vs r=.84). They examined the relation between absolute heart rate and RPE, not age-predicted maximum heart rate. Stronger correlations have been consistently reported when heart rates are reported as percentages of maximal values,[28,30] as we did in the present study. Because the Borg RPE Scale covers the whole exercise range, the effect of age must be considered if heart rate is correlated with RPE; the use of age-predicted maximum heart rate adjusts for this.

Research using intermittent and continuous walking and running protocols in healthy subjects has reported a correlation between absolute or relative heart rates and RPE of r equal to .71 to .94.[31] The correlation for exercise intensities between 55% and 85% of age-predicted maximum heart rate that we found falls within this range. Although they found some variability at lower exercise intensities, both Steed et al[32] and Hetzler et al[33] reported high correlations (r=.74 and r=.81, respectively) between RPE and percentage of age-predicted maximum heart rate for all intensities between rest and maximal workload during exercises on land. These correlations are higher than the r equal to .66 found over the full range of workloads for our subjects, a fact that is possibly explained by the large variability in RPE found at the lower exercise intensities. It is also probable that patients in this group were less familiar with rating exercise because they were a patient population, compared with subjects in other studies, who were often sports science students.

One possible explanation for the variability in RPE found at lower exercise intensities in our study involves the type of input that dominated subjects' perceptions. RPE represent an integrated response generated from many physiologic, psychologic, and environmental inputs.[15] Physiologic inputs can be classified into those of central origin (eg, cardiorespiratory factors—breathlessness and minute ventilation) and those of local origin (eg, muscle or joint pain).[14] Normally, central factors dominate perceptions at higher exercise intensities and local factors dominate at low to moderate intensities, although this will vary depending on the exercise modality and protocol.

The relation between local and central factors and RPE is complex. Moreover, some factors such as breathlessness and local muscle pain can be consciously monitored. If an individual concentrates on 1 of these factors (eg, back or leg pain) or values a particular factor over others, that factor can dominate perceptions of exertion.[34] Particular exercises used during the testing sessions may have elicited back or leg pain in some subjects, thus limiting the intensity at which they exercised. They may also have perceived the exercise to be more intense because of increased pain. This may have dominated perceptions of exertion during these exercises to the extent that the RPE reflected the level of pain elicited rather than an overall feeling of exertion or fatigue. This phenomenon was apparent in patients who did not reach an exercise intensity of 55% of age-predicted maximum heart rate, because the VAS rating of pain during exercise accounted for 58% of the variation in the analysis that predicted perceived exertion. At lower intensities, pain may have dominated the exertional symptoms, whereas at higher intensities other symptoms of overall fatigue may have overshadowed pain symptoms, in alignment with the sensory processing model of Levanthal and Everhart.[35]

It might be expected that if back or leg pain were implicated in RPE variability at low exercise intensities, a subject's level of disability (ODQ) would have some association with perceived exertions. There was no association between the degree of disability and the rating of perceived exertion, which is perhaps explained by the fact that the assessment of disability is complex and multifactorial and considers other influences in addition to pain.

In the group as a whole, back and leg pain was not provoked by the hydrotherapy exercises; indeed, the exercises were designed to minimize such stresses. Therefore, it would appear that the back and leg pain implicated in RPE variability was related to particular exercises for individual subjects; that is, the association between back and leg pain and RPE varied, depending on the particular exercise performed rather than on the subject's overall level of disability.

CONCLUSION

We examined perceptions of exertion in patients with chronic back pain during hydrotherapy sessions. At workloads below 55% of age-predicted maximum heart rate, variability existed in the relation between RPE and exercise intensity. Back or leg pain elicited by some exercises may have influenced the subjects' perceptions of exertion. However, for workloads suggested by the ACSM[25] as being safe and sufficient to induce an aerobic training response (55%–85% of age-predicted maximum heart rate), we found that relative exercise intensity was strongly associated with RPE. Our findings suggest that the Borg RPE Scale may be an appropriate tool for monitoring exercise intensity in patients with chronic back pain, when they can exercise at a level above 55% of age-predicted maximum heart rate. At lower exercise intensities, RPE lacks precision. The reliability of the response needs to be examined further. It remains to be determined whether subjects with chronic back pain can self-regulate their exercise intensities using RPE.

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