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Original Article

Rating of Perceived Exertion as an Indicator of Exercise Intensity in Paraplegics

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Abstract

Background: Energy expenditure is of paramount importance in the assessment of usefulness of wheelchair for paraplegics. Despite widespread recognition of problems associated with currently available mobility systems for persons with spinal cord injuries, development of more efficient systems has been slow. Lack of a suitable and simple technique for the assessment of energy expenditure in paraplegics has perhaps contributed to this slowness.

Objective: To assess the energy expenditure with a simple technique, *i.e.* rating of perceived exertion during arm crank ergometry and crutch walking in paraplegics.

Methods: The experiments can be divided into three phases; firstly, assessment of energy expenditure during seated arm crank ergometry in 10 paraplegics and 20 able-bodied subjects; secondly, upright arm crank ergometry in seven paraplegics and 20 able-bodied subjects. Arm crank ergometry was carried out with an incremental series protocol at three work rates (16, 28 and 40 watts) and at a cranking rate of 50 rpm. The third part was to assess the energy expenditure during crutch walking in five paraplegics and in 10 able-bodied subjects whilst walking with axillary crutches and knee-ankle-foot orthoses. All subjects walked at their preferred speed on a figure of eight track. We measured the oxygen consumption, using the Douglas bag technique or the face mask method, and evaluated the rating of perceived exertion by the standard 6-20 Borg scale.

Results: The non-significant difference of two measured variables (oxygen consumption and rating of perceived exertion) between paraplegic and able-bodied subjects showed the consistency of measured variables for the assessment of energy expenditure during seated arm activities (*e.g.*, wheelchair propulsion) in paraplegics. However, during upright arm crank ergometry, paraplegics found work at any given rate harder upright than seated. The results indicated a greater load on the cardiorespiratory system in paraplegics during crutch walking. The different responses to these types of arm exercises in thoracic paraplegics could be partly or wholly explained by impaired mechanisms of venous return in paraplegics, problems that would be particularly severe in upright posture. In addition, dividing by speed standardizes, both the energy cost and the physiological cost index; this has not been done for perceived exertion.

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Conclusion: Though more high lesion patients should obviously be studied, this strongly suggests that perceived exertion is not a suitable indicator for comparison among subjects whose preferred walking speeds are different. However, for comparison between individuals, crutch walking at a given speed on treadmill could be of value.

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Keywords • Arm crank ergometry • crutch walking • energy expenditure

Introduction

An important question for rehabilitation team who deal with spinal cord injuries is as to how a paraplegic perceives the amount of work he performs. In 1962, Borg devised a simple rating method by which one could evaluate the strain of physical work subjectively.[1] He also showed a strong correlation between perceived exertion and work intensity during exercise in able-bodied subjects.

The factors responsible for perceived exertion are multiple and complex. The individual, however, evaluates his perceived exertion during physical work due to at least two factors:[2]

i. Local factors: A muscular response for perception of effort as a local factor is based on mediation of feeling of strain in exercising muscles. The parameters, which provide sensory input for perceived exertion, may include muscle lactate, Golgi tendon activity and general muscle sensation[3] More recent thoughts suggest that other muscle metabolites, and K^+ ions might be considered alongside lactate.

ii. Central factors: They consist of pulmonary ventilation and circulation and perhaps, direct sensory effects of muscle metabolites acting upon receptors located centrally.

It should be noted that during exercise below the level of lesion in paraplegics (*e.g.*, electrically induced leg cycle ergometry) the local factors cannot be involved as inputs for perceived exertion because the afferent nerves are not intact. Thus, the perceived exertion responses to exercise below the level of lesion in paraplegics might not be the same as in able-bodied subjects. To the best of our knowledge, no published data in this area is available. Nonetheless, from the point of view of fundamental physiology, the experiment seems worth doing as it might help to distinguish between local and central factors contributions to perceived exertion.

A few authors used the rating of perceived exertion previously as an index of the strain of physical activity in paraplegics during maximal arm ergometry.[4,5] To the best of our knowledge, there is no published data regarding perceived exertion responses to sub-maximal arm exercise in paraplegic subjects.

This work was conducted to study the effect of three types of arm exercises on the rating of perceived exertion in both paraplegic and able-bodied subjects.

Patients and Methods

Procedure of arm crank ergometry experiment

We studied 20 able-bodied and 10 paraplegic subjects for seated arm crank ergometry and 20 able-bodied subjects and seven paraplegics for upright arm crank ergometry. Tables 1 and 2 summarize their characteristics.

The arm crank ergometer used was modified from a standard, friction-belt bicycle ergometer of the weight-loaded type (Monark). This ergometer was mounted on rigid frames with different heights (for seated and upright arm crank ergometry, separately). We used a standard wheelchair and adjusted its height for each individual. In upright arm crank ergometry, we also adjusted the heights of the volunteers relative to the ergometer. Our criterion for this adjustment (in the vertical plane) in both seated and upright arm crank ergometry was to level the ergometer crank shaft with subject's shoulder joint. For upright arm crank ergometry, the paraplegics used their own calipers and were supported by a frame using straps around the knee and waist. The same equipment was adopted for able-bodied subjects.

Each subject fasted (food, alcohol and tobacco) at least two hours before data collection and took no medication. The temperature in the laboratory was between 20°C and 22°C. Before the experiment, the weight and height of subjects were measured. Oxygen consumption was measured by the Douglas bag technique. Perceived exertion was evaluated by the standard 6-20 Borg scale. Heart rate was measured by sport tester (It was calibrated against standard EKG).

Before each exercise test, the subjects familiarized themselves with the equipment by arm cranking. Then, they rested for five minutes in the same position. An incremental series of three work rates was then completed. The real work rates adopted were 16, 28 and 40 watts. The chosen work rates were derived from a previous pilot study to be within the capacity of all subjects. Cranking rate was standardized at 50 rpm, monitored by a counter, and the number of crank revolutions per minute was displayed continuously. Each work rate was maintained for five minutes.

Procedure of crutch walking

Ten able-bodied subjects (Table 2) and five paraplegics (Table 1) participated in this mode of

Table 1: Clinical details of paraplegic subject

Paraplegic subjects No.	Mode of exercise	Age (Yrs)	Weight (kg)	Height (cm)	Age of Lesion (Yrs)	Cause of injury (Yrs)	Level of lesion
1	SAE	44	75	160	25	TB of spine	T_5, incomplete
2	SAE, UAE	35	73	178	15	Traumatic (sports)	T_5, complete
3	SAE, UAE, CW	45	83.5	172.5	8	Traumatic (traffic)	T_6, complete
4	SAE, UAE	21	70	165	21	Spina bifida	T_8, complete
5	SAE	27	95	170	8	Traumatic (sports)	T_8, complete
6	SAE, UAE, CW	23	59.6	186	3.5	Traumatic (sport)	T_{11}, complete
7	SAE	19	90	165	19	Spina bifida	L_1, incomplete
8	SAE, UAE, CW	37	81.6	175	11	Traumatic (industry)	L_1, incomplete
9	SAE, UAE, CW	37	80.5	161	37	Spina bifida	L_2, incomplete
10	SAE, UAE, CW	47	58	157.7	45	Polio	L_2, incomplete
11	SAE, UAE, NSP	30	94	190	14	Operation	C_6, incomplete
12	SAE, NSP	23	63	165	6	Traumatic (traffic)	L_2, incomplete
Mean (subjects No: 1-10)		33.5	76.6	168.7	19.3		
SEM (subjects No: 1-10)		3.2	3.8	2.9	4.2		

SAE: Volunteer in seated arm crank ergometry, UAE: Volunteer in upright arm crank ergometry, CW: Volunteer in crutch walking, NSP: Non-sports paraplegic, SEM: Standard error of mean

exercise. Each able-bodied subject was asked to do an adjusted knee-ankle-foot orthosis with locked knee and ankle. Then, asked to rest in the wheel-chair. The paraplegic volunteers used their own calipers whenever possible. These were all knee-ankle–foot orthosis. The mean±SEM mass of the callipers was similar in all experiments (3.2±0.6 kg for paraplegics and 3.5±0.0 kg (*i.e.,* all calipers used for able-bodied subjects weighed the same) for able-bodied subjects). Standard axillary crutches were

Table 2: Details of able-bodied subjects

Able-bodied Subjects No.	Mode of exrcise	Age (Yrs)	Weight (kg)	Height (cm)
1	SAE, UAE, CW	27	62	172
2	SAE, UAE, CW	22	73.8	182
3	SAE, UAE, CW	21	65.3	179.3
4	SAE, UAE, CW	24	84.4	186
5	SAE, UAE, CW	31	82.4	184
6	SAE, UAE, CW	29	90	188
7	SAE, UAE, CW	35	84.8	186
8	SAE, UAE, CW	27	66.7	174.2
9	SAE, UAE, CW	27	93.5	191.9
10	SAE, UAE, CW	24	70.7	177
11	SAE, UAE	25	67.5	178.9
12	SAE, UAE	24	57.5	166
13	SAE, UAE	21	71	182
14	SAE, UAE	20	75	183
15	SAE, UAE	20	97.5	191
16	SAE, UAE	22	67.3	175.4
17	SAE, UAE	20	62.5	171
18	SAE, UAE	27	82	189
19	SAE, UAE	24	61.8	172.1
20	SAE, UAE	27	79.5	177.2
Mean		24.8	74.8	180.2
SEM		0.89	2.56	1.62

SAE: Volunteer in seated arm crank ergometry, UAE: Volunteer in upright arm crank ergometry, CW: Volunteer in crutch walking

Table 3: Heart rate (HR), oxygen consumption, energy cost, physiological cost index, speed and rating of perceived exertion (RPE) during crutch walking at preferred speed in thoracic and lumbar paraplegics. Mean±SE of these variables in lumbar paraplegics and able-bodied subjects are also indicated.

Volunteers	Level of lesion	HR (beats.min $^{-1}$)	O_2 (ml.kg^{-1}.min^{-1})	Energy Cost (ml.kg^{-1}.m^{-1})	PCI (beats.min^{-1})	Speed (m.min^{-1})	RPE
DT	T_6	132	10.60	1.14	7.53	9.301	13
RO	T_{11}	178	12.06	2.22	18.60	5.43	19
MG	L_1	156	21.60	0.49	2.08	43.85	15
MM	L_2	103	19.43	0.49	0.94	39.55	11
CD	L_2	123	15.32	0.75	1.96	20.45	15
Lumbar paraplegics		127±15	18.78±1.87	0.58±0.09	1.66±0.37	34.62±7.33	13.7±1.4
Able-bodied subjects		107±5.0	14.58±0.84	0.52±0.03	1.46±0.11	28.05±1.463	13±0.6

used. Subjects were initially familiarized with the swing-to crutch walking. The crutches were adjusted to a height approximately five cm below the subject's axilla with handgrip positioned to allow approximately 25° of elbow flexion. The subjects wore a face-mask system for the measurement of oxygen consumption (It was calibrated against the Douglas bag technique). For familiarization purposes, the face mask was introduced to the subjects before sampling. Oxygen consumption was measured during two last minutes of each stage of crutch walking. Rating of perceived exertion was evaluated at the end of each experiment. Each subject walked at his own preferred speed on a figure of eight track. Each exercise period lasted five minutes. Time and distance were recorded simultaneously to calculate the velocity.

Statistical analyses

Repeated measures analysis of variance was used to determine the effect of the type of subject (paraplegic or able-bodied) and power output (16, 28 and 40 watts) on each measured variable (oxygen consumption and perceived exertion) during arm crank ergometry.

Results

No statistically significant difference was observed in rating of perceived exertion between paraplegics

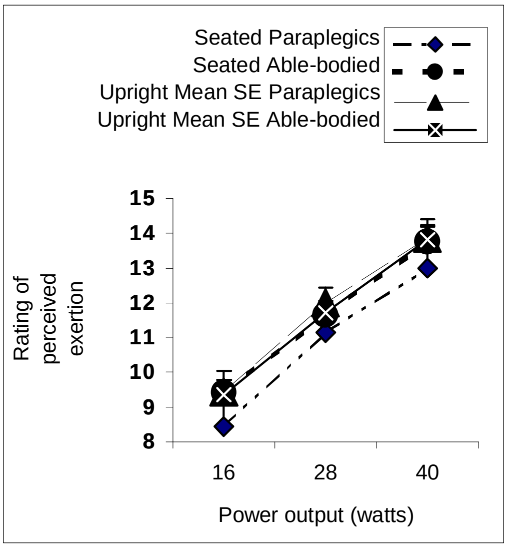

Figure 1: Mean±SEM of rating of perceived exertion plotted against the power out put during seated and upright arm crank ergometry in 7 sports-active paraplegics and 20 able-bodied subjects

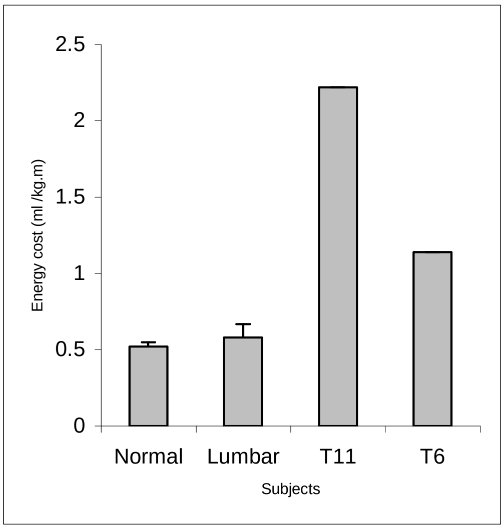

Figure 2: Mean±SEM of energy cost in 10 able-bodied subjects, 3 lumbar paraplegics and energy cost of thoracic paraplegics during crutch walking at preferred speed

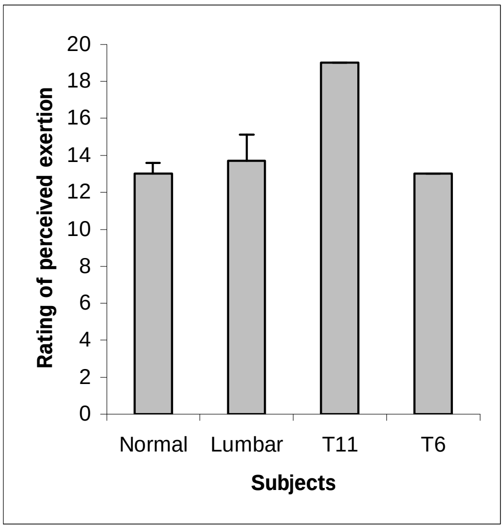

Figure 3: The mean±SEM of rating of perceived exertion in 10 able-bodied subjects, three lumbar paraplegics, and perceived exertion of two thoracic paraplegics during crutch walking at preferred speed

and able-bodied subjects at any of the chosen work rates in seated arm crank ergometry.

Figure 1, displays the data for subjects' perceived exertion. Clearly, there was no postural effect in normal subjects. Taking in to account, an acceptable level of clinical (though not the statistical) significance ($0.05<p<0.07$), it could be suggested that paraplegics found work at any given rate, harder upright than seated.

Figures 2 and 3 indicate the energy cost and perceived exertion for able-bodied subjects and paraplegics, respectively. The data are also tabulated separately for each of the five paraplegics in Table 3. Preferred speed of crutch walking was lower in thoracic paraplegics than in lumbar and able-bodied subjects. Nevertheless, energy cost even at these speeds was higher (Fig. 2). However, perceived exertion was higher in only one of the two patients with thoracic lesion (Fig. 3).

Discussion

People primarily seek medical attention when they feel ill, and not for the treatment of a special disease. Patients with severe reduction of their physical working capacity and a subsequent strain are more likely to seek medical attention. In my opinion, perceived exertion is the single best indicator of the degree of physical strain.[6]

In paraplegics, during exercise above the level of lesion (*e.g.*, arm crank ergometry) both local and central pathways are intact, as in able-bodied subjects. In this study, perceived exertion did not show any significant difference between paraplegic and able-bodied subjects during seated arm crank ergometry. This is in line with oxygen consumption responses to seated arm crank ergometry.

The results of this work in paraplegics also show significant correlation between perceived exertion and oxygen consumption, and also, power output during both seated and upright arm crank ergometry. However, Figure 1 illustrates that the increased perceived exertion in upright as compared with seated arm crank ergometry was higher in paraplegics than in able-bodied subjects. This might not be considered surprising, because of lack of familiarity of paraplegics with upright arm activity and their difficulty in performing it.

The perceived exertion quantified subjective feelings of effort during physical activity.[7] However, despite the studies about the physiological responses to crutch walking in able-bodied subjects, to the best of our knowledge, no published experiment examining the perceptual responses during crutch walking was available.

In any ambulatory study (with or without assisting devices), walking speed must be taken into consideration, because there is a linear relationship between energy expenditure and velocity.[8] Both energy cost (ml $kg^{-1}m^{-1}$) and physiological cost index (beats min^{-1}) are standardized by dividing them by speed. Then, they are used as indicators for comparison among different individuals during crutch walking. This has not been done for perceived exertion. In spite of clearly higher energy cost and also lower preferred speed of crutch walking in T_6, as compared with the mean of those in able-bodied subjects and lumbar paraplegics, perceived exertion showed only slight differences between groups (Fig. 3). Though more high lesion patients should obviously be studied, and this alone strongly suggests that perceived exertion is not a suitable indicator for comparison among subjects whose preferred walking speeds are different, for comparison between individuals, crutch walking at a given speed on treadmill could be of value.

For a strong statistical analysis, as is normal in a study with able-bodied subjects, a large number of paraplegics with the same level of lesion, completeness and cause of injury would be needed which is not readily available to the people who are working in this field.

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References

1 Stamford BA: Validity and reliability of subjective rating of perceived exertion during work. *ERGOA* 1976;**19:**53-60.

2 Ekblom B, Goldbarg AN: The influence of physical training and other factors on the subjective rating of perceived exertion. *Acta Physiol Scand 1971*;**83:**399-406.

3 Mihevic PM: Sensory cues for perceived exertion: a review. *Med Sci Sports Exerc* 1981;**13:** 150-63.

4 Gayle GW, Pohlman RL, Glaser RM, et al: Car diorespiratory and perceptual responses to arm crank and wheelchair exercise using various and rims in male paraplegics. *Res Q Exerc Sport 1990;***61:**224-32.

5 Eriksson P, Lofstrom L, Ekblom B: Aerobic power during maximal exercise in untrained and well-trained persons with quadriplegia and paraplegia. *Scand J Rehabil Med 1988*;**20:**141-7.

6 Borg G: Psychological bases of perceived exertion: *Med Sci Sports Exerc 1982*;**14:**377-81.

7 Bhambani YN, Clarkson H: Physiological and perceptual stress of three modes of ambulation: walking, axillary crutch walking and running (abstract). *Arch. Phys Med Rehabil 1989*;**68:**662-3.

8 Hinton CA, Cullen KE: Energy expenditure during ambulation with Ortho crutches and axillary crutches. *Phys Ther1982;***62:**813-9.