SÃO PAULO MEDICAL JOURNAL

ORIGINAL ARTICLE

Rachel Muszkat, Paulo Yazbek Jr., Claudia T. Arango, Maria Cecília Moreira, Ivani C. Trombetta, Linamara Rizzo Battistella.

Assessment of functional capacity during gait using a reciprocal propulsion orthosis (ARGO) – A comparative study with a conventional mechanical orthosis

This work was done at the Rehabilitation Medicine Center of the Medical Scholl of the University of São Paulo, Brasil.

One subject (male, 24 years) with an incomplete motor and sensitive SCI, neurological level C6-C7 was submitted to a comparative study during gait using an advanced reciprocaiting gait othosis (ARGO) and a conventional mechanical orthosis (CMO) and respiratory and metabolic variables were compared at peak effort and in the second minute of recovery. We found that the ARGO, as with the CMO, not garantee gait independence but the ARGO does enable a more functional gait pattern with a more efficient ventilation . The ratio of CO2/O2 showed that ARGO enable aerobic conditions of work and the energy expenditure using is significantly lower than CMO.

Key words: Spinal cord injury; Steeper advanced reciprocating gait orthosis; Conventional mechanical orthosis; spiroergometer; VO2max; anaerobic threshold.

INTRODUCTION

It is well known that gait using a long leg mechanical orthosis results in fatigue and is accentuated when the subject is in poor physical condition. Conventional assessment of the locomotor system using orthopaedic and biomechanical methods does not always predict problems which may arise with the use of walking aids and orthoses. A substantial improvement can be obtained in the methods of assessment if techniques are used which take into account the patient as a whole. However methods of assessment of cardiopulmonary function in this cases have often been somewhat subjective and inaccurate.

The introduction of the Steeper advanced reciprocating gait orthosis (ARGO) in 1991 led to significant improvement in the gait pattern in patients using the orthosis. Based on clinical observations we decided to assess cardiopulmonary function in such patients, using a spiroergometer, to provide a more accurate assessment of thee benefit of the orthosis. In the present paper, a comparison was made between a conventional mechanical orthosis (CMO) and a reciprocal propulsion orthosis (ARGO).

Address for correspondence: *Dr. Linamara R. Battistella*
Divisão de Reabilitação do Hospital das Clínicas – FMUSP
Rua Diderot, 43, V. Mariana – CEP 04116-030 – P.O. Box 8091
São Paulo – SP – Brasil

MATERIAL AND METHODS

A number of respiratory and metabolic variables were compared during gait in a patient using firstly a conventional mechanical orthosis and a then reciprocal propulsion orthosis, and the aerobic potential was determined in each case. The patient was a 24 year old male (Weight – 64kg; height 1.82m) with an incomplete motor and sensitive tetraplegia due to a road traffic accident 3 years 11 months previously. The level of the lesion was C6/C7 and the patient had no cardiopulmonary diseases or complications. A resting electrocardiogram and spiroergometer

method reading were obtained (Beckman – metabolic measurement cart – M.M.C – OM/11 – LB2) (Fig. 1). The patient then walked a distance of nine meters using firstly the CMO and then the ARGO on different days. The apparatus corrects for the ambient conditions (STPD – Standard temperature, pressure and dry). The variables studied were: Pulmonary ventilation (VE – l/min); respiratory rate (R/min); tidal volume (Vt); oxygen consumption (VO2 – ml/min); ventilatory equivalent (VE/VO2 – liters of air ventilated per 100ml of oxygen consumed); respiratory exchange ratio (RER-CO2/O2). These variables were observed at peak effort and in the second minute of recovery in each case (table I). The distance travelled, time taken an speed of the patient were also considered.

Fatigue was also assessed subjectively using the Borg scale (7-20).

Technical characteristics of the orthosis used and method of function. Two orthoses were used:

1. A locally built bilateral long leg orthosis with pelvic band support and an ankle mechanism which permitted 0-10o dorsiflexion and 0o plantarflexion. The orthosis was made of duraluminium and weighed 4kg. Propulsive force is provided by the patient's upper limbs with the orthosis providing stability. The patient walks with a two point gait (Fig. 2).
2. A British built but locally assembled ARGO, developed from the reciprocating gait orthosis (RGO – Roy Douglas 1983, Louisiana State University; Hugh Steeper, 1985 USA), by attachment of a pneumatic device between the hip and knee, which serves to facilitate standing and sitting. The orthosis is made of stainless steel and certain duraluminium alloys and is a bilateral long leg orthosis with external rods that reach the tenth thoracic vertebra. Plastic 90o ankle orthosis are attached at the ankle joint and total weight is 6kg (Fig. 2).

This orthosis provides added stability and by supporting the trunk enables reciprocal movement of

Figure 1 – Patient using the ARGO during the spiroergometric test.

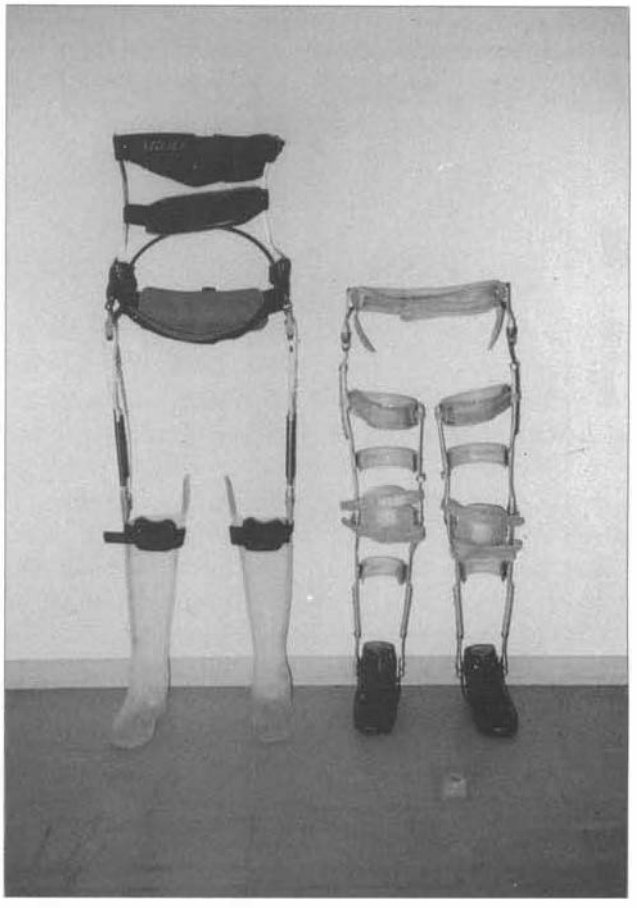

Figure 2 – Advanced Reciprocating gait orthosis (ARGO) and Conventional mechanical orthosis (CMO)

Table 1

Parameters used and variables observed in the male patient using CMO and ARGO at the peak effort and recovery.

	CMO		ARGO	
	Peak Effort	*Recovery 2*	*Peak Effort*	*Recovery 2*
Distance Travelled* (m)	9		9	
Time Taken (min.)	3.25		2	
Speed (m/min.)	2.77		4.5	
Pulmonary Ventilation (VE-L/min)	21.9	19.2	20.5	11.6
Respiratory Rate (R/min)	31.8	25.7	23.9	15.9
Tidal Volume (ml)	690	750	860	730
Oxigen Consumption (VO2 ml)	670	450	760	430
Ventilatory Equivalent** (VE/VO2)	2.5	3.2	2.0	2.0
Respiratory/Exchange Ratio (RER) (VCO2/O2)	0.90	1.06	0.82	0.86
Fatigue (BORG scale)	17	16	8	7

* The distance travelled was fixed in nine meters due to fatigue of the patient when using CMO.

** VEq - obtained in other condition (ATPS).

the lower limbs using the hip propulsion mechanism. The patient walks with a four point gait. The upper limbs also provide some propulsive force although less than tbe CMO.

Canadian style crutches were used in both cases.

RESULTS

Table I shows the results obtained with both orthoses (Table I). The speed attained using the CMO was 2.77 m/min. with fatigue rated at 17 according to the Borg scale. When using the ARGO the patient walked at 4.5 m/min. with a fatigue rating of 8.

Oxygen consumption was 670 ml/min at peak effort and 450 ml/min after recovery using the CMO and 760m ml/min an 430 ml/min respectively with the ARGO. The RER was 0.90 with the CMO during the test. exceeding 1.00 during recovery while with the ARGO the corresponding values were 0.82 and 0.86 (Fig. 3). Using the CMO. the patient ventilated 2.5l in order to consume 100ml of O2 during the test and 3.2l/100ml in recovery. Using the ARGO. these values were 2.0l/100ml in both instances (Fig. 4).

For the ratio VE/VO2. environmental conditions were taken into account and so the result differ from isolated readings.

DISCUSSION

Until a few decades ago. paraplegic patients were considered to have a shortened life span in addition to severe functional limitations. Advances in clinical. tech-

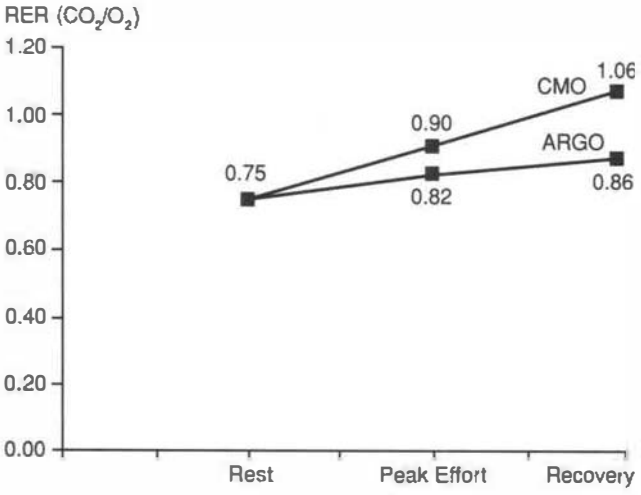

Figure 3 – Respiratory exchange ratio - RER (CO2/O2) observed at rest, at peak effort and after two minutes of recovery.

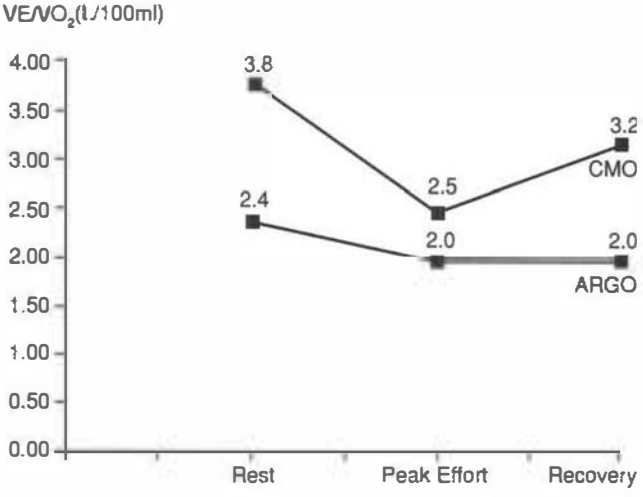

Figure 4 – Ventilatory equivalent (VE/VO2) observed at rest, peak effort after two minutes of recovery.

nological and rehabilitation methods have considerably improved the outlook.

The functional capacity has been increased by the use of orthoses and thus improve quality of life. An orthosis will often lead to a decrease in disuse osteoporosis, which is a common complication of paraplegia (Benassey 1968; Philips 1985) and decrease the incidence of pathologic fractures. Articular function is also improved and urinary function is stimulated. Furthermore, ambulation helps to avoid muscle atrophy and bedsores.

The use of an orthosis permits an upright posture and locomotion which greatly facilitates daily activities. However, CMOs require significant energy expenditure, due to the reliance on the upper limbs for propulsion and this restricts their use to lower level cord lesions. In view of these limitations, newer devices have been developed, and we observed a number of aspects of the ARGO which led us to perform this study.

This modification of the ARGO enabled easier gait and with less effort (Borg scale) and better cardiovascular performance. It can thus be more confidently prescribed by health professionals. Although only one patient was studied, the results were encouraging The ARGO enabled 61% faster gait than the CMO, while economizing oxygen consumption by 62% (VE/VO2) maintaining aerobic conditions (CO2/O2 – table I) and thus preventing the onset of anaerobic metabolism.

The knee locking system of the ARGO which distinguishes it from a conventional ARGO givers the user greater independence and facilitates standing and sitting. We did not , however, study this aspect, although it is likely that it also enables less energy expenditure. The ARGO can be worn underneath clothing, which for some is decisive in the choice of orthosis.

The overload on the locomotor system in patients using orthoses is worse when they walk with two point gait. The ARGO by allowing four point gait and also facilitating stepping, improves the state of muscles bones and joints (Fig. 5).

Another aspect which must he considered is the ARGOs high cost, especially in developing countries where social services do not assist in the acquisition of such apparatus by patients. Furthermore, the orthosis does not guarantee that patients with locomotor problems and lower limb paralysis will walk but is merely an added resource in the rehabilitation program of these patients. Each case must be assessed individually. However, we can conclude that the energy expenditure using the ARGO is significantly lower than with other orthotic devices and as such will enable patients with low spinal cord lesions to achieve greater function and improved gait. Furthermore, patients with higher lesions may be more easily fitted with these orthoses.

CONCLUSION

Assessment of functional capacity during gait using an orthosis showed the O2 consumption using the ARGO was 13% higher although gait was faster and less tired even though the orthosis was 25% heavier than a CMO. The ARGO, as with other orthotic devices, does not guar-

Figure 5 – Four point gait with ARGO.

antee independence for the patient with regard to locomotion but does enable a more functional gait pattern and 61% more efficient ventilation. The ratio of CO2/O2 showed that gait with the CMO led to anaerobic metabolism while the ARGO enabled aerobic conditions to be maintained.

REFERENCES

1. BURKETT, L.N.; CHISVM, J.; STONE, W. & FERNHALL, B. – 1990 Exercise capacity of untrained spinal cord injury individuals and the relationship of peak oxygen uptake to level of injury. **Paraplegia, 28:** 512-521, 1990.
2. CLAUSEN, J. P. – The effect of physical training on cardiovascular adjustments to exercise in man. **Physiol Rev, 57:** 779-815, 1977
3. FIGONI, S. F. – Perspectives on cardiovascular fitness. Am **SCI Jan Parapl Soc, 13:** 63-71, 1990
4. FIGONI, S. F.; BOILEAU, R. A.; MASS, B. H. & LARRSES, J. R. – Physiologic responses of quadriplegic and able bodied men during exercise at the same VO2. **Adap Phys Act Q, 5:** 130-9, 1988.
5. JEFFERSON, R. J. & WHITTLE, M. W. – Performance of three walking orthoses for the paralysed: A case study using gait analysis. **Prosthetics and Orthoses International 1990, 14:** 103-110, 1992.
6. NYHA – Criteria committee of the NY heart association. Nomenclature and criteria for diagnosis of the heart and great vessels. **6ª ed Boston, Little Brown,** 1964
7. WEBER, K.T. & JANICKI, J.S. – Lactate production during and submaximal exercise in patients with chronic heart failure. **J Am Coll Cardiol, 6:** 717, 1985.
8. WEBER, K. T.; KINASEWITZ, G. T.; JANICKI, J. S. & FISHMAN, A P. – Oxygen utilization and ventilation during exercise in patients with chronic cardiac failure. **Circulation, 65:** 1218, 1982.
9. WOLF, S. L. – Bases funcionais e morfológicas para exercicios terapeuticos. Terapeutica por exercicios; Manole SP, 1980.
10. YAZBEK, Jr. P.; HAEBISCH, H.; KEDOR, H. H.; CAMARGO, Jr. P. A.; SARAIVA, J. F. & SERRO-AZUL, L. G. – Aspectos propedeuticos no uso de ergoespirometria – medida direta de gases expirados. **Arq Bras Cardiol, 44:** 291, 1985.

RESUMO

O objetivo deste trabalho foi determinar a potência aeróbia e a capacidade funcional durante a marcha de um paciente portador de lesão medular através da avaliação ergoespirométrica (Beckman - Metabolic Meansura-ment Cart - M.M.C. - OM/11 - LB2).

Paciente de 24 anos, com lesão medular incompleta sensitivo-motora, com nível neurológico C6-C7, foi submetido, durante a marcha, a um estudo comparativo usando uma órtese de reciprocação avançada (ARGO) e uma órtese mecânica convencional (CMO).

A ARGO, assim como a CMO, não garante marcha independente, no entanto, a ARGO possibilitou um padrão de marcha mais funcional com ventilação mais eficiente. A relação CO2/O2, mostrou que a ARGO fornece melhores condições aeróbias de trabalho com gasto energético menor se comparada com a CMO.