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Original Article

Treadmill exercise testing with increasing inclination as exercise protocol for wheelchair athletes

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Study design: Treadmill testing on a progressive incline of 11 wheelchair athletes.
Objective: To determine if a novel treadmill exercise protocol which uses increments in inclination, rather than the standard increments in velocity, can be used to effectively determine maximum oxygen uptake VO_{2max} for elite wheelchair athletes.
Setting: Nottwil, Switzerland.
Methods: Eleven elite wheelchair basketball players (29.3 ± 6.3 years, 72.7 ± 16.9 kg and 177 ± 9.6 cm) performed an exercise protocol with increasing inclination on the treadmill. Eight players had a spinal cord injury (SCI), two had no lesion of the central nervous system and one had poliomyelitis. VO_{2max} and heart rate were measured continuously, while serum lactate was determined immediately after the exercise protocol.
Results: Athletes reached a maximal heart rate of 185 ± 11.4 bpm and maximal lactate of 10.2 ± 2.1 mmol/l. VO_{2max} was 35.1 ± 4.9 ml/min/kg. The correlation between heart rate and VO_2 at different inclinations was statistically significant and comparable to able-bodied subjects.
Conclusions: An exercise protocol with increasing inclination is a valid alternative to an exercise protocol with increasing velocity.
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Keywords: paraplegia; tetraplegia; VO_{2max}; exercise protocol; wheelchair

Introduction

The determination of maximum oxygen uptake (VO_{2max}) is a general indicator of cardiorespiratory fitness of an individual.[1]

Performance in a basketball game is based upon endurance, force, velocity, coordination and mobility. This applies likewise to wheelchair basketball. In order to test training progress and improve training efficacy regular performance testing is indispensable.

In wheelchair athletes, VO_{2max} tests are regularly performed with increasing velocity on a treadmill with consistent inclination until exhaustion of the athlete.[2–5] This principle is also used in able-bodied basketball players.[6]

Basketball players should achieve both high velocity and good endurance in order to play at a high level. Exercise testing for wheelchair basketball players is difficult. Their wheelchair is not constructed to maintain high velocities during a long period of time, but rather for bouts of acceleration and deceleration. In order to simulate acceleration we tested an exercise protocol with constant speed but increasing inclination on the treadmill until the athlete was exhausted. We wanted to know whether the increasing VO_2 during exercise correlates with the increasing heart rate as it is known in protocols with increasing velocity.

Methods

Subjects
Eleven members of the Swiss national team in wheelchair basketball were tested in the laboratory of the Institute of Sports Medicine in the Swiss paraplegic center in Nottwil. Eight had a spinal cord injury (one with a tetraplegia, seven with a paraplegia), one had poliomyelitis, one an amputated leg and one an injury at the knee with instability. The twelfth team member had to be excluded

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Table 1 The athletes

Athlete	*Classification according ISMGF*	*Classification according ASIA*	*Level of lesion*	*Age* (years)	*Weight* (kg)	*Height* (cm)
1	3	C	L 2*	41	65	182
2	2.5	D	C 5*	21	84	193
3	2	A	Th 7	38	62	176
4	4.5		a	27	69.5	178
5	1	A	Th 7	27	80	180
6	1	A	Th 5	33	64	171
7	4.5		b	28	110	183
8	2	B	Th 12*	28	62	174
9	1	D	Th 4	29	85	186
10	3.5	C	Th 12*	31	74	176
11	3		c	20	45	155
Average	2.54			29.3	72.7	177.6
Standard deviation	1.23			6.3	16.9	9.6

ISMGF, International Stoke Mandeville Game Federation; ASIA, American Spinal Injury Association; *, incomplete lesion; a, pedestrian with knee injury; b, athlete with amputation of the upper limb left; c, athlete with poliomyelitis

because of a recent fracture of the hip. Table 1 shows anthropometric data of the athletes.

Exercise protocol

The athletes performed the test with their own sports wheelchairs. The wheelchairs of some of the athletes were too wide for the treadmill, in which case they had to use their wheelchairs for daily life. After the athletes arrived in the laboratory, the wheelchair was fixed to the treadmill (Saturn, HP Cosmos, München, Germany) with a mobile lever arm so that the athlete could not fall from the treadmill. Ventilation (VE), oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were measured continuously with an open circuit spirometry system (Oxycon Alpha, Mijnhardt BV, Bunnik, Netherlands) throughout the exercise. Concentration of gas and volume were calibrated before every test. Heart rates were recorded with a Sporttester (Polar 4000, Polar Electro, OY, Kempele, Finland) every 5 s during the test. At rest and at cessation of the exercise arterialized blood samples were taken with capillary tubes from the hyperemic earlobe. Concentration of lactate was measured by an enzymatic method (Super GL Ambulance, Ruhrtal Labor Technik, Möhnesee, Germany). Exercise protocol started at a speed of 8 km/h and an inclination of 1%. Every 2 min inclination increased by 0.5% and speed remained at 8 km/h. At the end of each step, heart rate and VO_2 were noted. Athletes were encouraged to continue until exhaustion.

Statistical methods

All metabolic parameters were tested by non-parametric tests for differences between the subgroup of team members with SCI and the ones without SCI. A linear regression was fitted to the heart rate and VO_2 of each grade.

Results

The individual physiological characteristics of the athletes are summarized in Table 2. At a maximal inclination of $4.13 \pm 0.83\%$ (range 3% to 5.5%) they finished the exercise protocol with a VO_{2max} of 35.1 ± 4.9 ml/min/kg (range 25.8% to 40.4%). The linear correlation between increasing heart rate and increasing oxygen consumption revealed high statistical significance and is shown in Figure 2. According to a Kruskal-Wallis one way analysis of variance, team members with SCI reached significantly higher lactate concentrations at cessation than team members without SCI (Figure 1). For all other physiological parameters there was no difference between the two subgroups.

Discussion

A wheelchair basketball team is composed of five field players and at most seven substitutes. The players have different physical handicaps for which they get points

Table 2 Values at cessation of the test

Athlete	VO_{2max} (ml/min/kg)	*Lactate* (mmol/l)	*Inclination* (%)
1	38.3	10.20	4
2	33.3	8.44	4
3	37.2	12.40	5
4	38.9	9.39	5.5
5	31.0	9.58	3
6	35.0	10.50	3.5
7	28.2	8.35	3.5
8	40	14.00	5
9	28.5	9.79	3.5
10	40.4	12.9	5.5
11	38.4	6.91	3.5
Average	35.1	10.2	4.13
Standard deviation	4.9	2.1	0.83

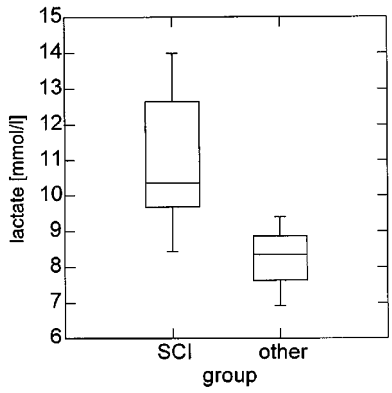

Figure 1 Lactate at cessation in SCI and others

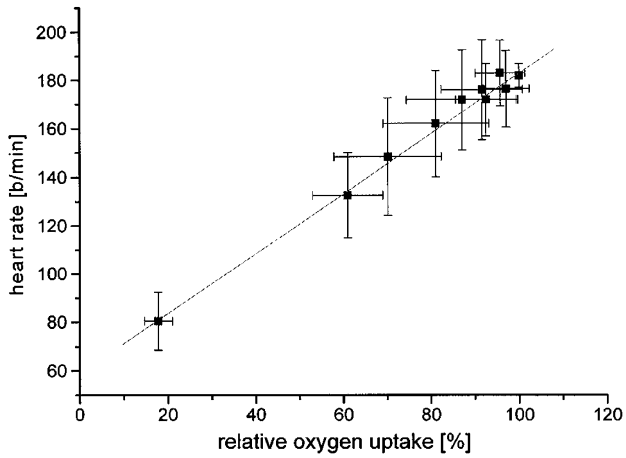

Figure 2 Correlation of heart rate and VO_2 during increasing intensity

according to severity. The five field players of a wheelchair basketball team can have at maximum 14.5 points. As long as this number of handicap points is not exceeded single players can also have no handicap at all. This system makes it possible for athletes with a wide range of physical handicaps to play together.

A criterion for testing physical exhaustion in an exercise test is the lactate concentration at cessation of the test. Athletes should reach at least 10 mmol/l.[7] Our athletes reached a lactate of 10.2 ± 2.1 mmol/l (Table 2). Studies measuring lactate concentrations after maximal exercise in athletes with SCI reached values of about 11 mol/l.[2,8,9] In our study the team members with SCI reached significantly higher lactate concentrations than the team members who do not use a wheelchair in daily life (Figure 1). It seems that the players of our team who do not use a wheelchair on a regular basis are unable to reach their physical limitations by means of an exercise test using wheelchair propulsion.

VO_{2max} is the classical variable in the field of exercise physiology to indicate the cardiorespiratory fitness of athletes.[1] The correct determination of VO_{2max} requires a maximum degree of exertion. An incremental exercise test for wheelchair athletes can be performed on an ergometer with armcranking,[10,11] on a treadmill with increasing velocity,[12] with increasing resistance[4,13] or increasing inclination and increasing velocity.[14]

Our athletes reached a VO_{2max} of 35.1 ± 4.9 ml/min/kg (Table 2). This agrees with results of other studies, where wheelchair athletes reached a VO_{2max} of 30–40 ml/min/kg in exercise protocols with increasing velocity[2,3] or increasing resistance.[4,13] Only highly trained endurance wheelchair athletes can reach a VO_{2max} of more than 50 ml/min/kg,[15] as opposed to able bodied athletes who reach VO_{2max} values of 75 to 85 ml/min/kg due to the larger muscle mass actively involved.[16]

Injury to the spinal cord leading to a complete or incomplete lesion affects the circulatory system.[17,18] SCI people with a lesion above T4 have a loss of the sympathetic control of the heart, in which case heart rate can not rise above 130 bpm.[4,8] In people with lesions below T4, heart rate can rise normally during physical exercise.[17,19] At maximal exercise, everyone has to sustain an adequate cardiac output in order to reach VO_{2max}. In SCI, the components of cardiac output, heart rate and stroke volume, are modified.[20] The loss of the sympathetic control below the level of injury limits vasoconstriction in inactive tissues allowing the mean blood pressure to fall and blood to pool in the lower limbs. The venous return is decreased and this leads to a lower end-diastolic volume and stroke volume. As shown in Figure 2, in our athletes heart rate and oxygen consumption rose consistently with increasing intensity. Of our 11 athletes, only one athlete had a lesion above T4 (athlete 2). Because he had an incomplete lesion, his heart rate rose above 130 bpm to reach a maximum of 168 bpm.

The findings of our study show that an exercise protocol for wheelchair athletes with increasing inclination instead of increasing velocity or resistance on a treadmill is a valid alternative to determine VO_{2max}. Increasing inclination is a better approach to simulate acceleration from standing than is an exercise protocol of increasing velocities with a skilfully demanding propulsion technique at high velocities. Since it is recommended to perform the exercise test as closely to the sports activity as possible, wheelchair propulsion is the preferred activity to arm cranking during exercise tests in wheelchair athletes. An exception may be athletes who do not use a wheelchair for every day life activities. In athletes with a lesion below T4 increases in heart rate and VO_2 are linearly correlated during exercise of increasing intensity.

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