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Anthropometric features of wheelchair marathon race competitors with spinal cord injuries

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The anthropometric data of the health check programme in the Oita Wheelchair Marathon Race were analysed. In the past 10 years, a total of 2677 competitors participated in this programme. Age, height, body weight, body fat, lung vital capacity, girth of chest, girth of upper arm, grasping force and power of upper arm were compared between 710 fine competitors and 99 poor competitors. Power of the upper arms and lung vital capacity played a major part in the result of the races. It was suggested that these two factors had major influences on the achievement of this type of sports activity.

Keywords: spinal cord injury; anthropometric features; wheelchair marathon race.

Introduction

Many sports activities today are available for persons with a spinal cord injury. In Japan, tennis and basketball are quite popular among these people. Recently, wheelchair road races have been established nationwide, and many competitors participate in races just like professional athletes.

Most of the rehabilitation professionals encourage disabled persons to maintain physical fitness and prevent the 'disuse syndrome'. We believe that sports activities for the disabled should serve to preserve their residual physical function, and should be designed to prevent any damage caused by careless overwork. Concerning the physical burden of the wheelchair marathon race, Asayama *et al* evaluated the physical fitness of the competitors by examining their oxygen consumption and suggested safety precautions for the race. The number of competitors who received immediate medical treatment in wheelchair marathon races is known to be small. For example, less than five competitors received medical treatment per race in the Oita Wheelchair Marathon Race and nobody required hospitalisation (unpublished report).

The purpose of this study is to pinpoint the features of competitors' bodies which have an influence on the achievement of this sport activity by reviewing all of the personal anthropometric data collected at the Oita Wheelchair Marathon Race held in the past 10 years.

Methods and materials

The Oita Wheelchair Marathon Race has been held every year since 1981, and is known as the biggest road race for the disabled in Japan. It is divided into two races according to distance, the full marathon being 42.195 km and the half marathon being 21.095 km. The author's department has conducted the health check programme for the competitors every year. Subjects of this study were 2,677 wheelchair bound competitors who took part in this programme between 1983 and 1992.

In the health check programme, the following anthropometric data were recorded: age, height, body weight, body fat, lung vital capacity, girth of chest, girth of upper arm, grasping force, and muscle power of upper arm.

Wilson's formula was adopted to get the percent of body fat by measuring skinfolds at triceps, subscapula and suprailium.[2] Lung vital capacity was measured on the wheelchair by using a portable spirometer (Autospiro AS-500, Minato Medical Science). The maximum circumference of the upper arm was adopted for analysis. Grasping force of both hands was measured, and the larger side was defined as the dominant side. We evaluated the muscle power of the upper arm by using a Bullworker-type instrument containing a steel spring: participants pull and push it, and the mean of both measurements was adopted for analysis.

In order to clarify the physical character of the wheelchair marathon competititors, personal records were compared between competitors who completed the full marathon and competitors who dropped out of the half marathon. The author termed the former group 'fine racers group', and the latter group 'poor racers group' for convenience. The records were compared in every annual race taking into account the differences of race conditions such as weather, temperature or condition of the road. In the past 10 annual races, six were considered to contain a sufficient number of

Table I Comparison of anthropometric measurements between fine racers group and poor racers group (I)

Date of race	Fine racers group	Poor racers group	
	Age (years)		
83	33.5 ± 6.9 (n = 31)	37.8 ± 9.0 (n = 12)	NS
86	32.4 ± 7.8 (n = 70)	34.6 ± 11.3 (n = 9)	NS
88	32.5 ± 6.8 (n = 93)	30.5 ± 6.7 (n = 12)	NS
90	33.9 ± 8.4 (n = 158)	31.5 ± 9.2 (n = 37)	NS
91	33.9 ± 2.8 (n = 158)	30.9 ± 12.4 (n = 12)	NS
92	35.2 ± 8.0 (n = 160)	28.8 ± 10.9 (n = 15)	$p < 0.05$
	Height (cm)		
83	170.4 ± 6.3 (n = 30)	165.3 ± 5.5 (n = 13)	$p < 0.01$
86	168.4 ± 10.4 (n = 70)	167.4 ± 8.4 (n = 10)	NS
88	170.4 ± 8.2 (n = 85)	168.2 ± 6.6 (n = 10)	NS
90	169.5 ± 11.2 (n = 181)	164.8 ± 10.4 (n = 37)	$p < 0.01$
91	169.4 ± 9.3 (n = 149)	164.7 ± 9.5 (n = 11)	NS
92	168.8 ± 8.8 (n = 145)	157.0 ± 11.8 (n = 13)	$p < 0.01$
	Body weight (kg)		
83	56.9 ± 7.5 (n = 31)	55.4 ± 10.3 (n = 13)	NS
86	57.7 ± 9.1 (n = 70)	56.8 ± 6.6 (n = 10)	NS
88	59.2 ± 11.2 (n = 89)	60.8 ± 13.9 (n = 11)	NS
90	59.0 ± 9.5 (n = 183)	57.6 ± 9.5 (n = 35)	NS
91	58.5 ± 9.9 (n = 156)	54.6 ± 10.0 (n = 11)	NS
92	58.6 ± 8.7 (n = 148)	56.5 ± 13.7 (n = 14)	NS
	Body fat (%)		
83	18.3 ± 4.7 (n = 31)	18.1 ± 4.7 (n = 13)	NS
86	17.6 ± 5.0 (n = 70)	15.6 ± 4.2 (n = 8)	NS
88	17.8 ± 4.4 (n = 93)	16.7 ± 5.3 (n = 12)	NS
90	18.2 ± 4.5 (n = 192)	19.7 ± 6.4 (n = 31)	NS
91	18.0 ± 5.2 (n = 157)	16.8 ± 7.4 (n = 12)	NS
92	18.7 ± 4.3 (n = 157)	23.7 ± 8.8 (n = 15)	$p < 0.05$
	Lung vital capacity (ml)		
83	4325.0 ± 813.5 (n = 32)	3346.2 ± 642.4 (n = 13)	$p < 0.01$
86	3829.6 ± 949.2 (n = 71)	3088.9 ± 631.8 (n = 9)	$p < 0.01$
88	3812.5 ± 854.0 (n = 93)	3358.3 ± 1063.3 (n = 12)	NS
90	4069.6 ± 846.9 (n = 196)	3287.8 ± 896.9 (n = 36)	$p < 0.01$
91	4085.1 ± 2707.4 (n = 158)	3140.8 ± 570.5 (n = 12)	$p < 0.01$
92	3932.0 ± 850.6 (n = 157)	2611.3 ± 669.8 (n = 15)	$p < 0.01$

subjects for comparison. Finally, 710 fine racers and 99 poor racers were analysed in this study.

Statistical methods
Values were reported as the mean ± 1 standard deviation (SD). The statistical analysis of the data was performed by using Student's t test and the chi square test. Results were considered significant when $p < 0.05$.

Results

The results of comparison in each measurement are presented in Tables I and II.

The ratio (i.e. the number of races which showed a statistical difference: 6 years) was as follows: muscle power of upper arm 6:6; lung vital capacity 5:6; girth of chest 4:6; girth of upper arm 4:6; grasping force of dominant hand 3:6; height 3:6; age 1:6; body fat 1:6; body weight 0:6.

Discussion

The contribution of each factor to wheelchair marathon races is indicated by the ratio, i.e. the number of races which showed statistical differences: 6 years. Muscle power of upper arm showed the largest contribution. Because the method of evaluating this factor was relatively rough, being conducted briefly for a large population, it was not clear which muscles on the shoulder girdle were included in 'muscle power of upper arm'. The only fact that could be determined was that the muscle power which pushed the wheelchair forward had the

Table II Comparison of anthropometric measurements between fine racers group and poor racers group (II)

Date of race	Fine racers group	Poor racers group	
	Girth of chest (cm)		
83	97.5 ± 5.3 (n = 32)	90.7 ± 5.8 (n = 13)	$p < 0.01$
86	96.1 ± 6.7 (n = 71)	90.4 ± 5.3 (n = 9)	$p < 0.01$
88	97.9 ± 6.5 (n = 93)	94.3 ± 8.7 (n = 12)	NS
90	98.0 ± 7.4 (n = 193)	92.3 ± 8.5 (n = 36)	$p < 0.01$
91	98.7 ± 6.7 (n = 157)	82.9 ± 26.0 (n = 12)	$p < 0.05$
92	97.7 ± 7.2 (n = 157)	93.6 ± 9.4 (n = 15)	NS
	Girth of upper arm (cm)		
83	32.0 ± 2.9 (n = 31)	28.2 ± 2.3 (n = 13)	$p < 0.01$
86	30.0 ± 2.7 (n = 71)	27.6 ± 3.6 (n = 9)	$p < 0.05$
88	31.3 ± 2.6 (n = 93)	29.0 ± 3.5 (n = 12)	$p < 0.05$
90	28.5 ± 8.1 (n = 193)	28.0 ± 5.4 (n = 35)	NS
91	31.3 ± 2.8 (n = 158)	26.5 ± 7.4 (n = 12)	$p < 0.01$
92	31.3 ± 3.2 (n = 157)	29.6 ± 4.0 (n = 15)	NS
	Grasping force of dominant hand (kg)		
83	56.0 ± 7.9 (n = 31)	48.4 ± 14.1 (n = 13)	NS
86	47.2 ± 15.0 (n = 71)	38.9 ± 17.2 (n = 9)	NS
88	51.9 ± 13.2 (n = 93)	45.3 ± 17.5 (n = 12)	NS
90	51.2 ± 13.4 (n = 193)	33.6 ± 17.8 (n = 36)	$p < 0.01$
91	50.9 ± 12.2 (n = 158)	28.2 ± 21.9 (n = 12)	$p < 0.01$
92	51.1 ± 10.2 (n = 157)	36.4 ± 16.3 (n = 15)	$p < 0.01$
	Muscle power of upper arm (kg)		
83	24.3 ± 3.7 (n = 31)	20.7 ± 5.7 (n = 13)	$p < 0.05$
86	43.7 ± 12.1 (n = 71)	24.3 ± 11.9 (n = 9)	$p < 0.01$
88	41.5 ± 12.4 (n = 93)	33.0 ± 13.2 (n = 12)	$p < 0.05$
90	43.6 ± 12.5 (n = 193)	26.6 ± 12.2 (n = 36)	$p < 0.01$
91	43.9 ± 12.0 (n = 158)	22.1 ± 14.7 (n = 12)	$p < 0.01$
92	42.0 ± 25.9 (n = 157)	20.8 ± 24.9 (n = 15)	$p < 0.01$

largest contribution. The author considered that the deltoid was the largest contributor to this factor with trained competitiors, which corresponds with another study we conducted using surface EMG (Fig 1). Because the paralytic level of competitors ranged from cervical to cauda equina, the possibility that the poor racers group had been occupied mostly by quadriplegic athletes remained. Table III shows the number of competitors with quadriplegia in each race. Half of the six races did not show the predominance of quadriplegia in the poor racers group; however, some consideration for those with quadriplegia is desirable so as not to discourage them from participating in this sport. The Oita Wheelchair Marathon Race prepares a classified commendation to solve this issue.

Lung vital capacity showed the second largest contribution. This maintains muscle power and activates the cardiovascular system, indicating that muscle power and lung vital capacity are as essential to the wheelchair marathon athlete as an engine and oil are to a car.

The cardiovascular state (blood pressure and heart rate) before the races are compared (Table IV). The number of evaluated races is relatively small, however, and no significant difference can be found between the two groups. Asayama *et al* used the memory box to obtain the heart rate during the race and found that the elite competitors

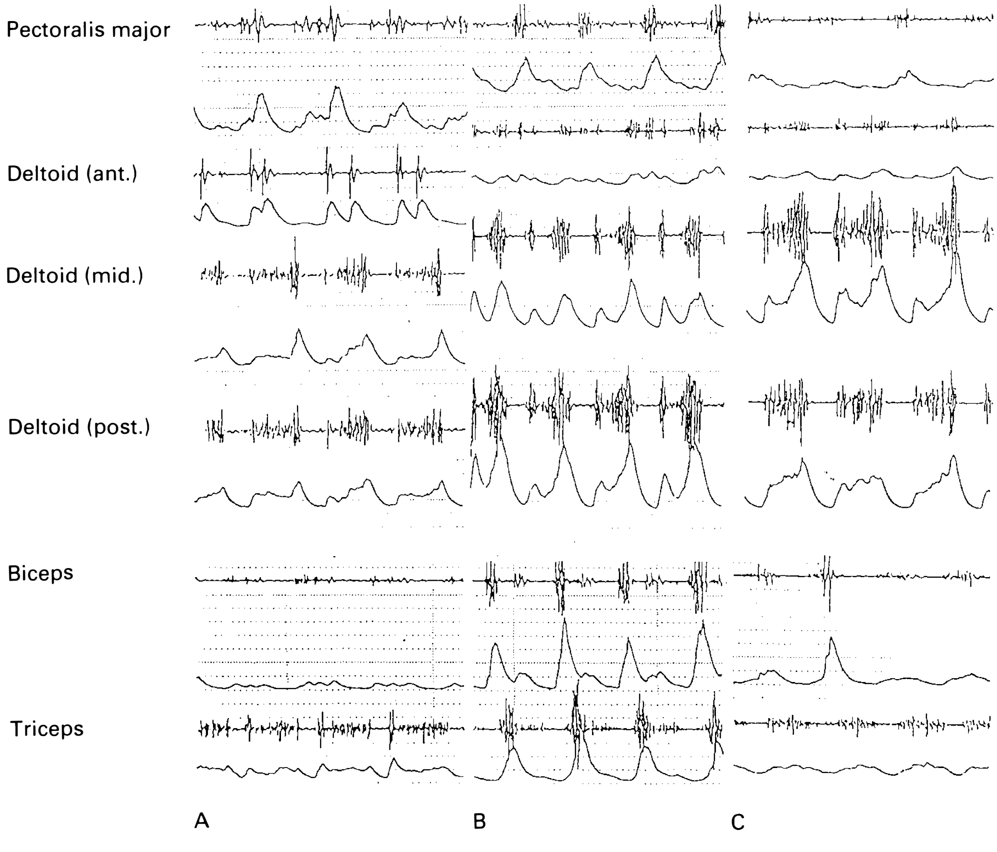

Figure 1 Surface EMG record with three competitors. Subject A = 37 yr male, L1 paraplegia, well trained full marathon competitor. Subject B = 40 yr male, L2 paraplegia, half marathon competitor with little experience. Subject C = 16 yr male, T12 paraplegia, half marathon competitor with little experience. This study was recorded on the wheelchair-treadmill, and all subjects pushed the wheelchairs at the rate of 60 strokes per min.

Table III Comparison of the number of quadriplegic competitors

Date of race	Fine racers group Quadriplegia/Total	Poor racers group Quadriplegia/Total	
83	0/32 (0%)	2/12 (15.4%)	–
86	5/71 (7.0%)	2/10 (20.0%)	NS
88	5/93 (6.5%)	1/12 (8.3%)	NS
90	13/196 (6.6%)	12/37 (32.4%)	$p < 0.01$
91	10/158 (6.3%)	4/12 (33.3%)	$p < 0.01$
92	9/160 (5.6%)	2/15 (13.3%)	NS

Table IV Comparison of the cardiovascular state between fine racers group and poor racers group

Date of race	Fine racers group	Poor racers group	
	Systolic blood pressure (mmHg)		
83	139.2 ± 17.3 (n = 29)	130.2 ± 22.6 (n = 13)	NS
86	131.9 ± 13.6 (n = 62)	129.9 ± 23.8 (n = 9)	NS
91	123.6 ± 17.5 (n = 147)	115.1 ± 30.7 (n = 11)	NS
92	129.3 ± 21.3 (n = 120)	135.8 ± 17.4 (n = 9)	NS
	Diastolic blood pressure (mmHg)		
83	77.9 ± 15.2 (n = 29)	78.5 ± 14.8 (n = 13)	NS
86	77.2 ± 10.0 (n = 62)	77.0 ± 12.4 (n = 9)	NS
91	72.1 ± 11.0 (n = 147)	69.6 ± 21.2 (n = 11)	NS
92	73.9 ± 13.7 (n = 120)	78.0 ± 12.1 (n = 9)	NS
	Heart rate (beat/min)		
91	78.8 ± 12.7 (n = 146)	81.5 ± 18.6 (n = 11)	NS
92	76.4 ± 13.3 (n = 117)	79.8 ± 15.6 (n = 9)	NS

showed high heart rates lasting more than 2 hours.[1] Coutts recorded heart rates of paraplegic athletes during other sport activities and concluded that the average participant in some sport activities would experience an aerobic training effect.[3] The introduction of other measurements, for example echocardiography, will be useful to indicate the cardiovascular state of wheelchair marathon competitors in the static phase.

Contrary to expectation, the contribution of age was quite small. This situation did not appear to agree with our conclusion mentioned above, because aging has a large effect on muscle power and lung vital capacity. Two hypotheses could be indicated: (1) the mechanism of aging in a wheelchair bound population is different from that in an able bodied population; (2) driving wheelchairs in their daily lives activates their general condition and decelerates the aging process. Concerning the latter point, Gass & Camp reported that a significant cardiovascular and metabolic response occurred in highly trained paraplegic men with the evaluation of physical fitness.[4] Okuma *et al* evaluated the transition of the oxygen uptake over several years and concluded that individual training for wheelchair marathon competitors had improved their physical fitness.[5] In paraplegic road racers (10 km distance), Hooker & Wells evaluated the aerobic power of competitors and reported that intense wheelchair propulsion exercise training can enhance upper body cardiopulmonary fitness to levels higher than untrained able bodied persons.[6] However, it has not been revealed whether or not driving wheelchairs in daily life improves physical fitness. Eriksson *et al* described in their report, which compared the disabled group with able bodied individuals, how wheelchair performance is a very specific type of physical work.[7] More studies are undoubtedly needed in order to be certain of these hypostheses.

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