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Transition of Physical Fitness in Wheelchair Marathon Competitors over Several Years

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Summary

Twenty eight stress tests for 14 wheelchair marathon competitors were performed to determine their physical fitness just before the Oita International wheelchair marathon since 1984. All the subjects were wheelchair-bound Japanese males and workers at Sun Industry. Oxygen consumption at the maximal workload was significantly larger than that of non-athletic paraplegics and the mean values were 35·0 ± 4·8 ml/kg in competitors and 22·6 ± 5·0 ml/min/kg in non-athletic paraplegics. Eight competitors had more than 2 stress tests and 6 of them had 3 tests from 1984 to 1987. The oxygen consumption at the maximal workload of their third test was very high (46·5 ± 6·8 ml/min/kg) equal to highly trained paraplegics, and was larger than the result of the first test significantly. Their physical fitness was reduced significantly during the off season, however their physical fitness was maintained at a satisfactory higher level than that of non-athletes. This study demonstrated that individual training for wheelchair marathoners had improved the competitors' physical fitness over several years.
Key words: *Wheelchair sports; Physical fitness; Paraplegia.*

The first Oita International Wheelchair Marathon was held in Oita prefecture in Japan in 1981, the physical fitness of paraplegics during the race was evaluated and in the following years the same studies were made on the competitors of wheelchair marathoners who were thought to have the best chance of finishing at the top of the race (Asayama, *et al.*, 1984, 1985). Since the fourth meeting in 1984, we have been studying the physical fitness of ordinary Japanese competitors, workers of Sun Industry in Oita prefecture. They were not trained but were regular participants of the wheelchair marathon race. Recently some of them have improved significantly in physical fitness and could achieve good time records in wheelchair marathon racing. In this report the transition of

physical fitness of competitors over several years is presented, including comparison with that of non-athletic paraplegics and the influence of wheelchair sports for 'their' physical fitness is discussed.

Subjects and methods

Twenty eight stress tests for 14 wheelchair marathon competitors were performed to determine their physical fitness in well trained condition from 1984 to 1987. All stress tests were carried out within a week just before the fourth to seventh Oita international wheelchair marathon races. Eight competitors had more than 2 stress tests and 6 of them had 3 tests and the other 6 had only 1.

All competitors in this study were Japanese males and workers at Sun Industry in Oita prefecture, Japan. Sun Industry is a unique institution for the disabled, and consists of factories for large Japanese enterprises such as Sony and Honda with common accommodations for disabled workers, established by the late Dr Yutaka Nakamura in 1975. The competitors for this study consisted of 10 paraplegic patients with spinal cord injuries (T7–L1); 2 had had polyomyelitis, 1 patient had a bilateral above knee amputation, and 1 had cerebral palsy. Their mean age was 30·8 ± 6·7 years.

We performed another two different series of stress tests as a control study. One was done for 7 non-athletic paraplegics due to spinal cord injury (T4–L3) just before the seventh Oita international wheelchair marathon race in November 1987. These paraplegics were all Japanese males and workers at Sun Industry and their mean age was 31·4 ± 8·0 years. They did not play any sports in their daily life, and had no physical problems except their spinal dysfunction. The other control study was carried out on the 6 competitors in March 1988, off season for the wheelchair marathon. These competitors also had stress tests just before the seventh Oita international wheelchair marathon on November 1987. It enabled us to compare their physical fitness just before the race with that of the off season.

All the stress tests were performed at the gym at Sun industry. After 13 minutes rest on the wheelchair, each subject was requested to drive the wheelchair on the treadmill at the speed of 60 m per minute. The grade was subsequently increased by 1 degree every 4 minutes first from 2 degrees up to the maximal degree until each subject could not drive his wheelchair with his maximal effort. The expired gas was collected in a Douglas bag during the final minute of each grade. O_2 and CO_2 content were analysed with a gas analyser (1H21A,NEC-Scan). Heart rate was monitored continuously using telemetric ECG equipment. Blood pressure was also measured and blood samples were taken from the earlobe immediately after each grade of workload to determine serum lactate concentration.

Routine physical characteristics, body height, weight, body fat(%), vital capacity, chest girth, upper arm girth and grasping force were also measured. Body fat(%) was calculated using the formula of Wilson *et al.* (1981) by measuring the skin fold at the triceps, subscapula and suprailium.

Results

Comparison of physical fitness of competitors with that of non-athletic paraplegics

Eight of 14 competitors had more than 2 stress tests, so the data of the first test was used for comparison with non-athletic paraplegics. Physical characteristics of competitors and non-athletic paraplegics are shown in Table I. There was no significant difference except body fat(%) and chest girth.

The mean values of the peak heart rate (PeakHR), the peak serum lactic acid (PeakLACTATE) and the peak oxygen consumption (PeakVO_2) of 14 competitors and 7 non-athletic paraplegics at maximal workload are shown in Table II. Oxygen consumption at onset of blood lactate accumulation ($\dot{V}O_{2OBLA}$) was shown in the same table. OBLA means the point where the serum lactic acid exceeded 4 mmoles/1. (Kindermann *et al.*, 1979). There was no remarkable difference in PeakHR and PeakLACTATE between the two groups, and these values were high enough to evaluate maximal oxygen consumption ($\dot{V}O_{2max}$). PeakV/O ($=\dot{V}O_{2max}$) and $\dot{V}O_{2OBLA}$ were significantly larger in competitors than in non-athletic paraplegics ($p < 0{\cdot}01$).

The transition of physical fitness of competitors over several years

Eight competitors carried out more than 2 stress tests from 1984 to 1987, and 6 of them had 3 tests. There was no remarkable change in their physical characteristics. Mean values of PeakHR, PeakLACTATE, peakV/O_2 and $\dot{V}O_{2OBLA}$ were shown in Table III. There was no significant difference in their PeakHR and PeakLACTATE. Peak V/O_2 had increased significantly between the first and the third stress tests ($p < 0{\cdot}01$) and $\dot{V}O_{2OBLA}$ had increased also ($p < 0{\cdot}05$).

Comparison of physical fitness just before the race with that of the off season. The physical fitness of 6 competitors just before the seventh race in November 1987 was compared with that of them during the off season in March 1988. There was no remarkable difference in PeakHR and PeakLACTATE. PeakV/O_2 during the off season was reduced significantly ($p < 0{\cdot}05$), but still maintained at a higher level than that of non-athletic paraplegics ($p < 0{\cdot}01$).

Discussion

This study demonstrated that individual training for wheelchair marathoners had improved the physical fitness of competitors over several years. This conclusion was supported by the following results. (1) PeakV/O_2 and $\dot{V}O_{2OBLA}$ of the competitors was superior to those of non-athletic paraplegics. (2) PeakV/O_2 and $\dot{V}O_{2OBLA}$ of competitors has improved over several years. (3) PeakV/O_2 of competitors was reduced during the off season. There are a lot of reports concerning the effects of training on the improvement of physical fitness of subjects (Saltin *et al.* 1968; Ekblom *et al.*, 1968; Taylor *et al.*, 1986). Two significant differences appear in our study. The first is that all the subjects of this study were workers of Sun Industry, so the conditions of their daily life and life cycles were very similar to each other in such circumstance. The second difference is that subjects were not trained athletes but ordinary Japanese males with paraplegia and

Table I Physical characteristics of wheelchair marathon competitors and non-athletic paraplegics

	Age (years)	Height (cm)	Weight (kg)	Body fat (%)	Vital capacity (cc)	Chest girth (cm)	Upper arm girth (cm)	Grasping force (kg)
Competitors (n = 14)	30·8 ±6·7	164·6 ±6·9	51·8 ±10·7	13·7 ±5·5	3705·7 ±750·2	89·9 ±5·6	29·1 ±4·3	50·5 ±7·0
Non-athletic paraplegics (n = 7)	31·4 ±8·0	166·4 ±5·0	59·3 ±14·0	22·6** ±4·2	3728·6 ±940·5	96·2* ±6·6	29·4 ±2·5	50·2 ±6·3

* $p < 0.05$, ** $p < 0.01$ indicating significant difference between the wheelchair marathon competitors and non-athletic paraplegics. All other unmarked values were not significant at the 0.05 level.

Table II Comparison of physical fitness of wheelchair marathon competitors with that of non-athletic paraplegics

	Number	Peak HR (mean ± SD beats/min)	Peak Lactate (mean ± SD mmoles/l)	Peak $\dot{V}/O_2$ (mean ± SD l/min)	Peak $\dot{V}/O_2$ (mean ± SD ml/min/kg)	$\dot{V}O_{2OBLA}$ (mean ± SD ml/min/kg)
Competitors	14	174·5 ± 17·7	7·9 ± 2·4	1·80 ± 0·36	35·0 ± 4·8	28·6 ± 5·9
Non-athletic paraplegics	7	179·3 ± 20.0	8·0 ± 1.7	1·32 ± 0.26**	22·6 ± 5·0**	16·5 ± 3·5**

** $p < 0.01$ indicating significant difference between the wheelchair marathon competitors and non-athletic paraplegics. All other unmarked values were not significant at the 0·05 level.

Table III The transition of physical fitness of wheelchair marathon competitors over several years

	Number	Peak HR (mean ± SD beats/min)	Peak Lactate (mean ± SD mmoles/l)	Peak $\dot{V}/O_2$ (mean ± SD l/min)	Peak $\dot{V}/O_2$ (mean ± SD ml/min/kg)	$\dot{V}O_{2OBLA}$ (mean ± SD ml/min/kg)
Result of the first stress test	8	179·3 ± 18·5	7·9 ± 2·5	1·84 ± 0·32	35·2 ± 3·7	29·2 ± 2·9
Result of the second stress test	8	170·6 ± 11.1	7·7 ± 2.7	2·00 ± 0·55	37·7 ± 6.3	30·0 ± 5.9
Result of the third stress test	8	169·2 ± 20·4	7·0 ± 1·4	2·44 ± 0·34**	46·5 ± 6·8**	37·9 ± 8·0*

* $p < 0.05$, ** $p < 0.01$ indicating a significant difference between the result of the first stress test and that of the third one. All other unmarked values were not significant at the 0·05 level.

their training in wheelchair sports was performed voluntarily as a kind of recreation and not planned especially for experimental study, so the result of this study actually reflects the influence of wheelchair sports in the daily life of disabled people.

We used two kinds of characteristics to evaluate the physical fitness of subjects. One was peak oxygen consumption (Peak V/O_2 which was obtained at the maximal treadmill work load. The other was oxygen consumption at onset of blood lactate accumulation($\dot{V}O_{2OBLA}$). Astrand stated in his textbook (1977), two conditions to determine maximal oxygen consumption ($\dot{V}O_{2max}$). One was no increase in oxygen consumption in spite of the increased workload, the other

was the serum lactic acid concentration exceeding 8 mmoles/l. The mean value of peak serum lactic acid concentration in this study was about 8 mmoles/l, and their peak heart rate attained to quite high level (Astrand and Rodahl 1977; Rowell *et al.* 1964). So the Peak V/O_2 of this study seems to be very similar to $\dot{V}O_{2max}$. Aerobic-anaerobic threshold was also used for evaluation of capacity of aerobic energy metabolism with submaximal workload. Aerobic-anaerobic threshold means the transitional point from aerobic to anaerobic energy metabolism in muscle (Skinner and Mclellan, 1980). In our study, the point of 4 mmols/l of the serum lactic acid concentration was used to determine the aerobic-anaerobic threshold. This point is called onset of blood lactate accumulation (OBLA), and it is useful to determine clinically the aerobic-anaerobic threshold (Kindermann *et al.* 1979; Sjodin *et al.* 1981; Komi *et al.* 1981).

The physical fitness of competitors in our study was markedly superior to that of non-athletic paraplegics. These subjects in both groups were under similar circumstances at Sun Industry, and of course their ADL was independent. There is no significant difference in their physical characteristics except body fat and chest girth in both groups. The mean values of oxygen consumption at the maximal workload (PeakV/O_2) were 35·0 ± 4·8 ml/min/kg in competitors and 22·6 ± 5·0 ml/min/kg in non-athletic paraplegics. Pollock (1977) reported mean value of maximal oxygen consumption of elite marathon runners was 74·1 ± 2·6 ml/min/kg. The subjects of our study were not highly trained but ordinary Japanese paraplegic males. The mean value of $\dot{V}O_{2max}$ of able Japanese males aged 30 years was about 50 ml/min/kg. When exercise was performed by the arm only, $\dot{V}O_{2max}$ remains low in spite of increased heart rate, $\dot{V}O_{2max}$ in arm work at maximal effort was lower at about 20–60% than in leg exercises (Asmussen and Hemmingsen, 1958; Bar-Or and Zwiren, 1975; Davies and Sargeant, 1974; Vokac *et al.*, 1975). Considering these reports, the competitors in this study seem to have good physical fitness in their arm exercises, however physical fitness of non-athletic paraplegics seems to be rather low. Hjeltness *et al.* (1979) Clarke (1966) reported that the amount of activity of general paraplegics were very low. Saltin *et al.* (1968) reported that $\dot{V}O_{2max}$ of healthy volunteers had reduced significantly after 3 weeks' bed rest. Wheelchair sports seems to be very useful for the wheelchair-bound disabled to increase their daily activities. Asayama (1984, 1985) measured the heart rate of competitors during races at the Oita International Wheelchair Marathon, and stated that the competitors had maintained an extremely high heart rate during the entire race so the wheelchair marathons were very good for improving their endurance.

Peak V/O_2 of competitors increased significantly over the 3 stress tests for several years, also $\dot{V}O_{2OBLA}$ increased. There are many reports about the improvement of $\dot{V}O_{2max}$ and aerobic-anaerobic threshold after experimental aerobic training (Ekblom *et al.* 1968; Saltin *et al.*, 1968; Davis *et al.*, 1979; Taylor *et al.*, 1986). Pollock *et al.*, (1987) reported that aerobic training had prevented the decline of $\dot{V}O_{2max}$ due to ageing after 10 years follow-up. Such improvement of aerobic capacity is accompanied by many changes in the circulation system and in the activated muscles (Saltin *et al.*, 1968; Karlsson *et al.*, 1972; Ingjer, 1979; Ivy *et al.*, 1980; Sjodin *et al.*, 1981). Mean value of Peak V/O_2 of the third stress test was 46·5 ml/min/kg, which was very high and was equal to highly

Table IV Comparison of physical fitness of competitors just before the wheelchair marathon race with that during the off season

	Number	Peak HR (mean ± SD beats/min)	Peak Lactate (mean ± SD mmoles/l)	Peak $\dot{V}/O_2$ (mean ± SD l/min)	Peak $\dot{V}/O_2$ (mean ± SD ml/min/kg)	$\dot{V}O_{2OBLA}$ (mean ± SD ml/min/kg)
Just before the race	6	167·2 ± 18·6	8·3 ± 1·8	2·49 ± 0·54	43·6 ± 10·8	31·1 ± 11·5
During the off season	6	166·2 ± 16.2	9·0 ± 1.0	2·04 ± 0·38**	35·7 ± 6.9*	26·6 ± 5.2

* $p < 0·05$, ** $p < 0·01$ indicating significant difference between just before the race and during the off season. All other unmarked values were not significant at the 0·05 level.

trained paraplegics reported by Gass *et al.* (1987). Table IV shows the goal times at the Oita international wheelchair marathon after the fourth meeting. The time records of almost all competitors improved gradually and some of them became good athletes, who had been ordinary participants of wheelchair marathons some years ago. It seems to be affected by the satisfactory results of their physical fitness. The training of wheelchair marathoners start about 2 months before racing. Recently some of them are inclined to adapt themselves to well planned training, including aerobic training and weight training. The amount of training for wheelchair marathoners is surely increasing. During the off seasons almost all competitors play other wheelchair sports such as basketball or tennisball periodically which is good for their physical conditioning though their heart rate does not attain such high levels as in wheelchair marathon racing (Asayama *et al.*, 1985; Coutts, 1988). During the off season, physical fitness of competitors was reduced significantly because of a decrease in endurance training, but their physical fitness was still maintained at a higher level than that of non-athletic paraplegics.

Conclusions

This study demonstrated that the individual training for wheelchair marathoners had improved the physical fitness of competitors over several years.

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