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Paraplegia

Exercise Capacity of Untrained Spinal Cord Injured Individuals and the Relationship of Peak Oxygen Uptake to Level of Injury

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Summary

Twenty spinal cord injured individuals were tested for maximal oxygen uptake ($\dot{V}O_{2\ peak}$ using a hysteresis brake wheelchair ergometer. The subjects were divided into 4 groups as follows: (a) quadriplegics (4 subjects); (b) untrained female paraplegics (5 subjects); (c) untrained male paraplegics (7 subjects); and (d) trained male paraplegics (4 subjects). The $\dot{V}O_{2\ peak}$ were analysed by a one way ANOVA and Fisher's LSD multiple comparisons. The F-ratio (50·93) was significant ($p = < 0{\cdot}0001$). Fisher's LSD post hoc multiple comparisons found the following differences: (a) quadriplegics were significantly lower than the untrained paraplegic females, untrained paraplegic males and trained paraplegic males; (b) untrained females were significantly lower than the untrained male paraplegics, and trained paraplegic males; (c) untrained paraplegic males were significantly lower than the trained male paraplegics. A Spearman Rho correlation was calculated using injury level and $\dot{V}O_{2\ max}$ for all the untrained SCI individuals. The correlation was 0·68 and had a significance level of 0·0019. The present study combined with the known research literature gives strong evidence that $\dot{V}O_{2\ peak}$ in the untrained SCI is highly related to level of injury.
Key words: *Exercise; Female paraplegic; Male paraplegic; Quadriplegic; Maximum oxygen uptake.*

The continuing fitness boom in this country has reached beyond the average American and is starting to affect many different populations, including the spinal cord injured (SCI) individual. In conjunction with the increased exercise participation of the SCI individual the demand for physiological data and better understanding of their response and adaptation to exercise has also risen. Physiological deterioration, including bone and muscle atrophy, poor myocardial function, and a general decline in physical fitness often accompanies SCI wheelchair users (Geissler *et al.*, 1977; Hrubec and Ryder, 1980; Le and Price 1982). It has been demonstrated that SCI individual typically exhibit low maximal oxygen

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uptake ($\dot{V}O_{2\,max}$) (Boileau *et al.*, 1981; Cameron *et al.*, 1978; Ekblom and Lundberg, 1968; Wicks *et al.*, 1983), poor cardiac output (Boileau *et al.*, 1981; Stoboy *et al.*, 1971), and low maximal heart rates (Bergh *et al.*, 1976; Ekblom *et al.*, 1968).

Much of the past research on the SCI wheelchair user has concentrated on the male paraplegic athlete (Wicks *et al.*, 1983). Very little information is available concerning the untrained female paraplegic, the untrained male paraplegic and the quadriplegic. (Hooker and Wells, 1989; van der Woude *et al.*, 1989; Wicks *et al.*, 1983). Several researchers (Figoni 1984; Gass and Camp, 1979; Van Loan *et al.*, 1987; and Wicks *et al.*, 1983) have suggested that $\dot{V}O_{2\,max}$ is related to the level of spinal injury, but their data did not show such a relationship.

The purpose of this study was to expand the physiological data base of SCI individuals during maximal exercise. Specifically the investigation focused on: (a) untrained male paraplegics (b) untrained female paraplegics, (c) quadriplegics, and (d) the relationship between level of SCI and $\dot{V}O_{2\,max}$.

Methods and procedures

Subjects

Twenty SCI individuals volunteered to participate in the study. All subjects verbally agreed to participate in the study and signed an informed consent statement. There were 7 female subjects (5 paraplegics, 2 quadriplegics) and 13 male subjects (11 paraplegic, 2 quadriplegic). The level of injury ranged from C4–5 to L2–3. Table I contains subject characteristics and information about the level of injury. Table I is in order of injury with the highest level of injury first and the lowest level of injury last. The subjects were divided into 4 groups as follows: (a) quadriplegics (4 subjects); (b) untrained male paraplegics (7 subjects); (c) untrained female paraplegics (5 subjects); and (d) trained male paraplegics (4 subjects).

Test protocol

A maximal exercise test ($\dot{V}O_{2\,max}$) was conducted using a hysteresis brake wheelchair ergometer specifically developed for testing SCI individuals (Burkett *et al.*, 1987). The test protocol was identical to the one used by Burkett *et al.* (1987).

> 'The continuous test protocol consisted of (a) a 3 minute warm up at 5 mph with minimal resistance, (b) a 1 minute, 5 mph exercise mode with increased resistance, and (c) a 4 minute exercise mode at 5 mph, with resistance increased each minute until exhaustion.' (Burkett *et al.*, pp 68–69).

The 3 minute warm up workload was set by each individual subject. The subject warmed up at a workload that was close to his/her everyday ambulation workload. Maximal workload was achieved between the sixth and eighth minute of exercise which is recommended by Astrand and Rodahl (1986) for efficiency in inducing a maximal (peak) effort. To ensure valid $\dot{V}O_{2\,max}$ data, a super max test was conducted 10 minutes after the first $\dot{V}O_{2\,max}$. The super max protocol consisted of a 2 minute (80% of calculated $\dot{V}O_{2\,max}$) warm up, followed by a 2 minute bout at 120% of the calculated $\dot{V}O_{2\,max}$.

For collection of expired air, the subject breathed through a two-way Danials butterfly valve connected to a mixing chamber. Oxygen (O_2) and carbon dioxide

Table I General characteristics of subjects (modified from APAQ, 1988:5:1)

Subject number	Age	Sex	Wt.	Level of injury	Type of injury	Years since injury
7	23	M	75·0	C4 & 5	Inc. puncture	3
16	32	F	54·5	C6 & 7	Incomplete	5
15	26	M	59·1	C7	Complete	5
12	25	F	52·3	C7	Incomplete	7
17	29	F	55·5	T3 & 4	Inc. comp.	8
20	33	F	50·0	T4	Complete trans.	17
13	22	M	65·9	T5	Inc. comp.	6
4	31	M	59·5	T5 & 6	Inc. hyperext.	8
2	33	M	93·2	T5 & 6	Inc. bruise	11
14	33	M	68·2	T6	Inc. comp.	15
8	30	M	63·6	T7 & 8	Inc. bruise	12
19	21	F	68·2	T9	Complete comp.	4
3	27	M	59·1	T9	Inc. compres.	7
11	38	M	70·5	T10	Comp. bruise	18
18	39	F	54·4	T11 & 12	Complete bru.	8
9	37	M	68·2	T11 & 12	Inc. comp bru	8
1	27	M	65·9	T12	Complete	6
6	36	M	67·7	T12 & L1	Inc. trans	3
5	23	F	50·0	L1 & 2	Incomplete	1
10	33	M	71·3	L2 & 3	Complete	10

Male mean age = 30·46 mean wt = 68·25
Female mean age = 28·85 mean wt = 55·13

(CO_2) were analysed from the mixing chamber by an Applied Electrochemical S–3A O_2 analyser and a Beckman LB–2 CO_2 analyser. Inspired volumes were measured by a Parkinson–Lowan gas meter and converted to expired volume through the haldane transformation. Heart rate was measured by a Burdick FK–5A cardiotachometer. Instruments were interfaced with a Tektronix 4052 computer for online data collection. Data were collected continuously and calculated into 1 minute averages. Instruments were calibrated before each test.

Respiratory exchange ratios (RER) and $\dot{V}O_2$ (ml/kg^{-1}/min^{-1}) were examined at the conclusion of each test to determine if a maximal effort was induced. $\dot{V}_{2\,max}$ was defined as the achievement of one of the following factors: (a) a RER equal to or exceeding 1·12; (b) a plateau in the $\dot{V}O_2$ with an increase in workload; or (c) a difference in $\dot{V}O_2$ of less than 1·5 ml/kg^{-1}/min^{-1} between the maximal and super max tests.

Results

The data for the two exercise tests ($\dot{V}O_{2\,max}$ and super max) are contained in Table II. Super max tests were completed on subjects who were capable of a repeat maximal performance after a 10 minute rest. This excluded a complete super max on several subjects (1, 2, 8, 12, 15, 16, 18, and 20). Subjects 10, 12, 16, and 20 did not reach a RER of 1.12. Subjects 12, 16, and 20 were not able to complete a super max to check the validity of the $\dot{V}O_{2\,max}$ However, these subjects did have $\dot{V}O_2$s for the last 3 minutes of the max test that were within 1·35 ml/kg^{-1}/min^{-1} of each other, therefore a plateau of $\dot{V}O_2$ was achieved. Subjects 12, 16, and 20 would be considered to have reached a peak $\dot{V}O_2$. Subject 10 had a super max that was within 1 ml of his $\dot{V}O_{2\,max}$. Thus all subjects achieved a valid measure of $\dot{V}O_{2\,max}$ or $\dot{V}O_{2\,peak}$ according to the established criteria. As a check of tester reliability, subjects 1 and 2 completed 2 $\dot{V}O_{2\,max}$ tests 1 week apart. The $\dot{V}O_{2\,max}$ values for subject 1 were 29·34 and 29·47 ml/kg^{-1}/min^{-1}. The $\dot{V}O_{2\,max}$ values for subject 2 were 30·42 and 29·53 ml/kg^{-1}/min^{-1}.

Table II Maximal and super maximal data

Subject number	Level of injury	HR M	HR SM	$\dot{V}O_2$ (l/min^{-1}) M	$\dot{V}O_2$ (l/min^{-1}) SM	V_2 M	V_2 SM	RER M	RER SM	$\dot{V}O_2$ (ml/kg^{-1}/min^{-1}) M	$\dot{V}O_2$ (ml/kg^{-1}/min^{-1}) SM
7	C4 & 5	100	100	0·78	0·71	44·55	45·21	1·12	1·13	10·40	9·53
16	C6 & 7	120	NA	0·30	NA	12·18	NA	1·06	NA	5·31	NA
12	C7	130	NA	0·42	NA	18·74	NA	1·01	NA	7·99	NA
15	C7	186	NA	0·70	NA	22·37	NA	1·36	NA	11·89	NA
17	T3 & 4	180	160	0·72	0·57	35·22	27·75	1·19	1·08	13·07	10·32
20	T4	130	NA	0·77	NA	24·30	NA	0·98	NA	15·37	NA
13	T5	198	180	1·45	1·24	44·46	31·00	1·17	1·02	21·96	19·84
4	T5 & 6	175	175	1·41	1·39	46·09	44.22	1·41	1·11	23·75	23·39
2	T5 & 6	164	NA	2·83	NA	84·40	NA	1·23	NA	30·42	NA
14	T6	190	160	1·76	1·56	51·71	40·33	1·13	1·04	25·84	22·71
8	T7 & 8	220	NA	1·45	NA	47·55	NA	1·26	NA	22·81	NA
19	T9	180	140	1·17	1·14	41·75	39·85	1·14	1·17	18·35	17·13
3	T9	190	180	1·43	1·33	68·56	67·54	1·27	1·20	27·37	22·59
11	T10	160	170	1·85	1·82	66·66	69·44	1·49	1·13	26·29	25·87
18	T11 & 12	190	NA	0·82	NA	41·41	NA	1·26	NA	14·83	NA
9	T11 & 12	130	110	1·98	1·94	84·44	69·56	1·25	1·06	29·10	28·48
1	T12	187	NA	1·94	NA	77·92	NA	1·16	NA	29·47	NA
6	T12 & L1	170	170	1·50	1·41	94·27	54·02	1·20	1·24	22·28	20·97
5	L1 & 2	150	150	0·89	0·84	31·22	28·71	1·14	1·00	17·91	16·90
10	L2 & 3	130	120	1·86	1·86	77·73	75·83	1·09	1·08	26·18	26·96

M = max SM = super max

Table III contains information on the data from the 2 exercise tests arranged by groups (quadriplegics, untrained male paraplegics, untrained female paraplegics, trained male paraplegics). The subjects in each group are also arranged by injury level, with the first subject of each group being the highest level injury and the last subject in each group being the lowest level injury. The $\dot{V}O_{2\,max}$ ml/kg^{-1}/min^{-1} data from this table were analysed by a one way ANOVA and Fisher's LSD multiple comparisons; the results appear at the bottom of Table III. The F-ratio (50·93) was significant ($p = < 0·0001$). Fisher's LSD *post hoc* multiple comparisons found the following differences: (a) quadriplegics were significantly lower than the untrained paraplegic females, untrained paraplegic males and trained paraplegic males; (b) untrained females were significantly lower than the untrained male paraplegics, and trained paraplegic males; (c) untrained paraplegic males were significantly lower than the trained male paraplegics. All possible multiple comparisons were significant, thus all groups were significantly different from each other.

A Spearman Rho correlation was calculated using injury level and $\dot{V}O_{2\,max}$ for all the untrained SCI individuals. The correlation was 0·68 and had a significance level of 0·0019. When the trained subjects were included in the correlation the correlation dropped to 0·62, but was still significant ($p = < 0·002$).

Table III Maximal and super maximal data by groups

Subject number	HR M	HR SM	$\dot{V}O_2$ (l/min^{-1}) M	$\dot{V}O_2$ (l/min^{-1}) SM	V_2 M	V_2 SM	RER M	RER SM	VO_2 (ml/kg^{-1}/min^{-1}) M	VO_2 (ml/kg^{-1}/min^{-1}) SM
Quadriplegics										
7	100	100	0·78	0·71	44·55	45·21	1·12	1·13	10·40	9·53
16	120	NA	0·30	NA	12·18	NA	1·06	NA	5·31	NA
12	130	NA	0·42	NA	18·74	NA	1·01	NA	7·99	NA
15	186	NA	0·70	NA	22·37	NA	1·36	NA	11·89	NA
Male paraplegics untrained										
13	198	180	1·45	1·24	44·46	31·00	1·17	1·02	21·96	19·84
4	175	175	1·41	1·39	46·09	44·22	1·41	1·11	23·75	23·39
14	190	160	1·76	1·56	51·71	40·33	1·13	1·04	25·84	22·71
8	220	NA	1·45	NA	47·55	NA	1·26	NA	22·81	NA
3	190	180	1·43	1·33	68·56	67·54	1·27	1·20	27·37	22·59
9	130	110	1·98	1·94	84·44	69·56	1·25	1·06	29·10	28·48
6	170	170	1·50	1·41	94·27	54·02	1·20	1·24	22·28	20·97
Female paraplegics untrained										
17	180	160	0·72	0·57	35·22	27·75	1·19	1·08	13·07	10·32
20	130	NA	0·77	NA	24·30	NA	0·98	NA	15·37	NA
19	180	140	1·17	1·14	41·75	39·85	1·14	1·17	18·35	17·13
18	190	NA	0·82	NA	41·41	NA	1·26	NA	14·83	NA
5	150	150	0·89	0·84	31·22	28·71	1·14	1·00	17·91	16·90
Trained (all male para)										
2	164	NA	2·83	NA	84·40	NA	1·23	NA	30·42	NA
11	160	170	1·85	1·82	66·66	69·44	1·49	1·13	26·29	25·87
1	187	NA	1·94	NA	77·92	NA	1·16	NA	29·47	NA
10	130	120	1·86	1·86	77·73	75·83	1·09	1·08	26·18	26·96

M = max SM = super max

Mean quad $\dot{V}O_{2max}$ = 8·89 (S.D. = 2·88) ml/kg^{-1}/min^{-1}
Mean male para (untrained) $\dot{V}O_{2max}$ = 24·73 (S.D. = 2·76) ml/kg^{-1}/min^{-1}
Mean female para (untrained) $\dot{V}O_{2max}$ = 15·91 (S.D. = 2·18) ml/kg^{-1}/min^{-1}
Mean trained $\dot{V}O_{2max}$ = 28·09 (S.D. = 2·18) ml/kg^{-1}/min^{-1}

Anova table

Source	SS	DF	VAR. EST	F-RATIO	SIGN.
Among	995·25	3	331·75	50·93	0·0001
Within	104·23	16	6·51		
Total	1099·48	19			

Fisher's LSD multiple comparisons matrix of probabilities
(1 = quad, 2 = male para untrained, 3 = female para untrained, 4 = trained)

	1	2	3	4	
1	1·000	0·0001	0·001	0·0001	significant
2		1·000	0·0001	0·046	1 vs. 2, 3, 4
3			1·000	0·0001	2 vs. 3, 4
4				1·000	3 vs. 4

Discussion

There are several inherent problems that occur when an attempt is made to compare research findings on SCI individuals. One problem is how the subjects are grouped. Many investigators have chosen to group all their subjects together because of small subject numbers. It is difficult to compare those data with the present study. Some authors have included information on injury level and supplied individual data as well as mean data, but the practice is not universal. Another problem is the lack of information whether a true peak or not of $\dot{V}O_{2\ max}$ value was attained. The mode of exercise (wheelchair ergometer vs. arm crank ergometer) also influences the peak or $\dot{V}O_{2\ max}$ values attained (Shephard, 1988). The above comments must be considered when comparisons are attempted between studies on SCI wheelchair users.

$\dot{V}O_{2\ peak}$ or $\dot{V}O_{2\ max}$

The small mass of muscle in the arms can cause arm fatigue to limit maximal oxygen uptake tests. Glaser *et al.* (1979) completed research that indicated $\dot{V}O_{2\ max}$ of normal subjects as measured by arm work is about two thirds that achieved with running or cycling. There is evidence that oxygen uptake can be increased in paralysed individuals with arm work and simultaneous electrical stimulation of the legs (Strayer *et al.*, 1985). The term $\dot{V}O_{2\ max}$ has been used up to this point (in the article), however the term peak rather then maximal would be more appropriate to use when describing arm work by SCI subjects to attain $\dot{V}O_2$ data (Shephard, 1988; Franklin, 1985; Coutts *et al.*, 1983). Considering the past research, and the possibility of electrical stimulation to paralysed muscle to increase oxygen uptake, the subjects in this study should be considered to have reached a $\dot{V}O_{2\ peak}$ rather than a $\dot{V}O_{2\ max}$.

Quadriplegics

Wicks *et al.* (1983) reported on 2 trained female quadriplegics. The reported $\dot{V}O_{2\ peak}$ for the 2 subjects were 17·2 and 13·8 ml/kg^{-1}/min^{-1}. Those values are higher than the quadriplegics in the present study, but the subjects of Wicks *et al.* (1983) were trained and a difference would be expected.

Dreisinger *et al.* (1984) measured inactive male quadriplegics using a wheelchair ergometer and reported a mean $\dot{V}O_{2\ max}$ of 0·87 l/min^{-1}. That is higher than was found in this investigation (Table III, mean of 0·55). It is difficult to compare those results with the present data because they did not report the data in ml/kg^{-1}/min^{-1} and no mean weights were reported. Two of the quadriplegics in this study were female and 2 were male. The 2 males in the present study have similar values (0·78 and 0·70) to those reported by Dreisinger *et al.* (1984). It was not possible to determine if the Dreisinger *et al.* (1984) subjects attained a true peak performance since RER data were not reported.

Van Loan *et al.* (1987) found a mean value for $\dot{V}O_{2\ max}$ of 12·0 ml/kg^{-1}/min^{-1} and a RER mean of 0·92 for quadriplegics, versus 8·89 and 1·13 respectively for the present study. Van Loan *et al.* (1987) did not report if the subjects were male or female. The mean age and weight of their quadriplegics were 29·6 years and

62·2 kg which is a good match with the mean age and weight with the subjects in the present study (mean age = 26·5, mean weight = 60·23 kg). The highest $\dot{V}O_{2\,peak}$ found in the present study for a quadriplegic did not reach the mean for the Van Loan *et al.* (1987) study, yet the present study had RER's higher than the Van Loan *et al.* (1987) study. Shephard's review (1988) reported that the arm crank produced higher $\dot{V}O_2$ values than wheelchair ergometers. Since the present study used a wheelchair ergometer and Van Loan *et al.* used an arm crank ergometer, the different types of ergometers may account for the differences. The low RER's of Van Loan *et al.* could be a result of test learning and other problems associated with arm ergometry with quadriplegics (Shephard, 1969; Kolsky *et al.*, 1983). The differences may just be normal variation since so few studies have data for quadriplegics.

It is difficult to measure quadriplegics with an arm crank ergometer. Both the present study and Dreisinger *et al.* (1984) used a wheelchair ergometer. A majority of research efforts on maximum exercise with wheelchair users have used arm crank ergometers. Shephard's (1988) extensive review of research on SCI individuals reported 30 research articles with maximal exercise data but only 5 researchers used wheelchair ergometers. The lack of wheelchair ergometers may be contributing to the deficiency of information concerning maximum exercise values for quadriplegics.

Untrained female paraplegics

At present, only one other study has investigated the metabolic response to work of the inactive female paraplegic (Tahamont *et al.*, 1986). Several authors have investigated the athletic female paraplegic (Coutts and Stogryn, 1987; Morris, 1984; Wicks *et al.*, 1983).

Tahamont *et al.* had 4 SCI injured subjects, 2 other subjects were wheelchair users because of unspecified disease. The injury level of the 4 SCI subjects were comparable to those in this study. Both studies had a lumbar injury (L3–4 vs. L1–2) and 2 low thoracic injuries (T11–12, T10, vs. T11–12, T9). The present study had 2 SCI individuals with higher injuries than the Tahamont *et al.*, study. The mean age of the SCI subjects for Tahamont *et al.* was 27·5 years vs. 29·0 years for the present study. Weight was not reported in the Tahamont *et al.* study and therefore no weight comparisons can be made. Tahamont *et al.* used a wheelchair ergometer as did the present study. The present study and the Tahamont *et al.* study have a good match for subjects and a comparison of the result from both studies should be legitimate. Tahamont *et al.* reported a mean $\dot{V}O_{2\,peak}$ of 14·85 (SD = 1·04), vs. $\dot{V}O_{2\,peak}$ of 15·91 (SD = 2·18). It should be noted that the Tahamont *et al.* study did not report RER values. A t-test was used to determine if there was a statistical difference between the data of the 2 studies. The t-value was 1·35 (df = 9) and was not significant. Therefore the 2 studies represent the same population and the difference in $\dot{V}O_{2\,peak}$ is due to chance. It can be stated with some confidence that untrained paraplegic females between 20 and 35 years of age should exhibit $\dot{V}O_{2\,peak}$ of approximately 15 ml/kg^{-1}/min^{-1}.

Trained female paraplegics from the research literature (Coutts *et al.*, 1987; Morris, 1984; Wick *et al.*, 1983) have a combined $\dot{V}O_{2\,peak}$ mean of 23·08 ml/kg^{-1}/min^{-1}. The range is from 20·8 (Wicks *et al.*, 1983) to 28·9 (Coutts *et al.*, 1987). Those values are well above the values for the untrained female paraplegics in the present study and those in the Tahamont *et al.* study.

Untrained male paraplegics

Several research reports exist concerning the metabolic response to exercise of untrained male paraplegic (Coutts *et al.*, 1987; Dreisinger *et al.*, 1984; McConnell *et al.*, 1984; Zwiren and Bar-Or, 1975). The combined mean for $\dot{V}O_{2\ peak}$ for those research studies is 28·10 ml/kg^{-1}/min^{-1} vs. 24·73 found in the present study. The combined mean is higher than the mean in the present study. Coutts *et al.* study used a wheelchair ergometer and the data from that study is comparable with the result found in this study for untrained male paraplegic (25·97 vs. 24·73).

Trained male paraplegics

The literature has a number of research studies on the metabolic response to exercise of trained male paraplegics (Burke *et al.*, 1985; Cameron *et al.*, 1978; Crews *et al.*, 1982; Flandrois *et al.*, 1986; Gass and Camp, 1984; Gass *et al.*, 1981; Gass *et al.*, 1979; Wells *et al.*, 1988; Wicks *et al.*, 1983; Zwiren *et al.*, 1975). The mean $\dot{V}O_{2\ peak}$ for the trained male SCI individuals in the present study was 28·09 ml/kg^{-1}/min^{-1} vs. the combined group mean for the above studies of 31·70. The present studies values were higher than the Flandrois *et al.* values (26·05) and close to the Burke *et al.*, Crews *et al.*, and Wick *et al.* values (29·57, 28·45, and 29·21). The highest reported mean $\dot{V}O_{2\ peak}$ to date is 42·33 (Wells *et al.*, 1988) with an individual high of 55·0 ml/kg^{-1}/min^{-1} (Wells *et al.*, 1988). It can be concluded that trained male paraplegics in this study were representative of past results found in the literature.

Level of injury vs. $\dot{V}O_{2\ peak}$

The present study found a strong correlation between level of injury in untrained SCI individuals and $\dot{V}O_{2\ peak}$ ($r = 0{\cdot}68$). This correlation had been suggested by several researchers (Figoni, 1984; Gass *et al.*, 1979; Van Loan *et al.*, 1987; Wicks *et al.*, 1983). The theory for suggesting the above correlation was that the higher the level of injury, the greater the reduction in functional muscle mass and strength available for use in exercise tests. The finding of the present research supports the contention that $\dot{V}O_{2\ peak}$ in untrained SCI individuals is dependent upon the level of injury. The correlation found in the present study has an r^2 of 0·46, which means that almost 50% of an untrained SCI individuals $\dot{V}O_{2\ peak}$ is dependent on the level of injury to the spinal cord. If the data from the present study is combined with the data from Coutts *et al.* (1983) the correlation for level of injury with $\dot{V}O_{2\ peak}$ is 0·78. This combined data correlation indicates that 60% ($r^2 = 0{\cdot}60$) of an untrained SCI individuals $\dot{V}O_{2\ peak}$ is dependent on the level of injury to the spinal cord. Caution must be used when talking about level of injury and $\dot{V}O_{2\ peak}$ with trained SCI individuals, as evidenced by the fact that the with lower spinal cord injuries.

Conclusion

The present study combined with the known research literature gives strong evidence that the untrained SCI population consists of at least 3 distinct groups with respect to $\dot{V}O_{2\ peak}$; (a) untrained quadriplegics (b) untrained female paraplegics, and (c) untrained male paraplegics. There is good evidence that in the untrained SCI individual that $\dot{V}O_{2\ peak}$ is highly related to level of injury. It is recommended that future research with untrained SCI subjects observe the above grouping when reporting observations and data.

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