



Similar Results in Force-Velocity Test in Disabled Weight Lifters and Able-Bodied Physically Fit Students

by

Zdzisław Adach¹, A. Jaskólska², A. Jaskólski²

The aim of the study was (1) to evaluate the maximal power using a short-term force-velocity test in disabled weight lifters and able-bodied non-athletes subjects, and (2) to find if the parameters of the force-velocity test are related to results of the weight lifted on a bench, which is a specific sport test among disabled weight lifters. The force-velocity (F-V) test was used to evaluate the maximal power (P_{max}), predicted maximal resistance force (F_0) and velocity (V_0). The test was applied to 18 disabled weight lifters and 16 physical education students. The mean values of P_{max} , V_0 and F_0 did not differ significantly between groups. In weight lifters, the weight lifted on a bench correlated significantly with P_{max} and F_0 .

It was concluded that (1) in the same F-V test condition (without lower limb support), the results obtained by the able-bodied, non-trained, but physically fit students, do not differ from that of the wheelchair weight lifters; (2) the F-V test is useful for wheelchair weight lifters, as it effectively evaluates their anaerobic power and speed-strength abilities, which is very similar to the able-bodied subjects..

Key words: maximal anaerobic power, disabled weightlifters, non-trained men

Introduction

Spinal cord injuries can lead to a limitation or loss of motor capabilities, depending on the level and extent of damage. The quality of life of people with paraplegia, as in the case of people with amputated lower limbs, depends mostly on the capabilities of the trunk and upper limbs muscles. Systematic exercise and correctly performed training improves the capability of the motor system, reducing the load related to daily activity. This load in people with leg injuries are a significantly greater burden on anaerobic potential, which provides better anaerobic than aerobic capabilities (Hutzler et al., 1998).

From our literature reviews, there are only a few studies related to the anaerobic (Dallmeijer et al., 1994; Hutzler, 1998; Jacobs et al., 2003; van der

Woude et al., 1997) or aerobic capacity (Davies and Shepard, 1990; Janssen et al., 1988) assessment in disabled athletes and/or non-athlete wheelchair users (wheelchair athletes and non-athletes, respectively); and only Tsukagoshi and co-authors (1995) have used the force-velocity (F-V) test for describing anaerobic capability of wheelchair users. The F-V test was introduced by Vandewalle et al. (1985) for maximal anaerobic power (P_{max}) and force and velocity measurement, and it was found that in healthy able-bodied young men, the P_{max} and force are related to the maximal force developed in static (Jaskólska et al., 1988, 1990), quasi-static and dynamic conditions (Driss et al., 2002). However, it is not known if the same refers to disabled men.

Weight lifting is a sport discipline practiced by individuals with lower limb disabilities. A high level of achievement in this sport requires high muscle

¹ - Department of Physiology, University School of Physical Education,

² - Department of Kinesiology, Faculty of Physiotherapy, University School of Physical Education, Wrocław, Poland

power of the shoulder girdle and trunk muscles. As in the case of able-bodied individuals, systematic weight lifting training leads to muscle hypertrophy and muscular strength increases (Davies, 1993; Davies and Shepard, 1990; Jacobs et al., 2001; Tesch and Carlsson, 1983). Such training adaptations in skeletal muscle allow athletes (including weight lifters) to obtain high results in muscle power. Indeed, larger P_{\max} developed during F-V test was found in paraplegic basketball players (371 W) and track athletes (358 W), compared to paraplegic non-athletes (254 W) (Tsukagoshi et al., 1995). However, it is of interest to evaluate if able-bodied, active but not trained, subjects tested in the same conditions (without lower limbs support) are also weaker than disabled athletes. A lower muscle maximal power in non-athletes (even able-bodied) compared to trained subjects (even disabled) should be expected. However, Chin et al. (2002) has found that the physical fitness ($VO_{2\max}$, anaerobic threshold, maximum workload) of lower limb amputees was lower than that of able-bodied subjects, but after endurance training of the amputees, they obtained a physical fitness level similar to the untrained able-bodied subjects. Thus, we hypothesized that maximal anaerobic power could also be similar in trained disabled and untrained able-bodied subjects. To test this assumption, we applied the arm crank F-V test, since it allows for assessing maximal muscle power, as well as force and speed abilities.

The aim of the study was (1) to evaluate anaerobic power using F-V test in wheelchair weight lifters and able-bodied physical education students, and (2) to find if the parameters of the F-V test are related to the weight lifted on a bench - a specific sport test in disabled weight lifters.

The study was approved by the local ethics committee and conducted according to the Helsinki Declaration.

Subjects

The study was conducted on 18 male, disabled weight lifters (WL; mean age 31.8 ± 8.0 years; weight 74.8 ± 22.0 kg; 5.5 years of training) and 16 male, able-bodied physical education students (ST; mean age 23.1 ± 1.6 years; weight 75.6 ± 10.1 kg). To compare results of the disabled weight lifters and able-bodied students, the ergometric test was administered. The students were non-athletes but characterized by high physical activity. All disabled men were involved in weight lifting sport (bench

press), but the causes of their disability were different. Among the disabled subjects, 8 were disabled due to amputation of the lower limbs, 2 - thoracic spinal cord injury due to an accident, 2 - paraparesis related to Heine-Medin disease, 4 - paresis as a result of infantile cerebral palsy and defects, and 2 due to developmental defects of the lower limbs. They represented a national level of sport and participated in the preparations for the Paralympic Games. In the pre-study period they performed a training program for fitness development of muscles of the trunk, shoulder girdle and arm extensors, and exercises for bench weight lifting technique improvement. In addition, they also played wheelchair basketball as a primary complementary sport. In this period, they also participated in tests and control competitions. The contestants belonged to all weight categories specified in the regulations of this sport discipline.

Methods

The F-V test

The F-V test was used in order to determine the maximal anaerobic power (P_{\max}) and predicted maximal rotation speed (V_0) and resistance (F_0), individually. The test determines the highest power possible to achieve, based on the relationship between resistance force and rotation rate of the ergometer crank, in the range of 100-200 rev/min. Following a standard warm-up, the subject performed 5-7 efforts (each with a different resistance) on an arm crank cycloergometer. Each effort lasted 6 to 8 seconds. The first value of the resistance force was determined individually, based on the result of the first attempt of the test, where the rotation speed was approximately 160 rev/min. The resistance was then increased by 0.5 kg, with 5 minutes rest between. The subject was verbally encouraged to achieve the maximum rotation speed at each resistance, but if the speed decreased the exercise at that resistance was stopped.

The number of efforts (resistances) done by a subject depended on rotation speed that the subject developed at the biggest resistance. The resistance at which the subject could not maintain the speed of 100 rev/min was the last load applied in the protocol.

The test was performed on a Monark ergometer (818E model), specially adapted for using the upper limbs, in a sitting position on the subject's own

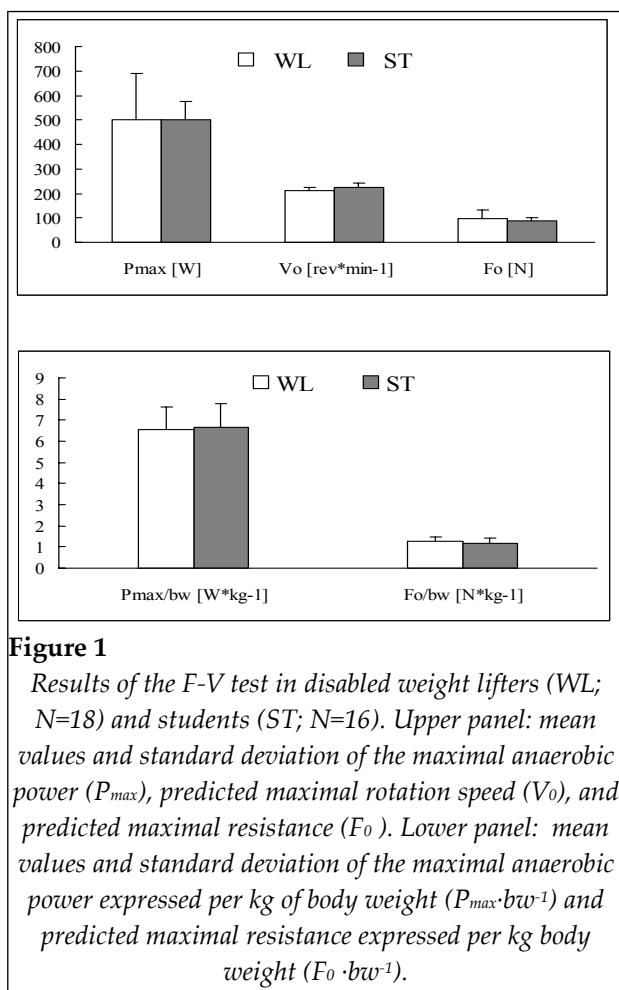


Figure 1

Results of the F-V test in disabled weight lifters (WL; N=18) and students (ST; N=16). Upper panel: mean values and standard deviation of the maximal anaerobic power (P_{max}), predicted maximal rotation speed (V_0), and predicted maximal resistance (F_0). Lower panel: mean values and standard deviation of the maximal anaerobic power expressed per kg of body weight ($P_{max} \cdot bw^{-1}$) and predicted maximal resistance expressed per kg body weight ($F_0 \cdot bw^{-1}$).

wheelchair that was fixed on a base to prevent any movement. The wheelchair was placed so that the shoulder line of the subject was at the level of the rotation axis of the ergometer crank, and so that in the extreme horizontal position of the limb, it was slightly bent at the elbow joint. Subjects were stabilized to achieve the highest values of muscular power output. Their pelvic girdles and femurs were immobilised with belts. The students were tested in the same position, with no contact with the ground or the ergometer, to prevent additional lower limbs stabilization and to ensure comparable test conditions. The resistance force was measured using a tensiometer (CAS, BC-15A type; system accuracy: sensor-transducer: ± 10 g), where a tape was attached for slowing down the flywheel. The sampling frequency was 60 Hz. The rotation speed was determined based on the time between consecutive passages of the photocell light through 2 out of 12 holes located uniformly at the circumference of the pedal disk. The actual resistance force and rotation speed were stored and displayed on a computer monitor, and then used to calculate the developed power,

which was averaged every 0.1 sec. The measurement started automatically when (after hearing the equipment readiness signal) the subject moved the pedals and the photocell light passed through the first hole of the pedal disk.

From the data of rotation speed and corresponding resistance force, the F-V relationship was calculated for each subject using a linear regression. Those data were used to compute the predicted maximal rotation speed at zero resistance (V_0), and maximal resistance at zero speed (F_0). According to the results of Vandewalle (1985), the greatest power (maximal power; P_{max}) is achieved at half of the predicted maximal resistance ($0.5 F_0$) and rotation speed ($0.5 V_0$), thus the following equation was applied to calculate the anaerobic maximal power: $P_{max} = 0.5 F_0 \cdot 0.5 V_0 = 0.25 F_0 \cdot V_0$.

Bench weight lifting

To assess a relationship between parameters of the force-velocity test and a specific sport test in disabled weight lifters, all subjects of that group performed 3 trials of maximal weight lifting on a bench and the heaviest weight lifted was taken as the maximal.

Statistical methods

The data were expressed as arithmetic means and standard deviations of the mean. Independent t-test was used to evaluate the differences between the two groups. Correlation coefficient was also calculated to assess the relationship between selected measured parameters. $P \leq 0.05$ was considered statistically significant.

Results

The mean value of the maximum anaerobic power was similar in both groups ($P > 0.05$). Also, the V_0 and F_0 did not differ significantly among groups, indicating a similar level of speed and strength of the working muscles (Figure 1). However, in the WL group, the absolute values of the P_{max} and F_0 (which depend on the subjects' body weight) showed much variance among subjects, while dispersion of the V_0 values among subjects was small, especially in the WL group (192 to 234 rev/min).

The correlation coefficients between P_{max} and F_0 indicates that the F_0 significantly affects the P_{max} in WL and ST, even when both parameters were expressed per kg body weight (Table 1).

Table 1

Correlation coefficients between selected parameters of the F-V test and body weight (bw) in disabled weight lifters (WL) and able-bodied students (ST). P_{max} = maximal anaerobic power; $P_{max} \cdot bw^{-1}$ = maximal anaerobic power expressed per kg of body weight; F_0 = predicted maximal resistance; $F_0 \cdot bw^{-1}$ = predicted maximal resistance expressed per kg of body weight; V_0 = predicted maximal rotation speed* = $p \leq 0.05$.

Group	Parameters	P_{max}	$P_{max} \cdot bw^{-1}$	F_0	$F_0 \cdot bw^{-1}$	V_0	bw
WL	P_{max}	x	0.714*	0.963*	-	0.176	0.898*
	$P_{max} \cdot bw^{-1}$		x	-	0.743*	0.182	-
	F_0			x	0.611*	0.007	0.919*
	$F_0 \cdot bw^{-1}$				x	0.299	-
ST	V_0					x	-0.143
	P_{max}	x	0.714*	0.844*	-	0.461	0.348
	$P_{max} \cdot bw^{-1}$		x	-	0.884*	0.196	-
	F_0			x	0.733*	-0.060	0.164
	$F_0 \cdot bw^{-1}$				x	-0.282	-
	V_0					x	0.361

However, the relationship between P_{max} and V_0 was not statistically significant. Also, it has been shown that a significant relationship between absolute values of P_{max} and the subjects' body weight and between F_0 and the body weight existed only in the WL group.

However, no significant correlation has been found when parameters were normalized to body weight. The relationship between V_0 and the result of the weight lifting test was not significant either (Table 2).

To test a relationship between parameters of the force-velocity test and results of the specific sport test, maximal weight lifted on a bench by disabled weight lifters was measured. The absolute value of the weight was 154.2 ± 32.0 kg, and relative to body

weight, 2.15 ± 0.43 kg \cdot kg⁻¹. The bench weight lifting results showed a significant relationship with P_{max} and F_0 (Table 2).

Discussion

The primary finding of the study was that able-bodied, physically active students developed maximal anaerobic power, measured during short-term F-V test, similar to that of the wheelchair weight lifters. Moreover, disabled weight lifters demonstrated maximal power and force, as measured during the F-V test, correlated significantly with the weight lifted on a bench.

The power recorded in the disabled weight lifters tested in the present study was higher than that reported by Tsukagoshi et al. (1995), in Japanese

Table 2

Correlation coefficient between selected parameters of the F-V test and weight lifted on a bench (kg) in disabled weight lifters. W = weight lifted on the bench [kg]; bw = body weight; P_{max} = maximal anaerobic power; $P_{max} \cdot bw^{-1}$ = maximal anaerobic power expressed per kg of body weight; F_0 = predicted maximal resistance; $F_0 \cdot bw^{-1}$ = predicted maximal resistance expressed per kg body weight; V_0 = predicted maximal rotation speed.

	Lifting test [kg]	Lifting test [kg/kgbm]
P_{max}	0.656**	x
P_{max}/kg	x	-0.169
F_0	0.709**	x
F_0/kg	x	0.062
V_0	-0.252	-0.160
BM	0.680**	x

wheelchair basketball players and track athletes, which likely resulted from weight lifting training specificity that was aimed at force and power improvement. The power developed by the able-bodied physical education students tested in the present study was also larger than the power of wheelchair, non-athletes tested by Tsukagoshi et al. (1995). The latter finding suggests that usage of wheelchair by itself may not have a significant influence on maximal anaerobic power measured during arm cranking test, or at least it is a weaker stimulus than the daily activity of able-bodied physical education students.

As was hypothesized, the wheelchair weight lifters obtained similar results in the F-V test as the able-bodied active, but not trained, physical education students, which agrees with the results of Chin et al. (2002), who compared physical fitness (aerobic capacity) of lower limb amputees before and after aerobic training, to able-bodied sedentary subjects. The lack of differences in the anaerobic P_{\max} and F_0 between wheelchair weight lifters and able-bodied physically fit students can be related to a few facts. (1) Although the disabled subjects were trained, the pattern of the upper limbs cranking movement (cyclic, alternating pattern of right and left limb movement) was not specific for their training (bench weight lifting), nor was it for the students. (2) Also, the wheelchair pattern of movement is not the same as cranking on a cycloergometer. On a wheelchair, both upper limbs are along the trunk and make simultaneous, parallel, non-alternating movements. Thus, wheelchair usage by itself does not seem to significantly affect the maximal power obtained by wheelchair weight lifters. This suggestion finds support in larger power achieved by the able-bodied physical education students tested in the present study, compared to wheelchair non-athletes tested by Tsukagoshi et al. (1995). (3) The tested able-bodied students are not typical sedentary subjects, due to their weekly activity related to their academic studies (weekly participation in gymnastics, athletic games, swimming, track and field). (4) The same F-V test conditions for both groups (a lack of lower limbs support in both groups) may also contribute to lack of group differences in results obtained in the F-V test. Our unpublished observations support this latter notion. We recorded much larger values of P_{\max} (891 ± 124 W) and F_0 (170 ± 28 N) in physical education students during the F-V test, conducted with lower limbs stabilization (support). Compared to conditions of stabilizing the pelvic girdle, lower

limbs stabilization allows a subject to develop higher force and power during work of the upper limbs. This is also confirmed by significant inter-individual differences in the tested parameters found in the WL group between the contestants with amputation of the lower limbs (at various levels) and the other subjects (with lower limb paresis caused by infantile cerebral palsy, Heine-Medin disease or spine injury after an accident). These findings are consistent with the results of Hutzler et al. (1998). However, lower limb stabilization seems to have only a minor effect on the V_0 , since its values recorded in WL and ST tested in our present study are similar to that which was recorded in students tested with lower limb stabilization ($226 - 233 \text{ rev} \cdot \text{min}^{-1}$) (Adach et al., 1999). Also, in the present study, a similar relationship between parameters of the F-V test was recorded in the WL and ST groups. The P_{\max} was found to be dependent on F_0 , as confirmed by a significant correlation between these parameters when expressed in absolute, as well as relative terms (per kg of body weight).

It is noteworthy that in the present study, the P_{\max} and F_0 values recorded in WL were much more dispersed than that in ST group. The power of the WL group was in the range of 286 to 888 W, and significantly depended on the subjects' body weight ($p \leq 0.05$). Such dependence was not seen in the ST group. This is likely an effect of intensive strength training by the disabled athletes, who have a tendency toward significant muscular hypertrophy, leading to larger muscle mass of the upper limbs and trunk, and very little effect on the lower limbs and pelvis muscles (Tesch and Carlsson, 1983). Hence, during the F-V test, the disabled weight lifters probably used more of their own muscle mass than the able-bodied students. According to van der Woude's findings (1997), the effect of the training period on weight lifters' results in the F-V test is probably none or small.

Previous studies by Jacobs et al. (2003) have shown the value in using the Wingate test for upper limbs in assessing anaerobic power in people with paraplegia. The P_{\max} obtained during F-V test in our study by WL group correlated significantly with F_0 , and they both correlated with the weight lifted on a bench. Thus, F_0 obtained in the F-V test can be used as an indicator of the maximum strength developed in quasi-static conditions, which agrees with the study by Driss et al. (2002), conducted on able-bodied athletes. These authors showed a significant cor-

relation between F_0 and force measured in dynamic and static conditions. A statistically significant relationship between P_{max} and the maximum isometric force in young, healthy people was also found by Jaskólska et al. (1988, 1990). Our present results showed, additionally, that P_{max} and F_0 measured during F-V test correlate with weight lifted on a bench. Thus, the F-V test is useful for disabled weight lifters in evaluating their anaerobic power and speed-strength abilities, which paralleled results of able-bodied subjects. This finding supports results from Hutzler et al. (1998) and Jacobs et al. (2003), who showed that in wheelchair weight lifting athletes, the upper body ergometer is very useful in evaluating their capabilities.

It was concluded that (1) in the same F-V test condition (without lower limb support), the results obtained by the able-bodied, non-trained, but physically fit students, do not differ from that of the wheelchair weight lifters; (2) the F-V test is useful for wheelchair weight lifters in evaluating their anaerobic power and speed-strength abilities, as similarly seen in able-bodied subjects.

Perspectives

Nowadays, there is a rapid increase in accident-related spinal cord and leg injuries, and thus, a rapid

increase in wheelchair users whose quality of life dramatically decreases. As has been shown (Tsukagoshi et al., 1995; Chin et al., 2002), systematic exercise and correctly performed training can improve the capability of the motor system of disabled people, thus reducing the load related to daily activity, and in some individuals, may lead to a high level of performance, enabling some to compete in different sport disciplines on a different level of competition (national, international). The present study also showed that improvement can be so large that the disabled can develop anaerobic capabilities similar to the able-bodied. However, there is a lack of well-controlled studies on recreational and sport training prescription in anaerobic and aerobic capacity in those with different disabilities. Studies on the most effective training program (in different groups of disabilities), using a load at which a subject developed maximal power (during F-V test) as an optimal load, needs to be conducted. Therefore, the results of the present investigation can be useful in prescription and control of the training program in disabled individuals.

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Corresponding author

Zdzisław Adach, dr hab.

Department of Physiology, Faculty of Physical Culture

University School of Physical Education,

ul. Estkowskiego 13

66-400 Gorzow Wlkp. Poland

Phone: +48 95 72 79 175

Fax: +48 95 72 79 149

E-mail: zadach@wp.pl