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WHOLE-BODY VIBRATION TRAINING COMPARED WITH RESISTANCE TRAINING: EFFECT ON SPASTICITY, MUSCLE STRENGTH AND MOTOR PERFORMANCE IN ADULTS WITH CEREBRAL PALSY

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Objective: **The aim of this study was to evaluate the effect on spasticity, muscle strength and motor performance after 8 weeks of whole-body vibration training compared with resistance training in adults with cerebral palsy.**

Methods: **Fourteen persons with spastic diplegia (21–41 years) were randomized to intervention with either whole-body vibration training (*n* = 7) or resistance training (*n* = 7). Pre- and post-training measures of spasticity using the modified Ashworth scale, muscle strength using isokinetic dynamometry, walking ability using Six-Minute Walk Test, balance using Timed Up and Go test and gross motor performance using Gross Motor Function Measure were performed.**

Results: **Spasticity decreased in knee extensors in the whole-body vibration group. Muscle strength increased in the resistance training group at the velocity 30°/s and in both groups at 90°/s. Six-Minute Walk Test and Timed Up and Go test did not change significantly. Gross Motor Function Measure increased in the whole-body vibration group.**

Conclusion: **These data suggest that an 8-week intervention of whole-body vibration training or resistance training can increase muscle strength, without negative effect on spasticity, in adults with cerebral palsy.**

Key words: adults, cerebral palsy, exercise, spasticity, strength training, vibration.

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INTRODUCTION

Cerebral palsy (CP) is an umbrella term for a group of motor impairment syndromes secondary to brain lesions in early stages of its development (1). The most common form is spastic diplegia (2). In this form both legs are more involved than the arms so that walking ability is affected. Andersson & Mattsson (3) investigated walking ability in adults with CP and found that 79% of those with spastic diplegia were able to walk with or without walking aids, but in 51% this ability had gradually decreased and 9% had stopped walking. One factor that could explain the impaired walking ability characterized by flexion in the knees and hips, is weakness of the quadriceps muscles (4). Strengthening of these muscles is therefore often a goal in the treatment of adults with CP. In 2 studies, 10 weeks of progressive resistance training (RT) were found to increase muscle strength in adults with CP (5, 6). Other studies on children with CP also reported good effect on muscle strength after RT (4, 7, 8).

Another method for muscle strengthening that recently has been used on healthy persons is whole-body vibration (WBV) training. It is practised on a vibrating platform where the person is standing in a static position or moving in dynamic movements. The vibrations stimulate the muscle spindles and the alpha-motoneurons, which initiates a muscle contraction according to the tonic vibration reflex (9). This reflex muscle contraction has been suggested to increase the synchronization of the motor units when combined with a voluntary contraction (9).

Several studies have investigated the long-term effect on muscle strength in healthy persons after WBV training with a variety of results. In one study by Torvinen et al. (10) isometric muscle strength and vertical jump height increased after 4 months of WBV training, but after 8 months of WBV training only vertical jump height increased but not muscle strength (11). The reason to the lack of increase in muscle strength after 8 months could be that the vibration intensity was too low to get further neuromuscular adaptation and that the control group also performed better in the repeated strength test. In the first study (10) the main increase in strength was seen after the first 2 months. De Ruiter et al. (12) could not find any improvements in muscle strength after 11 weeks of WBV training in healthy physically active students.

More marked effect on muscle strength after WBV training was shown when the training intensity was progressive. Delecluse et al. (13) compared WBV training with RT in a placebo-controlled study in young healthy women and found that WBV training could increase muscle strength to the same extent as RT. This was later confirmed in several studies including postmenopausal women (14–16).

The fact that people with CP could have benefits by muscle strengthening makes it interesting to find out if WBV training could be appropriate for this group. The aim of this study was to evaluate the effect on spasticity, muscle strength and motor performance after 8 weeks of WBV training compared with RT

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in adults with CP. If WBV training has a similar effect as RT it could be an alternative training method.

METHODS

Design

A prospective, randomized clinical trail was conducted with the alternatives WBV training or RT. The criteria for participation were that the individuals were diagnosed with spastic diplegia, were able to walk with or without walking aids and could understand and follow instructions. Subjects who had practiced RT during the last 6 months, had problems with pain, were taking medicine for spasticity or were pregnant were excluded.

Thirty-eight patients who had contact with the habilitation unit for adults at the Danderyd Hospital received information about the study. Fourteen patients (6 women and 8 men) agreed to participate. One of the patients was diagnosed hereditary spastic paraplegia, but was not excluded because he had similar disabilities as persons diagnosed with spastic diplegia.

The 14 participants were randomized to intervention with either WBV training or RT. The WBV group consisted of 7 persons (4 men and 3 women) with a mean age of 32 (range 24–41) years. The RT group consisted of 7 persons (4 men and 3 women) with a mean age of 30 (range 21–39) years. Individual data are presented in Table I. All participants were instructed not to alter their normal physical activities during participation in this study.

The study was approved by the Ethic Committee at the Karolinska Institute, Huddinge, Sweden.

Measurements

The tests were performed before and after the 8-week training period. All tests except the isokinetic strength test were performed by a physiotherapist who was not involved in the training procedure.

Spasticity. Spasticity was estimated according to the modified Ashworth scale (17), which has 6 degrees (0, 1, 1+, 2, 3, 4). The muscle groups estimated were hip flexors, hip adductors, knee extensors, knee flexors and plantar flexors of the foot. The intra- and inter-rater reliability of the modified Ashworth scale has been considered good (17), but the validity has been shown to be insufficient to be used as a 6-point ordinal scale to measure spasticity (18). Though it is still the most commonly used scale and nothing better is available.

Isokinetic muscle strength. Concentric and eccentric work and peak torque in quadriceps muscles were measured bilaterally by an isokinetic dynamometer (KIN-COM® 124E Plus CHATTECX Corporation) at 2 different angle speeds (30°/s, 90°/s). Similar tests on subjects with CP showed to be reliable when using these angle speeds (19–21). One practice session was performed one week before the actual test, to reduce the effect of learning (22, 23). One participant was excluded from this test because of his length and one participant was only able to test one leg. The position was sitting with hips in 80° of flexion. Chest, pelvis and thighs were secured with straps. The resistance pad was positioned over the distal part of the lower leg. The range of motion during the test was from 90° of knee flexion to almost full extension. The start force was 20 N and the gravity correction feature was eliminated (24). After 3 submaximal contractions and 2 minutes of rest, the patients were verbally encouraged to perform a maximal concentric contraction, rest 5 s, perform a maximal eccentric contraction and rest about 20 s before repeating the procedure. When 3 maximal efforts had been recorded a mean curve was saved (25). Isokinetic work was defined as the product of the mean torque and the range of motion (radians), for the part of the record where the torque exceeded zero. Peak torque was defined as the maximal force during the movement.

Walking ability. Walking ability was tested using the Six-Minute Walk Test (6MWT) (26, 27). One practice session was performed some days before the actual test, to reduce the effect of learning (28). The participants were instructed to walk back and forth in a hallway as far as possible for 6 minutes. Instructions and comments during the test were standardized using guidelines from the American Thoracic Society (27). The reproducibility of this test has been found to be good in patients with chronic heart failure (29) and in adults with CP (28).

Balance. Balance in basic mobility manoeuvres was tested with the Timed Up and Go test (TUG) (30). The participants sat on a standard armchair and were instructed to get up and walk in a comfortable and safe pace to a line on the floor 3 metres away, turn around, return to the chair and sit down again. The time required to complete the task was recorded. One practice session was performed once before the actual test. Intra- and inter-rater reliability of TUG has been found to be good in frail elderly persons (30), in persons with unilateral limb amputation (31) and in persons with Parkinson's disease (32). Another study on elderly persons showed poor test-retest reliability (33).

Gross motor function. The gross motor performance was tested with the Gross Motor Function Measure (GMFM) (34). It consists of 66 items within 5 dimensions: (A) lying and rolling; (B) sitting; (C) crawling and kneeling; (D) standing; (E) walking, running and jumping. The

Table I. *Gender, age, Six-Minute Walk Test (6MWT), gross motor function level by Gross Motor Function Classification System (GMFCS), spasticity by the modified Ashworth scale in the most affected muscle group on right and left leg, use of walking aid and wheel chair. Whole body vibration (WBV) group (n = 7) and resistance training (RT) group (n = 7)*

					Spasticity (0–4)			
	Gender	Age (years)	6MWT (metres)	GMFCS (1–5)	Right	Left	Walking aid	Wheelchair
WBV group								
1	M	29	470	2	3	2	No	Yes
2	M	30	84	3	3	3	Rollator	Yes
3	M	37	415	1	2	1+	No	No
4	F	26	384	2	1+	2	Foot orthosis	Partly
5	F	38	426	2	1	2	No	Partly
6	M	24	300	3	2	3	Rollator	Yes
7	F	41	188	2	3	3	No	Yes
RT group								
8	M	34	453	2	2	2	No	No
9	F	25	215	3	3	1	Leg orthosis	Yes
10	F	39	549	1	1	1	No	No
11	F	30	152	3	1+	1+	Rollator	Yes
12	M	21	110	3	2	2	Wall support	Yes
13	M	32	605	2	1	2	No	No
14	M	31	223	3	2	2	Wall support	Yes

items are scored using a 4-point scale (0, 1, 2, 3) and the scores are presented in percentages. In this study only dimensions D and E were assessed. The reliability and validity of the GMFM has been shown to be good in children with CP (34, 35).

Interventions

The WBV group exercised 3 times weekly during 8 weeks. Each session consisted of 5 minutes warming up, approximately 6 minutes of WBV training (rest included) and finished with a short program of muscle stretching. The WBV training was performed in a static standing position with hips and knees in 50° of flexion on a device called NEMES-LSC (Nemesis BV, Hengelo, The Netherlands). The participants were instructed to avoid holding on to the handles if possible and to focus on standing with equal weight on both legs. The WBV training program was progressive and consisted of 11 different levels of intensity with a frequency of 25–40 Hz (Table II). The choice of level was depending on the participant's rating of perceived exertion on the Borg CR-10 scale (36). The level of intensity when the rating of perceived exertion was "7/very strong" was considered being appropriate for the training session. Medians and ranges of the training levels used in each participant was 8 (1–10), 3 (1–3), 3 (1–3), 7 (1–9), 3 (1–6), 2 (1–2) and 3 (1–5) (Table II).

Like the WBV group, the RT group exercised 3 times weekly during 8 weeks. Each session consisted of the same type of warming up and stretching, but instead of WBV training this group performed RT in a leg press device. Three sets of 10–15 repetitions were performed with 2 minutes of rest in between. The program was progressive and the load was after the first or second week about 70% of 1 RM (repetition maximum) which means that the participant was able to complete as a maximum 7 to 10 repetitions (37). In the beginning of the training period the load was lower until the participants were able to control the movement. With the lower load 15 repetitions were performed.

Statistics

Results are presented as median and range. Wilcoxon's signed rank test was used to analyse differences over time and Mann-Whitney *U* test to analyse differences between the 2 groups. The statistical program JMP 3.2 was used. The level of significance was 0.05.

RESULTS

There were no significant differences, in any of the presented variables, between the WBV group and the RT group before the intervention period. All participants were present in at least 75% of the 24 training sessions. Medians for the presence of the participants in the WBV group and the RT group were 96% (79–100) and 92% (75–100), respectively. One participant in the RT group was exercising with lower load the 3 last weeks because of back pain.

Spasticity

Medians and ranges for estimated spasticity before and after 8 weeks of WBV training and RT are presented in Table III. Of the 5 tested muscle groups there was a significant reduction of spasticity in the knee extensors of the stronger leg in the WBV group ($p < 0.04$). In the RT group there were no significant changes.

Isokinetic muscle strength

Medians and ranges for concentric and eccentric muscle strength in the knee extensors of the participants' weaker and stronger leg are presented as work and peak torque at the angle speed 30°/s and 90°/s in Table IV. Individual results of concentric work in the weaker leg at 90°/s are illustrated in Fig. 1.

Concentric and eccentric work and peak torque increased ($p < 0.04$) in the RT group's weaker leg at the angle speed 30°/s (Table IV). In the RT group's stronger leg concentric work and peak torque increased ($p < 0.05$) at the angle speed 30°/s. In the WBV group the muscle strength did not increase significantly at the angle speed 30°/s. When comparing the groups the increase of eccentric work and concentric peak torque, were higher in the RT group's weaker leg ($p < 0.05$). The increase of concentric work was also higher, but not significant, in the RT group's weaker leg ($p = 0.051$).

At the angle speed 90°/s there was an increase of concentric ($p < 0.02$) and eccentric ($p < 0.03$) work and eccentric peak torque ($p < 0.04$) in the WBV group's weaker leg (Table IV, Fig. 1). In the RT group there was an increase of concentric work in the weaker leg ($p < 0.04$) and of concentric peak torque in the stronger leg ($p < 0.04$). When comparing the groups there were no significant differences in the changes of muscle strength.

Six-Minute Walk Test (6MWT)

Medians and ranges for 6MWT before and after 8 weeks of WBV training and RT are presented in Table V. Values for 6MWT did not change significantly in any group after training.

Timed Up and Go test (TUG)

Medians and ranges for TUG before and after 8 weeks of WBV training and RT are presented in Table V. Values for TUG did not change significantly in any group after training.

Table II. *Program for the whole-body vibration (WBV) training. Frequency (Hz), duration and rest(s) of WBV training for the 11 levels*

Level	Frequency (Hz)	WBV training and rest (s)				
1	25	WBV 4 × 30	Rest 120	WBV 4 × 30		
2	25	WBV 2 × 60	Rest 120	WBV 2 × 60		
3	30	WBV 2 × 60	Rest 120	WBV 2 × 60		
4	35	WBV 2 × 60	Rest 120	WBV 2 × 60		
5	40	WBV 2 × 60	Rest 120	WBV 2 × 60		
6	40	WBV 60 + 80	Rest 60	WBV 2 × 80		
7	40	WBV 110	Rest 120	WBV 110		
8	40	WBV 110	Rest 15	WBV 110		
9	40	WBV 110	Rest 15	WBV 110	Rest 15	WBV 110
10	40	WBV 110	Rest 15	WBV 2 × 110		
11	40	WBV 3 × 110				

Table III. *Results of spasticity estimated with the modified Ashworth scale (0, 1, 1+, 2, 3, 4) before and after 8 weeks of whole-body vibration (WBV) training (n = 7) or resistance training (RT) (n = 7). The participants' weaker and stronger legs are separated. Significant differences are marked with bold type*

	Weaker			Stronger		
	Before	After	*p*	Before	After	*p*
WBV group						
Hip flexors median	0	0	0.12	1	0	0.063
Range	0–1+	0–0		0–1	0–0	
Hip adductors median	1	0	0.063	0	0	0.12
Range	0–2	0–1+		0–2	0–1+	
Knee extensors median	2	2	0.25	3	1	**0.031**
Range	0–3	0–3		0–3	0–3	
Knee flexors median	0	0	0.25	0	0	0.12
Range	0–2	0–1		0–2	0–0	
Foot plantar flexors median	1	1	0.063	1+	1	0.25
Range	1–2	0–1+		1–2	0–2	
RT group						
Hip flexors median	0	0	0.12	0	0	0.12
Range	0–2	0–1		0–1+	0–0	
Hip adductors median	1	0	0.063	1	0	0.063
Range	0–2	0–0		0–2	0–1	
Knee extensors median	1+	1	0.063	1	1	0.34
Range	0–3	0–2		0–2	0–2	
Knee flexors median	0	0	0.50	0	0	0.50
Range	0–2	0–2		0–0	0–0	
Foot plantar flexors median	1+	1+	0.12	1	1	0.25
Range	0–3	0–2		0–2	0–2	

Gross Motor Function Measure (GMFM)

Medians and ranges for the GMFM before and after 8 weeks of WBV training and RT are presented in Table V. The total value for dimensions D and E increased in the WBV group ($p < 0.04$), but there was no significant increase in the RT group. When comparing the groups there was no significant difference in training effect between the WBV and RT group.

DISCUSSION

The aim of this study was to evaluate effect on spasticity, muscle strength and motor performance after 8 weeks of intervention with WBV training compared with RT. There was a significant decrease in spasticity in the knee extensors in the WBV group after the intervention period. The result of other estimated muscle groups showed no significant decrease in spasticity. It is important to consider the insufficient validity of the modified Ashworth scale. According to Pandyan et al. (18) it is not possible to discriminate between scores 1, 1+ and 2. Because of this aspect, we chose to conclude that the spasticity did not increase after any of the interventions. This is in line with previous studies on RT and spasticity in persons with CP (5, 38) and stroke (39, 40).

Isokinetic muscle strength increased in both intervention groups, but not in every parameter that was tested. We tested concentric and eccentric muscle contraction on both legs in 2 different angle speeds. The results were presented as both work and peak torque. Accordingly, the strength test had 8 parameters on each angle speed. At the slow angle speed the RT group showed increasing muscle strength in 6 parameters while there was no increase in the WBV group. At the rapid angle speed the WBV group showed significantly increasing muscle strength in 3 parameters and in 2 that was almost significant ($p < 0.055$) while the RT group showed increasing muscle strength in only 2 parameters. It is interesting that WBV training might have an effect on strength at rapid movements. This is in accordance with previous studies which have shown effects on explosive muscle strength in vertical jumps and in isokinetic testing at angle speeds $>90°/s$ (13–16).

The WBV group performed static exercises and therefore it had been appropriate with a measure of isometric strength. It is interesting that the WBV group, however, showed an increase in isokinetic strength. It is possible that this increase had been more marked if the WBV training was performed with dynamic movements similar to movements used in the leg press device.

Finally, we wanted to evaluate effects on motor performance, which were walking ability, balance and gross motor function. Walking distance in 6 minutes and balance in walking and turning did not change in any intervention group. The gross motor function increased significantly only in the WBV group. In previous studies on RT in persons with CP (5, 7) the same tests were used (6MWT, TUG and GMFM) and showed increased motor performance. In those studies the RT program consisted of 10 and 20 different exercises compared with only one in this study. It is probably necessary in both WBV training and RT that the training program is more extensive to obtain an effect on motor performance. It should be longer and consist of different types of exercises. Compared with 6 minutes of WBV training in one position in this study, other studies report increasing muscle strength after 20 minutes of WBV training in static and dynamic knee extensor exercises (13–16).

Table IV. *Isokinetic concentric (conc) and eccentric (ecc) muscle strength, at the angle speed 30°/s and 90°/s, presented as work (J) and peak torque (Nm), before and after 8 weeks of whole-body vibration (WBV) training and resistance training (RT). The participants' weaker and stronger legs are separated*

	Weaker			Stronger		
	Before	After	*p*	Before	After	*p*
30°/s						
WBV group	(*n* =7)	(*n* =7)		(*n* =7)	(*n* =7)	
Conc work (J) median	33	35	0.078	38	31	0.16
Range	2–39	3–41		13–64	15–73	
Ecc work (J) median	44	51	0.18	64	60	0.66
Range	15–74	15–69		27–76	24–91	
Conc peak torque (Nm) median	68	75	0.20	76	75	0.47
Range	18–93	25–104		28–125	38–146	
Ecc peak torque (Nm) median	76	105	0.20	123	120	0.50
Range	30–111	51–133		52–154	41–154	
RT group	(*n* =5)	(*n* =5)		(*n* =6)	(*n* =6)	
Conc work (J) median	38	50	**0.031**	34	39	**0.047**
Range	7–57	14–75		12–82	19–81	
Ecc work (J) median	66	85 Δ	**0.031**	56	60	0.11
Range	15–107	18–119		20–102	26–121	
Conc peak torque (Nm) median	81	120 Δ	**0.031**	74	92	**0.047**
Range	13–126	27–146		27–153	39–146	
Ecc peak torque (Nm) median	111	152	**0.031**	92	114	0.11
Range	27–199	32–222		33–175	45–231	
90°/s						
WBV group	(*n* =7)	(*n* =7)		(*n* =7)	(*n* =7)	
Conc work (J) median	15	26	**0.016**	17	23	0.055
Range	0–24	1–34		5–40	6–53	
Ecc work (J) median	49	61	**0.023**	64	65	0.59
Range	19–76	28–83		27–78	24–91	
Conc peak torque (Nm) median	33	53	0.055	40	54	0.23
Range	5–70	11–68		16–87	19–97	
Ecc peak torque (Nm) median	92	122	**0.039**	113	126	0.78
Range	34–141	38–160		40–152	33–147	
RT group	(*n* =5)	(*n* =5)		(*n* =6)	(*n* =6)	
Conc work (J) median	21	31	**0.031**	18	24	0.078
Range	1–43	4–56		1–71	4–70	
Ecc work (J) median	61	88	0.063	49	59	0.22
Range	21–113	24–112		24–120	28–118	
Conc peak torque (Nm) median	60	71	0.16	46	56	**0.031**
Range	9–111	10–103		11–125	14–136	
Ecc peak torque (Nm) median	102	151	0.094	85	104	0.20
Range	34–188	35–234		41–207	40–203	

J =joule; Nm =Newton metre; significant differences ($p < 0.05$) for changes over time are marked with bold type; Δ significant differences ($p < 0.05$) in changes between the groups.

In further studies it would be better with a more vigorous training program to get enough overload of the muscles to obtain a more marked effect on muscle strength and motor performance.

Based on the subjective reports of the participants, negative side-effects did seldom occur in the WBV group. One participant was very stiff in her legs in the evening after training. In the RT group negative side-effects were more common. Muscle

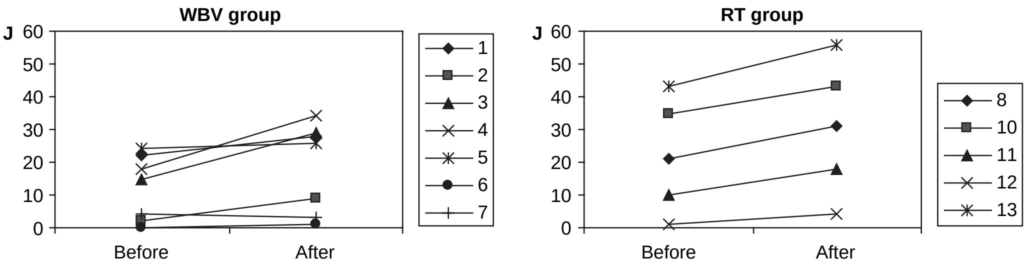

Fig. 1. Isokinetic concentric work (J) in the weaker leg, at the angle speed 90°/s, before and after 8 weeks of whole body vibration (WBV) training ($n = 7$) and resistance training (RT) ($n = 5$).

Table V. *Median values of Six-Minute Walk Test (6MWT), Timed Up and Go test (TUG) and Gross Motor Function Test (GMFM) dimensions D, E and total (T), before and after 8 weeks of whole-body vibration (WBV) training or resistance training (RT). Significant differences are marked with bold type*

	Before		After		
	Median	Range	Median	Range	*p*
WBV group					
6MWT (m)	384	84–470	376	83–439	0.72
TUG (s)	14	10–102	14	8–72	0.094
GMFM D (%)	79	38–85	82	54–95	0.063
GMFM E (%)	69	22–93	72	22–97	0.063
GMFM T (%)	76	30–89	77	38–96	**0.031**
RT group					
6MWT (m)	215	110–605	237	98–610	0.50
TUG (s)	15	7–30	16	7–30	0.41
GMFM D (%)	77	62–90	82	62–90	0.19
GMFM E (%)	57	25–89	61	31–89	0.31
GMFM T (%)	70	44–90	69	47–90	0.16

stiffness was on 3 occasions so bad that the participants chose to cancel the following exercise session. Another participant had problems with back pain at the beginning of the training period caused by uneven loading when performing the leg press exercise. Even if WBV training had few negative side-effects it was not free from risks. For some participants who had difficulties in standing with equal weight on both legs, the feet could slide off the vibration platform. It is therefore important that persons with motor disabilities have someone who is supervising and prepared to stabilize them if this is about to happen.

In conclusion, the data in this study suggest that 8 weeks of intervention with WBV can increase muscle strength during rapid movements and increase gross motor performance without negative effects on spasticity. The data also suggest that intervention with progressive RT can increase muscle strength at slow and rapid movements without negative effect on spasticity. Walking distance in 6 minutes and balance in basic mobility manoeuvres did not change significantly in any intervention group. When comparing the groups after the intervention period, there were no significant differences in changes of spasticity, muscle strength or gross motor performance.

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