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ORIGINAL ARTICLE

The Use of Mechanical Acoustic Vibrations to Improve Abdominal Contour

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Abstract Adaptive effects caused by mechanical acoustic vibrations on the neuromuscular system are widely described. These vibrations applied to the muscle belly cause the "vibration tonic reflex" characterized by an improvement in power contraction of the stimulated muscle. Mechanical acoustic vibrations of moderate strength placed on limited body areas produce a positive muscle activity without damage. A prospective study from January to September 2006 investigated 60 sedentary patients presenting with muscular hypotrophy associated or not associated with lipodystrophy of the abdominal region who desired a substantial contour improvement of such area without invasive procedures. Of these patients, 40 were subjected to a treatment protocol with mechanical acoustic vibrations applied to the abdomen, associated or not associated with physical aerobic exercise of moderate intensity. The remaining 20 patients engaged only in the physical training. The study aimed to evaluate whether the application of mechanical acoustic vibrations could improve body contour.

Keywords Abdominal contour · Mechanical acoustic vibrations

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Adaptive metabolic and mechanical responses of the human neuromuscular apparatus subjected to mechanical acoustic vibrations (MAV) are widely supported in the literature. These vibrations applied to muscle bellies and tendons cause the "vibration tonic reflex" characterized by an improvement in power contraction of the stimulated muscles [3, 4, 6, 9, 14].

Adaptations caused by the vibration tonic reflex involve particularly the superior motor centers of the neuromuscular apparatus [10]. These responses are characterized by an improvement in the neural stimulation that permits recruitment of a wider number of muscular fibers. Moreover, these vibrations cause hormonal adaptive responses, probably due to the action of metabolic muscular receptors. In fact, an increase in testosterone and somatotropic hormone concentrations and a simultaneous decrease in cortisol concentration have been documented [3].

In the literature, two main categories of studies on the effects of MAV applied to the human body are described [8]: the effects of MAV applied to the entire human body and the effects of MAV applied to limited body areas. The first group of studies shows the harmful effects on some body areas [8, 13], particularly the vertebras. The second group of studies analyzes low-intensity MAV applied to limited body areas such as single muscles or synergistic muscular groups. These low-intensity MAV produced positive effects without any body damage.

The improvements produced by high-frequency MAV seemed to be more suitable because they stimulated high-frequency contractions. These favorable effects have been used already in the rehabilitation of patients affected by a reduction in muscular tone caused by various diseases [7, 12]. Moreover, favorable aesthetic effects linked to significant muscular tone and power improvement comparable with those obtained using traditional isokinetic training have been noted.

Physical activity may provide a low-risk method of preventing weight gain and promoting maintenance of weight loss for overweight and obese women [11]. Exercise effectively reduces intraabdominal fat [5], a hidden risk factor for many chronic illnesses [1].

A prospective study investigated the effects on the abdominal contour of healthy sedentary patients caused by the machine called "VISS" (vibration sound system; Vissman, Rome, Italy), which emits high-frequency MAV. This study aimed to evaluate the cosmetic advantages of such treatment.

Materials and Methods

The prospective study, conducted in the Department of Plastic and Reconstructive Surgery of the University La Sapienza of Rome from January to December 2006, investigated 60 healthy patients (30 men and 30 women) ages 20 to 50 years (average, 35.8 years) who desired an improvement in the abdominal silhouette. The patients had a sedentary life (<60 min/week of moderate- and vigorous-intensity recreational activity and maximal oxygen consumption of <25 ml/kg/min) and a body mass index (BMI) of 21 to 25. They presented with moderate muscular hypotrophy of the anterior abdominal muscles associated or not associated with skin flaccidity and localized lipodystrophy.

The exclusion criteria for the study specified previous implantation of heart pacemakers or metal prosthesis, hormone replacement therapy, phlebopathy, arterial hypertension, neuropathy, diagnosis of diabetes, severe cardiopathy, infective or traumatic dermatitis, smoking, and pregnancy. Written informed consent was obtained from the patients.

The patients were randomly assigned to groups A, B, and C. Randomization was performed by random number generation, and group assignments were placed in sealed envelopes, which were opened by the study coordinator at the time of randomization. Randomization was stratified by sex and BMI (<23.5 vs >23.5) to ensure equal numbers of heavier and lighter patients in each study group. Each group consisted of 20 patients (10 men and 10 women).

Groups A and B were treated with MAV applied to the abdomen. During the 2 weeks of treatment with the VISS system and for the following month, group A performed physical aerobic exercises of moderate intensity; group B underwent only VISS stimulation without physical exercises; and group C performed the same physical exercises of moderate intensity as group A for 6 weeks without MAV application. Moderate-intensity physical activity refers to a level of effort at which a person should experience an increase in breathing or heart rate, a "perceived exertion" of 11 to 14 on the Borg scale [2], or the burning of 3.5 to 7 calories per minute (kcal/min).

The intervention included a 6-week exercise program intensively monitored by an exercise physiologist at a facility (University La Sapienza of Rome, Italy, and a commercial gym). The exercise intervention involved at least 45 min of moderate-intensity exercise 5 days per week for 6 weeks. The participants were required to attend three sessions per week at one of the study facilities and to exercise 2 days per week at home.

The training program began with a targeted maximal heart rate of 40% for 16 min per session and gradually increased to a rate of 60% to 75% for 45 min per session by week 6. The participants wore heart rate monitors (Polar Electro Inc., Woodbury, NY, USA) during their exercise sessions.

Facility sessions consisted of treadmill walking and stationary bicycling. Strength training comprising two sets of 10 repeated leg extensions, leg curls, leg press, chest press, and seated dumbbell row was recommended to decrease risk of injury and maintain joint stability but was not required. A variety of home exercises including walking, aerobics, and bicycling was suggested and encouraged. The participants were encouraged to wear their heart rate monitors when exercising at home.

For groups A and B, the treatment protocol involved two series of VISS applications. Each series comprised more sessions of MAV application. Four stimulators transmitting high-frequency MAV at a wave length of 100 or 300 Hz were laid on the abdomen and kept in contact with the skin by elastic compressive bands. These stimulators produced a negative pressure through a vacuum pump, which resulted in suitable adhesion to the patient's skin, and then transmitted high-frequency MAV. These should have stimulated the anterior abdominal muscles to improve power and tone. Each session was characterized by the emission of vibrations with a wave length of 100 Hz for 15 min combined with isometric contraction of the abdominal muscles. In fact, during this phase, patients were asked to contract the abdominal muscles voluntarily in an isometric manner every 5 min for 40 s. Then the session continued with vibrations at a wave length of 300 Hz for another 15 min, during which the abdominal muscles remained at rest.

The first cycle of treatment included three consecutive daily sessions, followed after 1 week by the second cycle composed of just two consecutive daily sessions. A hydrating lenitive cream was applied topically at the end of each treatment session to solve the light skin erythema caused by the vacuum pump. No results were related to any form of slimming diet or therapy during the study period.

Treatment efficacy was subjectively assessed using a patient questionnaire and by a panel of external physicians not involved in the study who analyzed pre- and post-treatment views. Objective evaluation also was performed using somatic measurements.

A questionnaire was submitted to the patients 1 month after treatment. Three questions were posed: (1) Did you note an improvement in the muscular power of the abdomen? (2) Did you note an improvement in the muscular resistance of the abdomen? (3) Did you note an improvement in the abdominal silhouette?

Objective measurements were executed before treatment began, at the end of VISS treatment (in groups A and B), and 1 month after VISS treatment (in groups A and B) or after the 6 weeks of physical training (in group C). The following parameters were evaluated: the subcostal circumference (SC), and supra-iliac crest circumference (SICC). The skin and subcutaneous thickness (PL) in the periumbilical region were measured with a plicometer. Also, BMI was evaluated before the treatment and 1 month after the VISS treatment or physical training. Parameter modifications were statistically compared by using the Wilcoxon signed rank test for paired values.

Results

Subjective evaluation highlighted the following results (Table 1). In group A, 16 patients noted muscular power improvement, 16 patients noted muscular resistance improvement, and 17 patients noted silhouette improvement. In group B, 15 patients noted muscular power improvement, 15 patients noted muscular resistance improvement, and 15 patients noted silhouette improvement. In group C, 10 patients noted muscular power improvement, 11 patients noted muscular resistance improvement, and 9 patients noted silhouette improvement.

In group A, clinical examination and photographic documentation showed improvement in the abdominal contour of most patients 1 month after treatment (Figs. 1 and 2). Objective evaluation showed a statistically significant reduction in all the parameters evaluated (Table 2). In particular, the SC, SICC, and PL parameters were significantly decreased from baseline to the immediate post-treatment follow-up assessment (Table 2a) and to 1 month after treatment (Table 2b), and between treatment end and 1 month follow-up evaluation (Table 2c). Moreover, BMI showed a significant reduction from baseline to 1 month after treatment (Table 2b).

In group B, clinical examination and photographic documentation showed an improvement in the abdominal contour of most patients 1 month after treatment (Figs. 3 and 4). Objective evaluation showed a statistically significant reduction in all parameters evaluated (Table 3). In particular, the SC, SICC, and PL parameters were significantly decreased from baseline to the immediate post-treatment follow-up assessment and to 1 month after treatment (Table 3a and b), but no significant changes were highlighted between treatment end and 1 month follow-up evaluation (Table 3c). Moreover, BMI showed a significant reduction from baseline to 1 month after treatment (Table 3b).

In group C, clinical examination and photographic documentation showed no improvement of the abdominal contour in most patients after 6 weeks of training with exercises of moderate intensity (Figs. 5 and 6). Objective evaluation showed no statistically significant reduction in the parameters evaluated except for SC (Table 4).

The complications encountered were some local lesions at the site of stimulators applied to the abdomen. In particular, a transient erythema lasting for 48 to 72 h was noted in four patients and treated with topical antiinflammatory-based cream. Superficial blisters developed in two patients, which were treated conservatively with saline solution, paraffin gauze, and sterile dressing (Fig. 7). No patient showed any lesion at the 1 month follow-up visit.

Discussion

The application of MAV to limited body areas allows improvement in motor ability through a proprioceptivity improvement in the neuromuscular plate [3, 4, 6, 9, 10, 14].

This focalized and circumscribed energy averts systemic damages to the body, gaining an effective advantage for circumscribed muscular groups [8].

Moreover, Saggini et al. [12] pointed out that the monolateral application of MAV produces a power improvement not only directly on the stimulated muscles, but also on the contralateral musculature due to adaptation of the neuromuscular plate. In our prospective study,

Table 1 Subjective results highlighted by patients' questionnaire

Questions	Group A		Group B		Group C	
	Yes	No	Yes	No	Yes	No
Did you note an improvement in the muscular power of the abdomen?	16	4	15	5	10	10
Did you note an improvement in the muscular resistance of the abdomen?	16	4	15	5	11	9
Did you note an improvement in the abdominal silhouette?	17	3	15	5	9	11

Fig. 1 Group A patient, frontal view. *Left:* Before treatment. *Right:* 1 month after vibration sound system (VISS) treatment

Fig. 2 Group A patient, lateral view. *Left:* Before treatment. *Right:* 1 month after vibration sound system (VISS) treatment

Table 2a Parameter modifications from baseline (t0) to immediately after treatment (t1) in group A

Parameter	t0 *M* ± *SD*	t2 *M* ± *SD*	*p* Value
BMI	22.6 ± 1.87	22.3 ± 1.79	<0.01
SC	82.1 ± 12.74	79.8 ± 12.48	<0.0001
SICC	87.1 ± 10.46	85.1 ± 10.17	<0.0001
PL	3.19 ± 1.022	2.73 ± 0.955	<0.0001

SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, skin and subcutaneous thickness of the periumbilical region

Table 2b Parameter modifications from baseline (t0) to 1 month after treatment (t2) in group A

Parameter	t0 *M* ± *SD*	t2 *M* ± *SD*	*p* Value
BMI	22.6 ± 1.87	22.3 ± 1.79	<0.01
SC	82.1 ± 12.74	78.8 ± 12.82	<0.0001
SICC	87.1 ± 10.46	83.8 ± 9.59	<0.0001
PL	3.19 ± 1.022	2.38 ± 0.973	<0.0001

BMI, body mass index; SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, skin and subcutaneous thickness of the periumbilical region

MAV, when locally applied, showed a subjective improvement in muscular tone and resistance, and an improvement in the body silhouette for most of the patients (Table 1). Pre- and post-treatment measurements objectively confirmed these observations (Tables 2 and 3).

Statistical analysis of parameter variations showed the significance of the results. Group A, which combined VISS treatment with physical aerobic exercises of moderate-intensity, showed a more significant reduction in the analyzed parameters than group B. This was evidenced by the statistical significance of parameter modifications between the immediate post-treatment measurements and those at the 1 month follow-up assessment. Furthermore, moderate-intensity exercises alone were not able to show evident improvements in the abdominal contour after 6 weeks of training.

Fig. 3 Group B patient, frontal view. *Left:* Before treatment. *Right:* 1 month after vibration sound system (VISS) treatment

Fig. 4 Group B patient, lateral view. *Left:* Before treatment. *Right:* 1 month after vibration sound system (VISS) treatment

In addition, the results observed were not related to any form of slimming diet or therapy during the study period. The BMI decreased slightly in all the groups, but significantly only in groups A and B. The slight BMI reduction in groups A and B can be explained by the fact that the reduction in body fat was balanced by the

Fig. 5 Group C patient, frontal view. *Left:* Before physical training. *Right:* 6 weeks after training

Fig. 6 Group C patient, lateral view. *Left:* Before physical training. *Right:* 6 weeks after training

Table 2c Parameter modifications from immediately after treatment (t1) to 1 month after treatment (t2) in group A

Parameter	t1 *M* ± *SD*	t2 *M* ± *SD*	*p* Value
SC	79.8 ± 12.48	22.3 ± 1.79	<0.001
SICC	85.1 ± 10.17	78.8 ± 12.82	<0.001
PL	2.73 ± 0.955	2.38 ± 0.973	<0.0001

SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, skin and subcutaneous thickness of the periumbilical region

Table 3a Parameter modifications from baseline (t0) to immediately after treatment (t1) in group B

Parameter	t0 *M* ± *SD*	t1 *M* ± *SD*	*p* Value
SC	82.05 ± 11.56	80 ± 10.83	<0.0001
SICC	88.2 ± 7.62	86.1 ± 7.25	<0.0001
PL	2.97 ± 0.715	2.3 ± 0.59	<0.0001

SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, skin and subcutaneous thickness of the periumbilical region

abdominal muscle hypertrophy produced by MAV. Abdominal contour improvement can be correlated with a force and tone enhancement of regional muscles.

On the basis of our observations, we affirm that the VISS treatment combined with physical aerobic exercises of moderate intensity produces better aesthetic results than VISS treatment alone or physical aerobic exercises alone. It appears that VISS treatment alone can produce a significant improvement in capability of the muscles during the treatment protocol, whereas the following observation period does not show a similar trend of significant improvement. In contrast, physical aerobic exercises of moderate-intensity, when combined with MAV stimulation, appear capable of providing a further progressive increase in muscle force after facilitation of the

Table 3b Parameter modifications from baseline (t0) to 1month after treatment (t2) in group B

Parameter	t0 *M* ± *SD*	t2 *M* ± *SD*	*p* Value
BMI	22.7 ± 2.06	22.5 ± 2.01	<0.05
SC	82.05 ± 11.56	79.84 ± 10.78	<0.0001
SICC	88.2 ± 7.62	86.4 ± 7.31	<0.0001
PL	2.97 ± 0.715	2.35 ± 0.653	<0.0001

BMI, body mass index; SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, subcutaneous thickness

Table 3c Parameter modifications from immediately after treatment (t1) to 1 month after treatment (t2) in group B

Parameter	t1 *M* ± *SD*	t2 *M* ± *SD*	*p* Value
SC	82 ± 10.83	79.84 ± 10.78	>0.05
SICC	86.1 ± 72.5	86.4 ± 7.31	>0.05
PL	2.3 ± 0.59	2.35 ± 0.653	>0.05

SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, skin and subcutaneous thickness of the periumbilical region

Table 4 Parameter modifications from baseline (t0) to 1 month after treatment (t2) in group C

Parameter	t0 *M* ± *SD*	t2 *M* ± *SD*	*p* Value
BMI	22.9 ± 1.54	22.8 ± 1.65	>0.05
SC	82.0 ± 11.55	81.48 ± 11.33	<0.05
SICC	87.8 ± 7.39	85.2 ± 12.02	>0.05
PL	2.94 ± 0.730	2.89 ± 0.793	>0.05

BMI, body mass index; SC, subcostal circumference; SICC, supra-iliac crest circumference; PL, skin and subcutaneous thickness of the periumbilical region

Fig. 7 Transient erythematic reaction caused by the vibration sound system (VISS) treatment

neuromuscular system due to mechanical acoustic vibrations realized by the VISS system.

Conclusions

Our study showed that VISS treatment may be used not only in the rehabilitative context to increase muscle capability [12], but also for aesthetic purposes. It allows an improvement in the body silhouette through an enhancement of the muscle force and tone of a definite muscular group, particularly if combined with physical aerobic exercises of moderate intensity.

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