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Preliminary results on the mobility after whole body vibration in immobilized children and adolescents

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Abstract

The present article is a preliminary report on the effect of Whole Body Vibration (WBV) on the mobility in long-term immobilized children and adolescents. WBV was applied to 6 children and adolescents (diagnoses: osteogenesis imperfecta, N=4; cerebral palsy, N=1; dysraphic defect of the lumbar spine, N=1) over a time period of 6 months. WBV was applied by a vibrating platform constructed on a tilt-table. The treatment effect was measured by alternations of the tilt-angle of the table and with the "Brief assessment of motor function" (BAMF). All 6 individuals were characterized by an improved mobility, which was documented by an increased tilt-angle or an improved BAMF-score. The authors concluded WBV might be a promising approach to improve mobility in severely motor-impaired children and adolescents. Therefore, the Cologne Standing-and-Walking-Trainer powered by Galileo is a suitable therapeutic device to apply WBV in immobilized children and adolescents.

Keywords: Osteogenesis Imperfecta, Muscle-Bone-Unit, Whole Body Vibration, Cerebral Palsy, Physiotherapy

Introduction

Whole Body Vibration (WBV) has been recently introduced to improve impaired biomechanical function of the musculoskeletal system in adults[1]. The therapeutic principle is based on the activation of proprioreceptive spinal circuits. These reflexes can be induced by upright standing on a vibrating platform (Figure 1). Because reflexes are related to the time-differential activation of spindles in muscles and tendons, the induction of the reflective muscular answer depends on forces (acceleration of gravity x body mass) over time applied to the muscular system by vibration. The frequency of vibration characterizes the type of activated spinal reflective answer. Therefore, lower frequencies decrease the muscular tonus in contrast to higher frequencies increasing the muscular tonus[2]. The application of vibrations increased bone formation and the metabolism in skeletal muscles and skin[3,4]. Interestingly, WBV is characterized to prevent the loss of bone and muscle mass in immobilized adults. Moreover, postmenopausal women might profit from WBV regarding their muscular function. In detail, WBV improves inter- and intramuscular co-ordination over induction of high-frequent muscular contractions of agonists and antagonists in the neuromuscular system. This effect mainly improves power in motor-impaired individuals. Ward et al. applied high-frequent vibration therapy with low amplitude to improve trabecular bone density in children affected with neuromuscular diseases[5]. Negative side effects were not reported after 6 months of intensive therapy. This positive experience with vibration therapy raised the hope that vibration-therapy with individually configured applied impulses on the neuromuscular system may improve the physical ability in motor-impaired children. The present study characterizes the preliminary therapeutic effects of the Cologne Standing-and-Walking-Trainer powered by Galileo (Figure 2) on the mobility of children and adolescents affected with diseases characterized by a disease-related sarcopenia due to physical immobilization. Patients of the present report were affected with osteogenesis imperfecta (OI), infantile cerebral palsy and Meningomyelocele (MMC).

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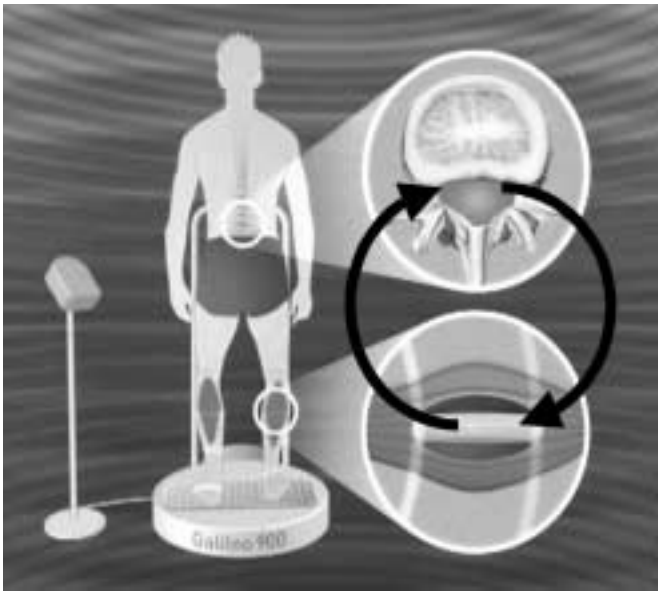

Figure 1. Schematic illustration of the reflex-circuit activated by WBV in a standing position.

Figure 2. The Cologne Standing-and-Walking-Trainer powered by Galileo for immobilized children and adolescents with severe motor-impairment.

Subjects and methods

The study group comprised 6 long-term immobilized children affected with OI (OI type III: N=2, OI type IV: N=2, aged 5.3-10.7)[6,7], infantile cerebral palsy (N=1) and a child with a dysraphic defect of the middle and lower spinal cord (N=1).

The Galileo WBV-system is a platform constructed as a see-saw with a rectangular axis to the individual's body length. The alternating platform elevates and lowers the right and left foot mutually inducing musculo-spinal reflexes. Thereby, muscles are activated on the side of the lowered foot and inhibited on the opposite side. Interestingly, inhibition is emphasized by lower frequencies in contrast to activation due to higher frequencies. Therefore, the frequency of vibration determines if WBV is characterized by tonus-increase or –decrease in skeletal muscles. Amplitude and frequency can be controlled in an analogous way. Thus, these parameters can be individually configured for the patient[8]. The Cologne Standing-and-Walking-Trainer is a Galileo WBV-system, which is supplemented by a tilt-table. The necessary force is described by F=(acceleration of gravity x body mass) x sin (tilt-angle) to keep the body in an upright position on the tilt-table. This force F is also a measure to characterize the ability to stand in a more or less vertical upright position. Mobility was characterized by a mobility score (brief assessment of motor-function, BAMF)[9].

The therapeutic program was conducted over a time period of 6 months. The patients and their parents were instructed in the use of the Cologne Standing-and-Walking-Trainer powered by Galileo before the training equipment was installed for 6 months at home. The program comprised 2 daily therapy sessions with 3 cycles each[10]. During the 6 month period of training, tilt-angle (10^{o}-90^{o}), frequency (15 Hz-22 Hz) and amplitude (0 mm-6 mm) were adapted in relation to the increase in the patient's physical ability. Already started therapies (e.g., drug administration such as bisphosphonates, physiotherapy) were continued during WBV.

Reports

Table 1 summarizes important parameters describing disease, diagnosis and treatment of 6 participants of the study. Individuals affected with OI are characterized by BAMF-score.

Patient 1 (OI)

The five-year-old girl was affected with OI type III. The disease was diagnosed prenatal because of ultrasonographically described malformations of the lower limbs. The infant was primarily treated with intravenous administered bisphosphonates at the age of 5 months. This treatment reduced skeletal pain, the frequency of fractures and increased the bone mineral density (BMD Z-score=-2SD at the age of 4 years). The patient had been treated with intensive physical therapy since birth. Surgical corrections of bone deformities were not applied.

Status before WBV: The participant was supported in a sitting position because of the decreased muscle force stabilizing body trunk and hips. The girl was mobilized by a wheelchair. The lower limbs were not functionally activated. Therefore the surgeons refused surgical correction of the limbs.

Status after WBV: Muscle force and mobility increased after 6 months of training with the Galileo system. The participant was able to elevate her body to an upright sitting position (+1 on the BMF-scale). Moreover, the force of the

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Diagnosis	OI III	OI IV	OI III	OI IV	ICP	MMC
Sex	F	F	F	F	F	F
Height [cm]	68	86	80	108	115	150
Weight [kg]	8.5	15	13	29	22	49.5
Age at start of WBV	5	8	9	10	5	15
Perinatal Diagnosis	Yes	Yes	Yes	Yes	No	Yes
Hereditive Disposition	No	Yes	No	No	No	No
Time period of bisphos-phonate therapy [years]	4	4.5	4	4	No	No
Osteosynthetic surgery	No	No	Yes	Yes	No	No
Constant physical therapy	Yes	Yes	Yes	No	Yes	Yes

Table 1. Characteristics of the entire study group.

lower extremities was increased to achieve a final force of 42 N. The patient started to move her limbs more frequently. Actually the surgeons are planning to correct the deformities of both lower limbs with intramedullary telescopic rods.

Patient 2 (OI)

The eight-year-old girl was affected with OI type IV. She was primarily treated with bisphoshonates at the age of 4 years. The girl was treated with physical therapy twice a week due to her delayed motor development.

Status before WBV: The girl was supported for standing. The elevation in an upright position was supported by her upper limbs (Gower-sign).

Status after WBV: The muscle force and mobility increased so that the girl stood without support and started walking with minimal support (+2 BAMF). The force development of the lower limbs increased to 109 N.

Patient 3 (OI)

The nine-year-old girl was affected with OI type III. The disease was diagnosed postnatal. The lower limbs underwent surgical stabilization with osteosynthesis because of multiple fractures. The therapy with bisphosphonates was started at the age of 6 years. Her mobility is limited to the use of a wheelchair due to her physical inability to stand or walk.

Status before WBV: The girl was characterized by a sufficient head control without the ability to sit for a longer time period.

Status after WBV: The patient achieved the physical ability to sit freely and to elevate the trunk into a sitting position without any support (+1 BAMF). With the support of the upper limbs the short time control of standing is possible. One of her intramedullary rods had already perforated the corticalis before starting the WBV. During the training period this rod caused temporary pain and the training was interrupted. There was no need for a surgical intervention. The girl increased the force to 106 N for the lower limbs.

Patient 4 (OI)

The patient was affected with OI type IV. The disease was diagnosed postnatal due to the malformations of the extremities. Several surgical interventions were necessary at the lower limbs because of those deformations. The lower extremities were stabilized by orthesis. The right upper limb was affected with a pseudarthrosis due to a fracture.

Status before WBV: The girl had the physical ability to walk 15 meters with support. Due to her muscular weakness, she was dependent on orthopaedic shoes stabilizing her ankles and she used a bandage to support her left knee. The support of walking by the upper limbs was limited by a pseudarthrosis of the right arm.

Status after WBV: The support in walking could be reduced and was only limited to support by an anterior walker. The force of the lower limbs was increased to 226 N. It was no longer necessary for her to support her joints by external fixation and she could buy normal shoes for the first time in her life.

Patient 5 (Infantile Cerebral Palsy, ICP)

The five-year-old girl was a former pre-term born infant of the 30th gestational week who was affected with a spastic cerebral palsy of the lower limbs. The girl was treated with physical therapy since birth (therapy according to concepts of Bobath and Vojta). The patient accomplished to stand and walk some steps with support at the age of 3 years.

Status before WBV: The child had the physical ability to walk 30 meters with support. She was using an anterior walker or crutches with ground contact at 4 points (quadripods). The Achilles tendon was shortened, but all other muscles and tendons were not characterized by contractions. The muscular system of the lower limbs was characterized by an increased muscular tonus (spastic). It was planned to start therapy with botulinum toxin to reduce the muscular tonus in her legs.

Exercising with WBV: The participant exercised 5 days a

week for 6 months. Initially, WBV was applied at a tilt-angle of 40° with 18 Hz over 3 minutes to decrease the muscular tone. This episode was followed by 3 times 3 minutes WBV with 13 Hz in an upright position. The knee joints were manually supported to minimize a deviation of the lower limbs from the vertical axis.

Status after WBV: Spastic was decreased in the lower limbs and the functionality of both feet was improved. Moreover, the physical therapy to decrease the spastics was supported by the reduction of the muscular tonus due to WBV. Therefore the neuropaediatricians decided to postpone the treatment with botulinum toxin. Her ability to walk improved during these 6 months. Actually she is only using normal crutches, she has prolonged her walking distance and can take a few steps unassisted.

Patient 6 (Dysraphic defect of the thoracolumbal spine, MMC)

The 15-year-old female adolescent was affected with lumbar MMC. She was intensively treated with physical therapy according to the Vojta concept. Contractions of muscles and tendons of the lower limbs were surgically corrected twice and a third operation was already planned. During her childhood she was able to walk with orthesis only reaching up to her lower leg. Despite intensive physical therapy she lost this capability and became dependent on orthesis reaching up to her thighs. She needed to have an external stabilization of her knees.

Status before WBV: Muscles innervated by the segments below th10 are characterized by spastic cerebral palsy. Therefore, muscles below the knee joints are completely paralyzed in contrast to upper muscles with a partial palsy. The contractions of the knee joints are described with 35° left and 40° right. The spine was characterized by a non-fixed hyperlordosis. The mobility is supported by a wheelchair because standing and walking a few steps had to be strongly supported.

Exercising with WBV: The patient exercised 3 cycles WBV daily with an oscillation frequency of 13 Hz over 6 months (5 days per week).

Status after WBV: The spine was extended due to the reduced lordosis. Moreover, contractions decreased. The right knee joint was characterized with a deficit of 10° in extension. Because of these improvements the planned operation was cancelled. The left knee joint was normalized in extension. The force of the lower limbs was increased to 312 N. This increase was especially due to an improved muscular force of her thighs. She became able to stabilize her knees on her own. Actually she started walking again with external support and orthesis only stabilizing her ankles.

Discussion

All participants were described to have profited from the conducted exercising program despite their original reasons of immobilization. Moreover, the WBV was accepted with a high compliance by all participants. Individuals affected with OI were characterized by an improved mobility (increased BAMF score) and an increase of force development in the lower limbs (increased tilt-angle in the physical therapy) after 6 months of therapy. The child affected with cerebral palsy showed a reduction of spastics and an improved functional motor pattern of walking. The indication for a therapy with botulinum toxin was reversed for the moment. The patient with the dysraphic defect was characterized by a decrease of joint-associated contractions. The surgical correction of contractures was cancelled. Both patients have been able to reduce their dependency on external support regarding crutches and orthesis. The reason for the described benefit becomes understandable for all participants despite their primary diseases when the general effect of immobilization on the musculoskeletal system is considered.

Immobilization of the musculoskeletal system is typically followed by loss of muscle mass (sarcopenia) and a subsequent decrease of bone mass (osteopenia). Therefore, immobilization is always related to sarcopenia and osteopenia despite its primary origin (e.g., cerebral palsy). The loss of muscle and bone mass decreases the functional competence of the musculoskeletal system and might be the reason of further immobilization. This consideration is the fundamental of the empirically based concept of primary and secondary bone diseases[11]. Primary bone diseases are characterized by a structural or metabolic defect of the skeletal development in contrast to secondary bone diseases based on immobilization[12]. Therefore, functional activation of the musculoskeletal system is a promising approach to improve mobility in motor impaired children and adolescents.

One of the described patients with OI developed problems with an intramedullary rod, which was already dislocated before starting WBV. Another patient who was not reported because she was training on a standing device only for a few weeks suffered a dislocation of a telescopic rod during the months of training. This patient had had a dislocation already 2 years before and another one month after she stopped the WBV. Dislocation of telescopic rods is a frequent event in individuals affected with OI[13]. Moreover, the analysis of the individual anatomical characteristics of these patients could not draw any connections between WBV and the dislocation osteosynthetic material. Nevertheless, a negative effect of WBV on the stability of implanted material cannot be excluded due to these preliminary data.

The present collective of participants was characterized by a high heterogeneity of diseases and their severity of immobility. Therefore, the present results are not comparative between different individuals. Nevertheless, the present data can be regarded as preliminary results to enhance the importance of this promising therapeutic strategy to regain mobility in severely motor-impaired children and adolescents.

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