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Original Research

Long-Term and Immediate Effects of Whole Body Vibration on Chronic Lameness in the Horse: A Pilot Study

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A R T I C L E I N F O

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A B S T R A C T

The effects of whole body vibration (WBV) in horses with chronic lameness were evaluated in an experimental, single subject, repeated measure design. To assess the long-term effect of WBV, eight horses not previously exposed to WBV were subject to WBV, 30 minutes twice daily, five days a week, for 60 days in addition to their regular exercise routine. Lameness was assessed subjectively and objectively 30 days before the start, at the start and 30 and 60 days after the start of the treatment (WBV). The immediate effect of WBV was assessed in four horses accustomed to WBV, by comparing lameness before and within 30 minutes of a single 30-minute WBV session at four different time intervals. Change in lameness was sought using paired *t* tests on the kinematic data. A *P*-value of $<.05$ was considered statistically significant. Intraindividual change was sought using a subjective and objective scoring system. No statistically significant change in lameness was seen after 30 or 60 days of WBV, respectively, in the chronically lame horses not previously exposed to WBV. However, a trend toward improvement was observed after the first 30 days of WBV, but this improvement appeared to be lost during the second 30 days of WBV. Although a statistically significant worsening of front limb lameness was seen immediately after a single 30-minute WBV session in the chronically lame horses accustomed to WBV, this result was largely attributed to a very significant worsening of the front limb lameness in one horse within that group.

1. Introduction

Lameness is a major health problem in horses [1], with up to 60% of the lameness estimated being related to osteoarthritis [2]. As such, chronic musculoskeletal pain in horses is a common problem and a multimodal approach is often used for their management, consisting of systemic nonsteroidal anti-inflammatory medication, intra-articular joint therapy, nutritional therapy, and a variety of other complementary therapeutic modalities, one of which, whole body vibration (WBV), has gained popularity over the last few years.

Whole body vibration in horses has anecdotally been used on a daily basis to stimulate healing in horses with acute musculoskeletal injuries or to provide pain relief in horses with chronic musculoskeletal pathologies. Furthermore, it has anecdotally been used right before

Ethical considerations: Prior to being enrolled in the study, owners completed an informed client consent form. A full physical and lameness examination was performed by the primary author (B.T.H.) before the start of the study to assure the horses were in good physical health and that there were no contraindications to participation in the study. As a safety measurement, all horses were lightly sedated with 0.006 to 0.01 mg/kg detomidine (Dormosedan) intravenously the first time they were introduced to the whole body vibration (WBV) platform. No sedation was needed or used after the introductory session. All horses were willing to walk and stand on the vibration platform and tolerated WBV well during subsequent treatment sessions. None of the horses showed any signs of pain or anxiety during WBV. A physical and lameness examination was repeated at monthly intervals. No adverse effects were noticed throughout the study. All horses that entered in the study completed the study.

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competitions as a warm-up tool to improve flexibility and performance. To this day, however, the use of WBV in horses is mainly based on its beneficial effects reported in the human literature [3] and some small equine-specific case reports. To the author's knowledge, only one unpublished article has been written so far on the use of WBV in the horse, in which it was concluded that WBV is safe and capable of inducing thermographic changes in the distal limbs and body of the horse (Tingbo M, unpublished data, 2007).

The aim of this study was to assess both the long-term and immediate effects of WBV on chronic lameness in the horse as commonly used in training and competition settings.

We hypothesized that daily WBV during a 60-day period would improve the degree of lameness in chronically lame horses not previously exposed to WBV. In addition, the author would like to know if a single 30-minute WBV session, in chronically lame horses accustomed to WBV, is capable of improving the degree of lameness within 30 minutes after the end of the WBV session.

2. Materials and Methods

2.1. Study Design

The study was an experimental, single-subject, repeated measure design. All participants were subjected to the treatment of WBV (day 0 to day 60) and evaluations taken at defined times (day 0, 30, and 60) to assess the long-term effect of treatment (WBV). A subgroup of the participants (four eventer horses) was selected based on convenience sampling to act as both controls (day-30 to day 0) and treatments (day 0 to day 60). Another subgroup of the participants (four dressage horses) was selected based on convenience sampling to assess the immediate effect of treatment (WBV) once the horse was accustomed to the treatment.

2.2. Horses

Through convenience sampling, eight horses (age 11.1 ± 4.4 years) were selected from a population of approximately 1,651 horses owned by clients of "Peninsula Equine Medical Center, Menlo Park, California". Inclusion criteria were as follows: mature horse (≥5-year-old), gradable lameness before the start of the study as well as a previous lameness history indicative of a chronic or recurring lameness, lameness not exceeding lameness score of 4/5 on an American Association of Equine Practitioners (AAEP) scale [4] and otherwise in good health, and a signed informed client consent form before the start of the study. A specific type and duration of exercise, as well as diet, was not a requirement, but for participation in the study, it was required that housing, farrier, rider, exercise regime, and diet remained the same from at least 3 months before the start of the study and throughout the duration of the study. Study subjects (Table 1) were involved in athletic activities (four dressage horses [A1, A2, A3, and A4] and four eventer horses [B1, B2, B3, and B4]). The sample group consisted of four Warmblood geldings (A1, A2, A3, and A4), two Irish sport horse geldings (B2 and B3), one Thoroughbred gelding (B4), and one Thoroughbred mare (B1). To assure the first 4 inclusion criteria were met, a full lameness workup was performed on each horse, before the start of WBV by a veterinarian (B.T.H.) experienced in lameness diagnosis and ultrasound imaging, with the results summarized in Table 1. All horses were lame ranging from grade 1 to grade 3 on an AAEP lameness scale [4]. Medical history was reviewed; showing that for all participants, the lameness presented at the start of the study was at least 8-month-old and no horse received any medical treatment within the last 6 months before the start of the study. After interpretation of the full lameness workup and diagnostics, four horses (A1, A2, A4,

Table 1
Horse, discipline, subjective AAEP lameness score (grade 0 to 5) and lameness diagnosis for each horse before the start of the study.

Horse	Discipline	AAEP Lameness Score (Grade 0 to 5)				Lameness Diagnosis and Imaging
		LF	RF	LH	RH	
A1	Dressage	**3**	0	1	0	LF: **chronic tendinopathy of the deep digital flexor** at the level of the navicular bursa (MRI) LH: mild osteoarthritis of the pastern joint (scintigraphy and x-rays)
A2	Dressage	0	**2**	0	0	RF: moderate **osteoarthritis of the coffin joint** with associated **chronic desmopathy of the collateral ligaments** (x-rays and ultrasound)
A3	Dressage	0	0	0	**1**	RF: mild enthesiopathy of the proximal suspensory (ultrasound) RH: severe **chronic desmopathy of the suspensory ligament** (ultrasound and x-rays)
A4	Dressage	**2**	0	1	0	LF: moderate **chronic tendinopathy of the deep digital flexor tendon** at the level of the fetlock/pastern (ultrasound) LH: moderate chronic tendinopathy of the deep digital flexor tendon at the level of the fetlock/pastern (ultrasound)
B1	Eventing	0	0	**1**	0	Axial skeleton: severe (grade 3) **kissing spines T13 to 17, facet joint arthritis T13-L2** (scintigraphy, x-rays, ultrasound)
B2	Eventing	0	1	0	**3**	RH: **inflammation of the stifle joint** (scintigraphy and ultrasound) Axial skeleton: capsulitis of the right C4-C5 and C5-C6 facet joints (scintigraphy and ultrasound)
B3	Eventing	**1**	0	1	0	LF: **inflammation of foot** (scintigraphy and ultrasound)
B4	Eventing	0	0	**1**	0	LH: moderate **inflammation in the distal tarsal joints** (scintigraphy) Axial skeleton: severe (grade 3) **kissing spines T14-L1, facet joint arthritis T17-L4**, inflammation of the sacro-iliac joints (scintigraphy, x-rays)

Abbreviations: AAEP, American Association of Equine Practitioners; LF, left front limb; LH, left hind limb; MRI, magnetic resonance imaging; RF, right front limb; RH, right hind limb.
Bold indicates the horse primary lameness issue(s) based on full lameness workup and diagnostics.

and B3) were considered of having primary front limb lameness and four horses (A3, B1, B2, and B4) were considered of having primary hind limb lameness. In all eight participants, a secondary or compensatory lameness was noticed to a lesser degree on at least one of the lameness evaluations performed during the study.

2.3. Whole Body Vibration and Exercise

All horses underwent WBV 5 days a week (Tuesday, Wednesday, Thursday, Saturday, and Sunday), twice daily (morning and afternoon) for 30 minutes at a frequency of 40 Hertz, amplitude of 0.8 millimeter, and an acceleration of 4.9 m/s^2 (0.5 g) for a total of 60 days using a mobile linear (vertical) type vibration platform (Vitafloor VM0; Vitafloor USA, Inc, Aromas, CA), producing an indirect vertical sinusoidal vibration applied to the feet. This was added to their normal exercise routine as mentioned previously. As a safety measurement, all horses were lightly sedated with 0.006 to 0.01 mg/kg detomidine; Zoetis, Florham Park, NJ (Dormosedan) intravenously the first time they were introduced to the WBV platform. No sedation was need after the introduction session. A hay net was provided while the horses were on the vibration platform to keep them occupied.

2.4. Lameness Assessment and Quantification

Lameness was assessed subjectively, using the AAEP lameness scale [4], by a veterinarian experienced in sports medicine and lameness evaluation (B.T.H.) as well as objectively by using a real-time handheld computer system using body-mounted inertial sensors (lameness locator; Equinosis, LLC, St. Louis, MO). The use and data interpretation of the body-mounted inertial sensors (Equinosis, LLC) have been described in other studies [5–7]. Briefly, the real-time handheld computer system (Equinosis, LLC) uses the vector sum (VS) of max diff head (the difference in the maximum position of the head after the stance phase of the right front limb compared to the left front limb) and min diff head (the difference in the minimum position of the head during the stance phase of the right forelimb compared to the left forelimb) to describe front limb lameness, with a VS $\geq$8.5 considered a significant front limb lameness. To describe the hind limb lameness, the real-time handheld computer system (Equinosis, LLC) uses the max diff pelvis (the difference in the maximum position of the pelvis after the stance phase of the right hind limb compared to the left hind limb) and the min diff pelvis (the difference in the minimum position of the pelvis during the stance phase of the right hind limb compared to the left hind limb), with a max diff pelvis or min diff pelvis >3 millimeter considered a significant push off or impact hind limb lameness, respectively.

Lameness was assessed at a trot on hard ground in a straight line using the same surface for all assessments. Four of the eight horses (B1, B2, B3, and B4) were used as control and assessed 30 days (day-30) prior the start of WBV and then again at the start (day 0) of WBV.

The effect of WBV on chronic lameness was assessed in two different ways, long-term and immediate. The long-term effect of WBV on chronic lameness was assessed in all eight horses, by comparing lameness grade at the start of WBV (day 0) and after 30 and 60 days of a WBV, respectively, as described previously. Thirty days into the WBV treatment, once horses were accustomed to the WBV, immediate effect of WBV was assessed in four of the eight horses (A1, A2, A3, and A4) by comparing the horse's lameness before and within 30 minutes of a 30-minute WBV session at 40 Hertz. This was repeated three more times at days 35, 55, and 60 of WBV, respectively.

Proximal hind limb flexion tests were performed in all eight horses at the start of and after 30 and 60 days of WBV treatment, respectively. LH and RH proximal limb flexion was performed on each horse for 1 minute after which the horse was trotted out. Proximal hind limb flexion test was graded subjectively as followed: negative (0), mild (1), mild to moderate (2), moderate (3), moderate to severe (4), and severe (5) positive.

2.5. Statistical Analysis

Kinematic data (VS, max diff pelvis and min diff pelvis) were analyzed using paired t-tests. P value of $<.05$ (95% confidence interval) was considered statistically significant. Intraindividual change was sought using a subjective and objective scoring system. For objective lameness assessment to be considered significantly different between data points, a difference in VS >8.5 for front limb lameness and a difference in max diff pelvis or min diff pelvis >3 for hind limb lameness was required. For subjective lameness assessment to be considered significantly different between data points, a change of at least one lameness score was required.

3. Results

3.1. Controls

3.1.1. Objective Lameness Assessment

For the four control horses (B1, B2, B3, and B4), there was no statistically significant difference in the front limb ($P = .4$) or hind limb (push off [$P = .6$] and impact [$P = .8$]) lameness between day-30 and day 0.

When we look at the front limb data individually (Tables 2 and 3), only one horse (B3) was considered of having primary front limb lameness. In that horse, there was a significant worsening of the front limb lameness from day-30 to day 0. When we look at the hind limb data individually (Tables 2 and 4), three horses (B1, B2, and B4) were considered of having primary hind limb lameness. Of these three horses, there was a significant worsening of the hind limb lameness in horses B1 and B2 and a significant improvement in horse B4 from day-30 to day 0. Table 2 shows that the horse B2 had a significant worsening of the front limb lameness (RF); however, this was considered to be mainly compensatory due to concurrent worsening of the hind limb lameness (RH). The significant improvement in front limb lameness (RF) in horse B1 was also considered to be mainly compensatory due to concurrent worsening of the hind limb lameness (LH).

Table 2
Objective lameness assessment data on long-term whole body vibration effect in chronically lame horses.

Horse	Front Limb Lameness				Hind Limb Lameness							
	Day-30	Day 0 WBV	Day 30 WBV	Day 60 WBV	Day-30		Day 0 WBV		Day 30 WBV		Day 60 WBV	
	VS	VS	VS	VS	Max Diff	Min Diff	Max Diff	Min Diff	Max Diff	Min Diff	Max Diff	Min Diff
A1	N/A	32.9	**16.0**	25.2	N/A	N/A	2.2	1.8	2.1	4.2	*6.1*	1.6
A2	N/A	20.1	17.4	*55.4*	N/A	N/A	1.3	1.7	1.7	*5.3*	*5.3*	*6.6*
A3	N/A	2.2	*17.1*	*22.5*	N/A	N/A	−0.3	5.3	1.6	6.4	*6.3*	6.9
A4	N/A	20.5	25.4	27.4	N/A	N/A	0.6	3.3	*3.9*	1.7	*4.1*	3.1
B1	17.2	7.0	2.5	3.4	3.2	3.2	7.0	4.1	4.9	2.2	**1.8**	**0.6**
B2	8.1	21.6	20.5	15.9	4.7	0.4	25.3	6.2	**17.5**	**2.5**	**11.1**	**1.1**
B3	8.0	17.5	**8.6**	N/A	5.5	1.8	2.6	−3.6	−1.6	−1.5	N/A	N/A
B4	5.7	11.4	*20.4*	8.2	14.2	5.5	8.6	7.4	10.0	8.6	7.9	9.7

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; max diff, max diff pelvis; min diff, min diff pelvis; N/A, no data available; VS, vector sum; WBV, whole body vibration.
Front limb lameness data expressed as vector sum. Vector sum ≥8.5 indicating significant front limb lameness. A difference in vector sum of >8.5 between data points is considered a significant change in front limb lameness. Hind limb lameness data expressed as max diff pelvis and min diff pelvis. A max diff or min diff >3 indicating a significant push off or impact hind limb lameness, respectively. A difference in max diff or min diff of >3 between data points is considered a significant change in hind limb lameness. Bold indicates a significant improvement in lameness compared to day 0. Italics indicate a significant worsening in lameness compared to day 0.

3.1.2. Subjective Lameness Assessment

For the horse B3 with primary front limb lameness, no significant difference was seen between day-30 and day 0. For the horses (B1, B2, and B4) with primary hind limb lameness, no significant difference was seen in horses B1 and B4, but a significant worsening was seen in the horse B2 (Supplementary Tables 1–3).

3.2. Long-Term WBV Effect on Lameness

3.2.1. Objective Lameness Assessment

For the eight treatment horses, there was no statistically significant difference in front limb lameness between day 0 and day 30 ($P = .9$), day 30 and day 60 ($P = .4$), and day 0 and day 60 ($P = .4$) of WBV. For the hind limb lameness, there was no statistically significant difference between day 0 and day 30 (push off [$P = .5$] and impact [$P = .7$]), between day 30 and day 60 (push off [$P = .9$] and impact [$P = .8$]), or between day 0 and day 60 (push off [$P = .9$] and impact [$P = 1$]).

When we look at the front limb data individually (Tables 2 and 3), 2/4 horses (A1 and B3) with primary front limb lameness show a significant improvement between day 0 and day 30. The two other horses (A2 and A4) show no significant change between day 0 and day 30. Between day 30 and day 60, one horse (B3) was lost for follow-up. Of the remaining three horses, two horses (A1 and A2) had a significant worsening of the lameness and one horse (A4) had no significant change. Between day 0 and day 60, 1/3 horses (A2) showed a significant worsening of the lameness and 2/3 horses (A1 and A4) showed no significant difference in lameness.

When we look at the hind limb data individually (Tables 2 and 4), 1/4 horses (B2) with primary hind limb lameness showed a significant improvement in lameness between day 0 and day 30. The other three horses (A3, B1, and B4) showed no significant change. Between day 30 and day 60 of WBV, 2/4 horses (B1 and B2) showed a significant improvement in lameness. One horse (A3), however, showed a significant worsening and one horse (B4) showed no significant change. Between day 0 and day 60 of WBV, 2/4 horses (B1, B2) showed a significant improvement in lameness, one horse (A3) showed a significant worsening in lameness, and the other horses (B4) showed no significant change.

Table 3
Objective lameness assessment data on long-term whole body vibration effect in horses with primary chronic front limb lameness.

Primary Front Limb Lameness						
Horse	Limb	Tissue Involved	Day-30	Day 0 WBV	Day 30 WBV	Day 60 WBV
			VS	VS	VS	VS
A1	LF	Tendon	N/A	32.9	**16.0**	25.2
A2	RF	Joint/collateral ligament	N/A	20.1	17.4	*55.4*
A4	LF	Tendon	N/A	20.5	25.4	27.4
B3	LF	Bone	8.0	17.5	**8.6**	N/A

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; LF, left front limb; N/A, no data available; RF, right front limb; VS, vector sum; WBV, whole body vibration.
Tissue involved—type of tissue where pathology was identified responsible for the lameness. Front limb lameness data expressed as vector sum. Vector sum ≥8.5 indicating a significant front limb lameness. A difference in vector sum of >8.5 between data points is considered a significant change in front limb lameness. Bold indicates a significant improvement in lameness compared to day 0. Italics indicate a significant worsening in lameness compared to day 0.

3.2.2. Subjective Lameness Assessment

Of the four horses with primary front limb lameness, a significant improvement was seen in 3/4 horses (A1, A2, and B3) between day 0 and day 30. One horse (A4) did not show a significant change. One horse (B3) was lost for the 60-day follow up. Of the three remaining horses, there was a significant worsening of the lameness between 30 and 60 days of WBV. The overall end result at 60-day WBV showed a significant worsening of the lameness between day 0 and day 60 for horses A2 and A4 and a significant improvement for horse A1. Of the four horses with primary

Table 4
Objective lameness assessment data on long-term whole body vibration effect in horses with primary chronic hind limb lameness.

Primary Hind Limb Lameness										
Horse	Limb	Tissue Involved	Day-30		Day 0 WBV		DAY 30 WBV		Day 60 WBV	
			Max Diff	Min Diff	Max Diff	Min Diff	Max Diff	Min Diff	Max Diff	Min Diff
A3	RH	Suspensory ligament	N/A	N/A	−0.3	5.3	1.6	6.4	*6.3*	6.9
B1	LH	Joint/bone	3.2	3.2	7.0	4.1	4.9	2.2	**1.8**	**0.6**
B2	RH	Joint	4.7	0.4	25.3	6.2	**17.5**	**2.5**	**11.1**	**1.1**
B4	LH	Joint/bone	14.2	5.5	8.6	7.4	10.0	8.6	7.9	9.7

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; LH, left hind limb; max diff, max diff pelvis; min diff, min diff pelvis; N/A, no data available; RH, right hind limb; WBV, whole body vibration.
Tissue involved—type of tissue where pathology was identified responsible for the lameness. Hind limb lameness data expressed as max diff and min diff pelvis. A max diff or min diff >3 indicating a significant push off or impact hind limb lameness, respectively. A difference in max diff or min diff of >3 between data points is considered a significant change in hind limb lameness. Bold indicates a significant improvement in lameness compared to day 0. Italics indicate a significant worsening in lameness compared to day 0.

hind limb lameness, one horse (B2) showed a significant improvement, one horse (B4) showed a significant worsening, and two horses (A3 and B1) showed no significant difference between day 0 and day 30. Between day 30 and day 60, one horse (B4) showed a significant improvement. The other horses (A3, B1, and B2) did not show a significant difference. From day 0 to day 60 of WBV, only 1/4 horses (B2) showed a significant improvement. The other three horses (A3, B1, and B4) showed no significant difference (Supplementary Tables 1–3).

3.3. Immediate WBV Effect on Lameness

3.3.1. Objective Lameness Assessment

For the four treatment horses (A1, A2, A3, and A4), there was a statistically significant worsening ($P < .001$) of the front limb lameness between pre- and post-WBV when all horses and all time frames were grouped together. There was no statistically significant difference in hind limb lameness (push off [$P = .08$] and impact [$P = .9$]) between pre- and post-WBV when all horses and all time frames were grouped together.

When we look at the front limb data individually (Table 5), horse A1 had a significant worsening of the lameness at 1/4 time frames. Horse A2 had a very significant worsening at 2/4 time frames. Horse A3 had a significant improvement at 1/4 time frames but a significant worsening at 1/4 time frames as well and another 1/4 time frames showed a borderline worsening of the lameness. Horse A4 showed a significant improvement at 1/4 time frames.

When we look at the hind limb data individually (Table 5), horse A1 showed a significant improvement at 2/4 time frames. At 1/4 time frames (trial 3), the hind limb data were affected by a worsening of the front limb lameness and as such cannot be thoroughly evaluated. Horse A2 hind limb lameness was compensatory to the front limb lameness and as such data are not worth further evaluating. Horse A3 showed a significant worsening of the hind limb lameness at 1/4 time frames; however, 2/4 time frames could not be evaluated because the hind limb lameness was skewed, by a worsening of the front limb lameness. Horse A4 showed no significant change in hind limb lameness at four time frames.

3.3.2. Subjective Lameness Assessment

If we group all four horses and all four time frames, a significant improvement in front limb lameness was seen at 4/16 time frames, a significant worsening was seen at 4/16 time frames, and no change at 8/16 time frames. Hind limb data are hard to interpret as they are skewed by a change in front limb lameness (see objective lameness assessment mentioned previously) and the fact that only one of the four horses (A3) was considered of having a primary hind limb lameness. In that horse (A3), a significant improvement in hind limb lameness was seen at 2/4 time frames and no significant difference was seen at the remaining 2/4 time frames (Supplementary Table 4).

3.4. Long-Term WBV Effect on Response to Proximal Hind Limb Flexion Test

In all eight horses, pain on left and right hind proximal limb flexion was assessed at days 0, 30, and 60 of WBV, respectively. Of the 16 proximal limb flexions performed each time, 12 were positive on day 0, eight were positive on day 30, and eight were positive on day 60. Ten of twelve positive proximal limb flexions improved with a least one grade at day 30, with 4/12 becoming negative. The remaining 2/12 flexions did not change at day 30. One horse was lost for follow-up at day 60, leaving 10 positive proximal limb flexions at day 0 to compare to day 60. Five of ten positive proximal limb flexions improved with at least one grade at day 60 compared to day 0, 3/10 did not change, 2/10 got worse, and two proximal limb flexions that were negative at day 0 became mild positive at day 60 (Supplementary Table 5).

4. Discussion

The results show no statistically significant difference in front limb or hind limb lameness before and after 30 and 60 days of WBV, respectively, meaning that long-term WBV has no positive or negative effects on chronic lameness in the horse. The sample group (eight horses), however, was small and lameness was diverse in the number of limbs affected per horse and the type of pathology responsible for the lameness. These variables most likely affected the end

Table 5
Objective lameness score on immediate WBV effect in chronically lame horses accustomed to whole body vibration.

HORSE	LIMB	TIME	TRIAL 1 – DAY 30 WBV			TRIAL 2 – DAY 35 WBV			TRIAL 3 – DAY 55 WBV			TRIAL 4 – DAY 60 WBV		
			VS	Max Diff	Min Diff	VS	Max Diff	Min Diff	VS	Max Diff	Min Diff	VS	Max Diff	Min Diff
A1	LF	PRE	16.0			18.0			36.8			25.2		
		POST	10.5			26.6			44.1			29.3		
	LH	PRE		2.1	4.2		3.7	5.2		0.8	1.9		6.1	1.6
		POST		1.2	1.0		1.8	0.3		7.4	0.9		4.4	2.2
A2	RF	PRE	17.4			33.7			38.3			55.5		
		POST	19.3			35.0			**78.4**			**98.3**		
	LH/RH	PRE		1.7	5.3		7.1	2.6		2.1	5.1		5.3	6.6
		POST		2.4	4.6		6.0	9.8		6.5	2.8		19.6	6.4
A3	RF	PRE	17.1			23.9			43.0			22.5		
		POST	12.9			11.3			55.6			30.6		
	RH	PRE		1.6	6.5		0.4	2.7		0.4	4.1		6.3	6.9
		POST		2.8	3.7		7.3	3.6		3.5	1.5		6.9	10.1
A4	LF	PRE	25.4			34.6			43.4			27.4		
		POST	21.7			38.3			31.4			28.7		
	LH	PRE		3.9	1.7		4.8	3.8		5.3	3.7		4.1	3.1
		POST		6.3	3.2		4.6	3.5		2.9	5.6		4.8	3.8

Abbreviations: WBV, whole body vibration, Pre, lameness before a single 30-min WBV session at 40 Hertz; Post, lameness within 30 min of a single 30-min WBV session at 40 Hertz; LF, left front; RF, right front; LH, left hind; RH, right hind; VS, vector sum; max diff, max diff pelvis; min diff, min diff pelvis. Front limb lameness data expressed as vector sum. Vector sum $\geq$8.5 indicating a significant front limb lameness. A difference in vector sum of $>$8.5 between data points is considered a significant change in front limb lameness. Hind limb lameness data expressed as max diff pelvis and min diff pelvis. A max diff or min diff $>$3 indicating a significant push off or impact hind limb lameness, respectively. A difference in max diff or min diff of $>$3 between data points is considered a significant change in hind limb lameness. Green indicates a significant improvement in lameness post WBV compared to pre WBV. Red indicates a significant worsening in lameness post WBV compared to pre WBV. Blue indicates a change from LH to RH lameness or vice versa before and after WBV. Horse A1 changed from no lameness in the hind limbs to a compensatory RH push off lameness due to worsening of the LF lameness in trial 3. The horse A3 changed from a RH impact and push off lameness to a LH push off lameness due to worsening of the RF lameness in trial 3. The horse A3 changed from a RH impact and push off lameness to a LH push off lameness and RH impact lameness due to worsening of the RF lameness in trial 4. The horse A2 LH push off and/or RH impact lameness changes as a compensation for the primary RF lameness.

result. For this reason, we evaluated the results on two subgroups (primary front limb lameness vs. primary hind limb lameness) as well as on an individual basis. When we look at the horses with primary front limb lameness, we can actually see that their is a significant improvement in 50 and 75% of the horses after the first 30 days of WBV according to objective and subjective lameness assessment, respectively, with no change in lameness in the remaining 25% to 50% of the horses. A significant worsening of the lameness seems to take place in 66% and 100% of the horses according to objective and subjective evaluation, respectively, during the second 30 days of WBV.

When we look at the horses with primary hind limb lameness, a significant improvement is seen in 25 and 50%

of the horse after 60 days of WBV according to the subjective and objective evaluation, respectively. Overall, however, the data on the long-term effect of WBV on primary hind limb lameness are equivocal.

When we look at the immediate effect of WBV on chronic lameness in the horse once the horse was accustomed to WBV for 30 days, there was a statistically significant worsening in front limb lameness within 30 minutes after the end of a single WBV session. When we look at the individual front limb data, this is mainly due to a very significant worsening of 2/4 time frames in one horse (A2) and this worsening seems to take place again at time points toward the end of the 60-day WBV study. The immediate effect of WBV on hind limb lameness showed no statistically significant difference in lameness, meaning no positive or negative effect could be seen. If we look at the individual hind limb data separately, the data are equivocal, indicating no conclusion can be drawn.

When we look at the long-term effect of WBV on the pain response induced by proximal hind limb flexion, approximately 83% of the flexions improved with at least one flexion score in the first 30 days of WBV, with no change in the other 17%. However, during the second 30 days of WBV, we saw a worsening of approximately 36% of the flexions, with only 21% of the flexions showing further improvement. The remaining 43% of the flexions were unchanged between day 30 and day 60 of WBV. These observations are similar to the trend noticed in horses with primary front limb lameness, namely a trend for lameness improvement or reduced pain during the first 30 days of WBV that is partially lost during the second 30 days of WBV. This trend is further partially supported by the data on the immediate effect of WBV on chronic lameness that show that a negative (adverse) response is seen (particularly in one horse [A2]) mainly during the second part of the WBV study. The reason for this is unclear, but human research on the effect of WBV on muscle has shown that a positive (favorable) response is more or less consistently achieved after 6 weeks, after which there may not be any further improvement [3]. As such, it is possible that tissue adaptation takes place over time and that a change in vibration parameters is needed if further improvement is sought past more or less 6 weeks. Negative effects of WBV are well known but those seem to occur after much longer exposure times over years and mostly at higher frequencies [8]. Another likely explanation for a trend toward worsening of the lameness in the second part of the study is that it is possible that exercise duration and or intensity was increased after the first part of the study as the horse felt better. Although exercise was not supposed to change, the author had no direct control over the exercise program of each individual horse.

The fact that we see an improvement in the primary lameness in 37.5% and 50% of the eight horses in the first 30 days of WBV, according to the objective and subjective data assessment, respectively, is quite good considering that this group of horses all have long standing chronic lameness issues with most of these attributed to moderate-to-severe pathologies.

It is noteworthy that of the four control horses, three got significantly worse before the start of the treatment (WBV) and those same three horses got significantly better during the treatment part of the study. This observation may indicate that WBV is more effective in improving an acute worsening of a chronic lameness.

The optimal vibration parameters, which are, frequency, amplitude, acceleration, and duration, to achieve maximum benefit of WBV in horses with lameness are currently not known. Furthermore, these parameters will most likely be different based on whether we are dealing with an acute versus chronic lameness, bone versus soft tissue injury, and whether the focus is on healing versus pain management.

The mechanism of action through which WBV effects lameness is most likely due to its ability to stimulate healing secondary to increased blood flow [9], angiogenesis [10], and cell proliferation [11], as well as its potential analgesic effect [12,13].

We used both a subjective and objective lameness evaluation to see if a change in lameness could be noticed. Although as a group (all eight horses) no statistically significant change in lameness could be identified over time, it does not mean that there was no improvement in gait or comfort per se. As Dyson [14] (2014) points out, the observers clinical assessment and evaluation of the horse under various circumstances is of vital importance to pinpoint minor gait irregularities, discomfort, or pain, which may not show as a gradable lameness. These changes, however, are very hard to quantify from a statistical perspective.

The fact that subjective and objective lameness assessments are not in line 100% does not come as a surprise either, with the accuracy of objective lameness assessment tools questioned in horses with multiple limb lameness or lameness on a circle [14]. Nevertheless, having both a subjective and objective assessment adds value to the data interpretation.

5. Conclusions

Relative short-term duration of WBV (30 days) may prove beneficial in horses with chronic musculoskeletal pathology. However, there are indicators that when WBV is used for a long period of time, adaptation to WBV may take place or WBV may have a potential negative impact on certain musculoskeletal injuries. It is clear that more research needs to be done with larger group size as well as more specific defined inclusion parameters such as type, location, and duration of lameness before more accurate recommendations can be made for the use of WBV in lame horses. The trend observed suggests that a parallel study using non–lame performance horses would be of interest to better assess the appropriateness of WBV in conditioned sport horses. Consideration of other objective assessment modalities such as force plates and videography may provide additional ways to analyze the effects of WBV on lameness and gait in the horse.

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Supplementary Table 1

Subjective lameness score over time on long-term whole body vibration effect in chronically lame horses according to the AAEP (American Association of Equine Practitioners) lameness score (grade 0 to 5).

Horse	Limb	Day-30	Day 0 WBV	Day 30 WBV	Day 60 WBV
A1	LF	N/A	3	**1**	**2**
	RF	N/A	0	0	0
	LH	N/A	1	**0**	1
	RH	N/A	0	0	0
A2	LF	N/A	0	0	0
	RF	N/A	2	**1**	*3*
	LH	N/A	0	0	0
	RH	N/A	0	*1*	*1*
A3	LF	N/A	0	0	0
	RF	N/A	0	*1*	*2*
	LH	N/A	0	0	0
	RH	N/A	1	1	1
A4	LF	N/A	2	2	*3*
	RF	N/A	0	0	0
	LH	N/A	1	1	*2*
	RH	N/A	0	0	0
B1	LF	0	0	0	0
	RF	0	0	0	0
	LH	1	1	1	1
	RH	0	0	0	0
B2	LF	0	0	0	0
	RF	0	1	**0**	**0**
	LH	0	0	0	0
	RH	1	3	**2**	**2**
B3	LF	1	1	**0**	N/A
	RF	0	0	0	N/A
	LH	1	1	**0**	N/A
	RH	0	0	0	N/A
B4	LF	0	0	0	0
	RF	0	0	0	0
	LH	1	1	*2*	1
	RH	0	0	0	*1*

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; LF, left front limb; LH, left hind limb; N/A, no data available; RF, right front limb; RH, right hind limb; WBV, whole body vibration.

Bold indicates a significant improvement in lameness compared to day 0. Italics indicate a significant worsening in lameness compared to day 0.

Supplementary Table 2

Subjective lameness score over time on long-term whole body vibration effect in horses with primary chronic front limb lameness according to the AAEP (American Association of Equine Practitioners) lameness score (grade 0 to 5).

Primary Front Limb Lameness						
Horse	Limb	Tissue Involved	Day-30	Day 0 WBV	Day 30 WBV	Day 60 WBV
A1	LF	Tendon	N/A	3	**1**	**2**
A2	RF	Joint/collateral ligament	N/A	2	**1**	*3*
A4	LF	Tendon	N/A	2	2	*3*
B3	LF	Bone	1	1	**0**	N/A

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; LF, left front limb; LH, left hind limb; N/A, no data available; RF, right front limb; RH, right hind limb; tissue involved—type of tissue where pathology was identified responsible for the lameness; WBV, whole body vibration.

Bold indicates a significant improvement in lameness compared to day 0. Italics indicate a significant worsening in lameness compared to day 0.

Supplementary Table 3

Subjective lameness score over time on long-term whole body vibration effect in horses with primary chronic hind limb lameness according to the AAEP (American Association of Equine Practitioners) lameness score (grade 0 to 5).

Primary Hind Limb Lameness						
Horse	Limb	Tissue Involved	Day-30	Day 0 WBV	Day 30 WBV	Day 60 WBV
A3	RH	Suspensory ligament	N/A	1	1	1
B1	LH	Joint/bone	1	1	1	1
B2	RH	Joint	1	3	**2**	**2**
B4	LH	Joint/bone	1	1	*2*	1

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; LF, left front limb; LH, left hind limb; RF, right front limb; RH, right hind limb; N/A, no data available; tissue involved—type of tissue where pathology was identified responsible for the lameness; WBV, whole body vibration.

Bold indicates a significant improvement in lameness compared to day 0. Italics indicate a significant worsening in lameness compared to day 0.

Supplementary Table 4

Subjective lameness score over time on immediate whole body vibration effect in chronically lame horses accustomed to whole body vibration according to the AAEP (American Association of Equine Practitioners) lameness score (grade 0 to 5).

Horse	Limb	Time	Trial 1—Day 30 WBV	Trial 2—Day 35 WBV	Trial 3—Day 55 WBV	Trial 4—Day 60 WBV
A1	LF	Pre	1	2	3	2
		Post	**0**	2	3	*3*
	LH	Pre	0	1	0	1
		Post	0	**0**	0	**0**
A2	RF	Pre	1	1	3	3
		Post	1	*2*	3	*4*
	LH	Pre	0	1	0	0
		Post	0	*2*	*1*	*2*
	RH	Pre	1	0	1	1
		Post	**0**	0	**0**	**0**
A3	RF	Pre	1	1	3	2
		Post	**0**	**0**	3	*3*
	RH	Pre	1	1	1	1
		Post	**0**	1	**0**	1
A4	LF	Pre	2	3	3	3
		Post	2	**2**	3	3
	LH	Pre	1	2	2	2
		Post	1	**1**	2	*3*

Abbreviations: LF, left front; LH, left hind; Post, lameness within 30 min of a single 30-min WBV session at 40 Hertz; Pre, lameness before a single 30-min WBV session at 40 Hertz; RF, right front; RH, right hind; WBV, whole body vibration.

Bold indicates a significant improvement in lameness. Italics indicate a significant worsening in lameness.

Supplementary Table 5
Subjective proximal hind limb flexion test (grade 0 to 5) before and during whole body vibration treatment.

Horse	Limb	Day-30	Day 0 WBV	Day 30 WBV	Day 60 WBV
A1	LH	N/A	3	**0**	**0**
	RH	N/A	0	0	0
A2	LH	N/A	1	1	1
	RH	N/A	2	**1**	*3*
A3	LH	N/A	0	0	*1*
	RH	N/A	3	**2**	*4*
A4	LH	N/A	4	**3**	**2**
	RH	N/A	1	**0**	1
B1	LH	2	2	**0**	**0**
	RH	0	0	0	0
B2	LH	1	3	**1**	**0**
	RH	1	3	**1**	**0**
B3	LH	1	2	**1**	N/A
	RH	1	1	**0**	N/A
B4	LH	2	1	1	1
	RH	0	0	0	*1*

Abbreviations: Day-30, 30 days before the start of WBV treatment; day 0, start of WBV treatment (baseline); day 30, 30 days into WBV treatment; day 60, 60 days into WBV treatment; LF, left front; LH, left hind; RF, right front; RH, right hind; WBV, whole body vibration.
Proximal hind limb flexion test was graded subjectively as followed: negative (0), mild (1), mild to moderate (2), moderate (3), moderate to severe (4), severe (5) positive, no data available (N/A). Bold indicates improvement of the proximal hind limb flexion test compared to day 0. Italics indicates worsening of the hind limb flexion test compared to day 0.