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Novel treatment (new drug/intervention; established drug/procedure in new situation)

Effect of whole body vibration on stereotypy of young children with autism

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Summary

The objective of this case was report on the effects of acute whole body vibration exposure on stereotyped behaviour of young children with autism. Four young boys (ages 4–5 years) diagnosed with autism participated. The children were participants in an early intensive behavioural intervention clinic and during downtimes stood on a whole body vibration platform with the machine turned off (control condition) and on (treatment condition) for three to four, 30 s periods (frequency=28 Hz; amplitude 0.97 mm). The outcome measure was frequency of stereotypic behaviour, which was evaluated for 5 min before and after standing on the vibration platform. The results revealed that whole body vibration was not able to uniformly decrease the rates of all types of stereotypy; that is, some stereotypy decreased while others were unchanged. Subjectively, the children enjoyed whole body vibration which was easy to integrate into the behavioural programme.

BACKGROUND

A recent report by the Centers for Disease Control and Prevention indicated the average prevalence of autism increased 57% between the years 2002 and 2006, and that on an average one child in every 110 will be diagnosed with autism.[1] The core features of autism include atypical development in socialisation, communication and behaviour. The last feature is characterised by 'stereotyped patterns of behaviour'[2] that often cause substantial problems to individuals with autism.[3] For example, stereotyped patterns of behaviour (ie, stereotypy) are often repetitive behaviours such as hand flapping, finger tapping, body rocking and repetitive vocalisations, which can consume the majority of waking hours and interfere with psychological development and potential progress in early intensive behavioural intervention programmes.[4–7] Consequently, therapies which attenuate stereotypy are needed to promote optimal developmental progress.

Techniques that have shown some effectiveness at reducing stereotypy include, pharmaceutical approaches,[8] behavioural approaches,[9] sensory integration approaches[10] and vigorous exercise.[11] Regarding vigorous exercise, Kern *et al*[12] observed that 15 min of jogging around a large open field at a 'mildly strenuous' pace produced a systemic decrease in stereotypy whereas 15 min of playing with a ball resulted in some stereotypies decreasing and some increasing after the intervention. Subsequent research, examining the effects of vigorous exercise and play on stereotypy, generally support the trend observed by Kern *et al*.[12–16]

One limitation of vigorous exercise protocols is that they are not practical for integration into early intensive behaviour intervention programmes. For instance, young children (ie, 3–5 years old) do not have the physical development, motivation or attention span to participate in vigorous exercise protocols and the time to implement them may sacrifice learning opportunities. A potential alternative to vigorous exercise that may reduce stereotypy is whole body vibration exposure.

Vibration is defined as an oscillatory motion that can be artificially produced using a vibration platform. When a person stands on a platform, the vibration waveform (sinusoidal, stochastic and random), amplitude (measured in mm), frequency (measured in Hz) and duration can be manipulated to have positive health benefits that may include regulation of physiological arousal similar to that observed during vigorous exercise.[17] In adults, periodic whole body vibration increases testosterone and growth hormone levels,[18] oxygen consumption[19] and muscle temperature.[20] Whole body vibration has also been shown to reduce repetitive hand tremors in patients with Parkinson's disease,[21] and increase bone density and physical mobility in immobilised children.[22–24] These latter studies have reported no negative side effects and recent research has indicated that a potential risk of using the procedure, transmissibility of vibration to the head, is minimal in young children.[25]

To our knowledge, the effect of whole body vibration on stereotypy of young children with autism is unknown but worthy of testing particularly since the effects of vibration exposure are largely independent of the motivation of the participant and short exposure times would not sacrifice learning opportunities in an intensive behaviour programme. Accordingly, the objective of this case was to report on the effects of acute whole body vibration exposure on stereotyped behaviour of several young children diagnosed with autism.

CASE PRESENTATION

Four children diagnosed with autism were selected to participate in the case report. Participants were from a sample of convenience and were included in this case report

Table 1 Participant characteristics

Characteristic	Participant number			
	One	Two	Three	Four
Gender	Male	Male	Male	male
Ethnicity	Caucasian	Caucasian	Caucasian	Caucasian
Age (years)	5	6	5	4
Mass (kg)	20.2	19.3	22.7	19.0
Diagnosis	Autism	Autism	Autism	Autism
Approximate number of words spoken	>200	2	5	100–200

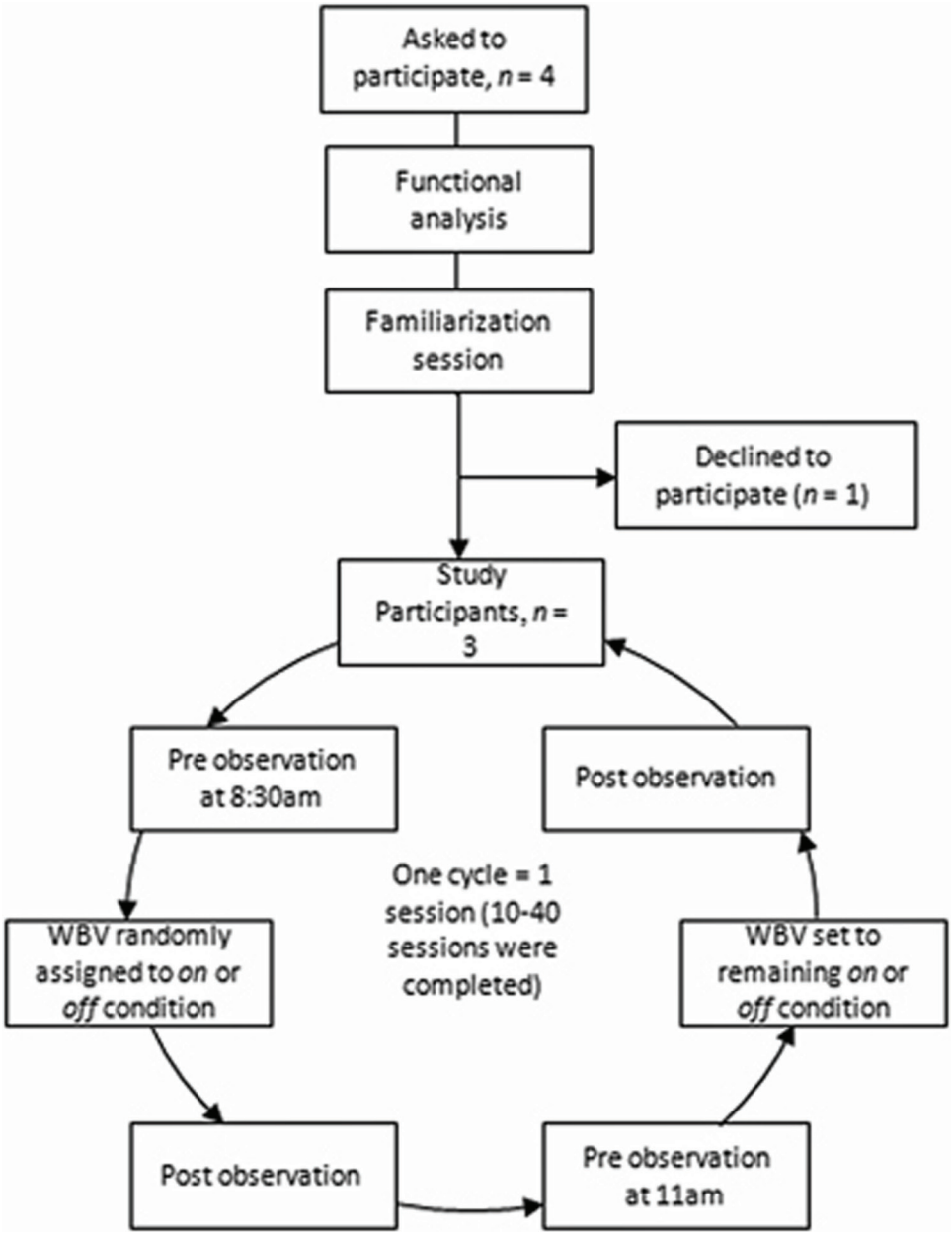

Figure 1 Flow diagram illustrating the procedures and components of one testing session, which included preobservation of stereotypy, exposure to whole body vibration (WBV) with the machine turned on and off, and postobservation of stereotypy.

because they met the following criteria: (A) between the ages of 4–6 years; (B) student in a clinic-based early intensive behavioural intervention programme; (C) diagnosed with autism by a qualified independent examiner using the *Diagnostic and Statistical Manual of Mental Disorders* criteria;[2] (D) display disruptive stereotypy that interfere with learning; and, (E) possess no other medical conditions (eg, epilepsy, spasticity, cerebral palsy or orthopaedic injuries)

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Table 2 List of stereotypic behaviours recorded and the dependent measure for all participants

Stereotypic behaviours	Dependent measure
Participant 1	
Repetitive vocalisations (non-sensical or incoherent)	Frequency of occurrence per 1-min interval
Participant 2	
Hand-mouthing (fingers crossing the lip threshold)	Frequency of occurrence per 1-min interval
Vigorous forward and backward rocking (bodyrocking)	Percentage of time (sec) per 1-min interval
Audible heavy breathing	Percentage of time (sec) per 1-min interval
Yelling	Percentage of time (sec) per 1-min interval
Participant 3	
Repetitive motion (pacing over a chalk-line)	Frequency of occurrence per 1-min interval
Repetitive vocalisations (non-sensical or incoherent)	Percentage of time (sec) per 1-min interval
Participant 4	
Hand flapping	No data
Hand manipulation (hands touching, rubbing or clutching)	No data
Repetitive vocalisations (non-sensical or incoherent, did not include echolalia)	No data

or taking medications. Because vibration training is considered an integrative treatment, participants were excluded if they began additional therapies during the treatment. Participant characteristics including measures of autism severity are summarised in table 1. This case report was approved by the University Institutional Review Board and informed consent was obtained from legal guardians of all participants.

TREATMENT

Dependent variables in the present case report were the frequencies and percentage of time intervals in which stereotypy was observed. The independent variable was whole body vibration. Experimental control was demonstrated within-subject by repeatedly evaluating the occurrence of stereotypy in the 5-min preceding and following whole body vibration and comparing that to levels of stereotypy before and after a control treatment consisting of standing on a vibration platform while it was turned off. Between 10 and 40 observations were made, before and after each condition to insure stability of the data. Single-case designs like this are common within the field of behavioural intervention research in children with autism where high intersubject behavioural variability is expected among participants. Additionally, the design is feasible and robust enough to evaluate statistical effects for pilot research.[26] This case report took place in a university setting that housed an early intensive behavioural intervention clinic.

PROCEDURES

A flow diagram illustrating the procedures may be observed in figure 1. Before the participants were exposed to whole body vibration, a functional analysis was performed to determine whether stereotypies of participants was maintained by socially mediated variables such as attention from staff members.[27] By demonstrating that the stereotypy were in fact maintained by non-social consequences, potential effectiveness of whole body vibration for treating stereotypy maintained by different variables was minimised. The specific stereotypy targeted for each participant is reported in table 2 and had been identified by a doctoral-level Board Certified Behavior Analyst who also supervised the functional analyses.

Within a week of completing the functional analysis, participants were given the opportunity to become familiarised with testing equipment and procedures. Familiarisation sessions were completed in one visit with testing commencing the same week. Procedures for testing included having trained graduate student observers take the participant from the classroom to an observation room for recording of stereotypy during the same day and time of each week. Once in the observation room, trained observers recorded the frequency of stereotypies using hand-held computers (eg, ASUS A626, Fremont, California, USA) for 5 min. Participants were then taken to an adjacent room that contained the vibration platform (i.Tonic; i.Tonic International B.V., Huizen, The Netherlands). Participants stood on the vibration platform with their knees slightly bent. Because some participants did not have receptive language, a technician provided tactile cues to insure proper knee bend. The vibration platform was not turned on for half of the testing sessions to serve as a control condition. For the other half of the sessions, the platform was turned on (frequency=28 Hz; amplitude 0.97 mm) for three to four, 30 s periods with 15 s between each period. Immediately after the randomly assigned vibration condition (ie, vibration machine on or off) was completed, participants were taken back to the observation room for 5 min of postobservation. We conducted between 10 and 40 sessions for each participant individually to insure stability of the data, which is required in a single-subject design. The vibration characteristics chosen appear to be well tolerated by children[25] and may be effective at stimulating physiological responses in special populations.[28]

Trained observers

Trained observers were psychology or exercise science graduate students who received at least 20 h of training in behavioural observation before the case report commenced. One observer recorded stereotypy 100% of the time for all testing sessions and two observers recorded stereotypy 30% of the time. One of the two observers was blinded as to the treatment just given. Observers independently recorded responses of each participant using customised software, which time-tagged events as they were scored that could then be analysed later to obtain overall or within-session frequency, or the percentage of intervals.[29] When an instance of stereotypy was observed,

Table 3 Mean (SD) stereotypy values (frequencies or percentages) for all participants before (pre) and after (post) whole body vibration with the machine turned on and off

		Machine on		Machine off	
Participant	**Stereotypy**	**Pre**	**Post**	**Pre**	**Post**
One	Vocalisations	2.90 (0.39)	2.28 (0.26)*†	2.89 (0.54)	2.80 (0.33)
Two	Hand-mouthing	0.77 (0.49)	1.20 (0.48)	0.68 (0.27)	0.70 (0.17)
	Bodyrocking	74.7 (6.28)	59.3 (20.3)	75.6 (10.1)	66.8 (8.60)
	Breathing	15.3 (4.60)	5.83 (0.68)*	10.8 (2.85)	11.6 (5.44)
	Yelling	9.10 (3.91)	5.38 (3.26)	7.62 (2.91)	4.62 (2.47)
Three	Motion	5.42 (1.61)	3.93 (1.47)	6.16 (0.94)	3.67 (0.95)
	Vocalisations	27.3 (7.78)	17.8 (5.14)*	29.4 (4.93)	19.2 (5.15)‡

*Significantly different from premachine on value ($p<0.05$).
†Significantly different from postmachine off value ($p<0.05$).
‡Significantly different from premachine off value ($p<0.05$).

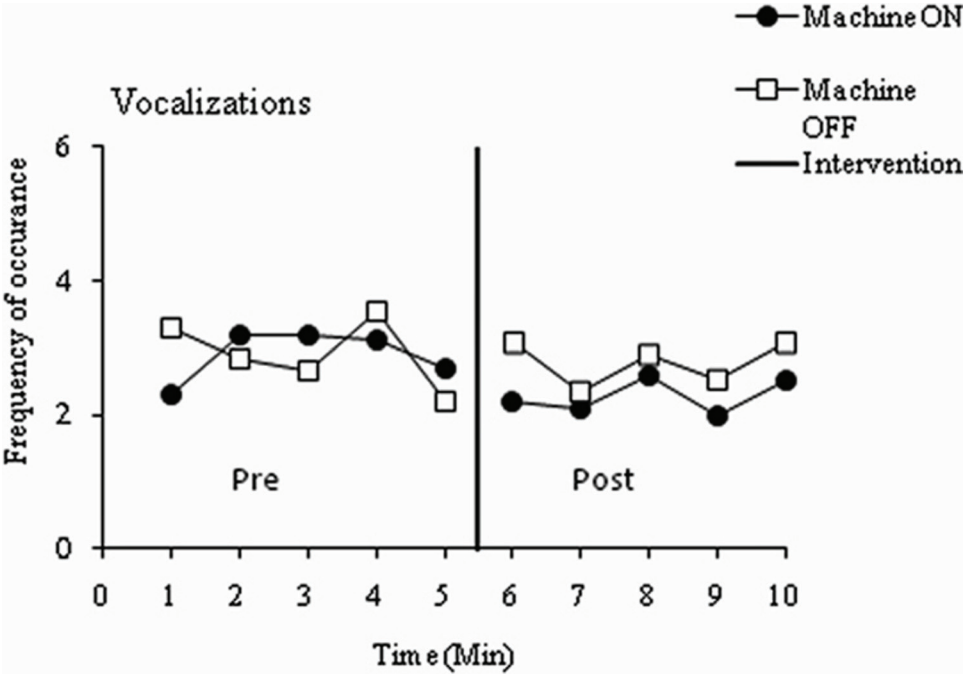

Figure 2 Stereotypy of participant one before (pre) and after (post) whole body vibration with the machine turned on (treatment) and off (control).

the trained observer clicked a precoded box in the window of the hand-held computer with a stylist that corresponded with the stereotypy of the participant.

Analysis

The reliability percentage between observers was calculated on an interval-by-interval basis by dividing the number of agreements by the number of agreements plus disagreements, and multiplying by 100. Depending on the stereotypy noted in table 2, frequency of occurrence or percentage of time in seconds per 1-min interval was computed. The 1-min values were than averaged for each session, which served as the statistical dependent variable. The non-parametric Wilcoxon signed rank test was used to compare frequency of stereotypy within (pre vs post) and between (machine on vs off) conditions with an ⍺-set at 0.05. The meaningfulness of any statistical differences between conditions was calculated using a variation of Cohen's *d*[30] statistic as described by Busk and Serlin[31] for single-subject designs. Interpretation of effect sizes (ES) was based on the following scale for single-subject designs[32] (<4.0=small, 4.1–10.0=medium and >10.1=large).

OUTCOME AND FOLLOW-UP

The interobserver reliability analysis indicated that observers were in agreement 85–100% of the time (mean=89.4, ±6.2%). During familiarisation sessions, it was observed that child four (table 1) was apprehensive to stand on the vibration platform and no extensive effort was made to persuade him. Consequently, stereotypy values with the machine on and off are reported for children 1–3 only (table 3). Figures 2–4 display the pattern of stereotypy of the participants before and after the whole body vibration intervention.

It can be observed in table 3 that stereotypy of participant one was significantly reduced (21%) in the post-test for the machine on condition (p=0.04; ES=1.6) but not when it was turned off (p=0.80). Postfrequency values for

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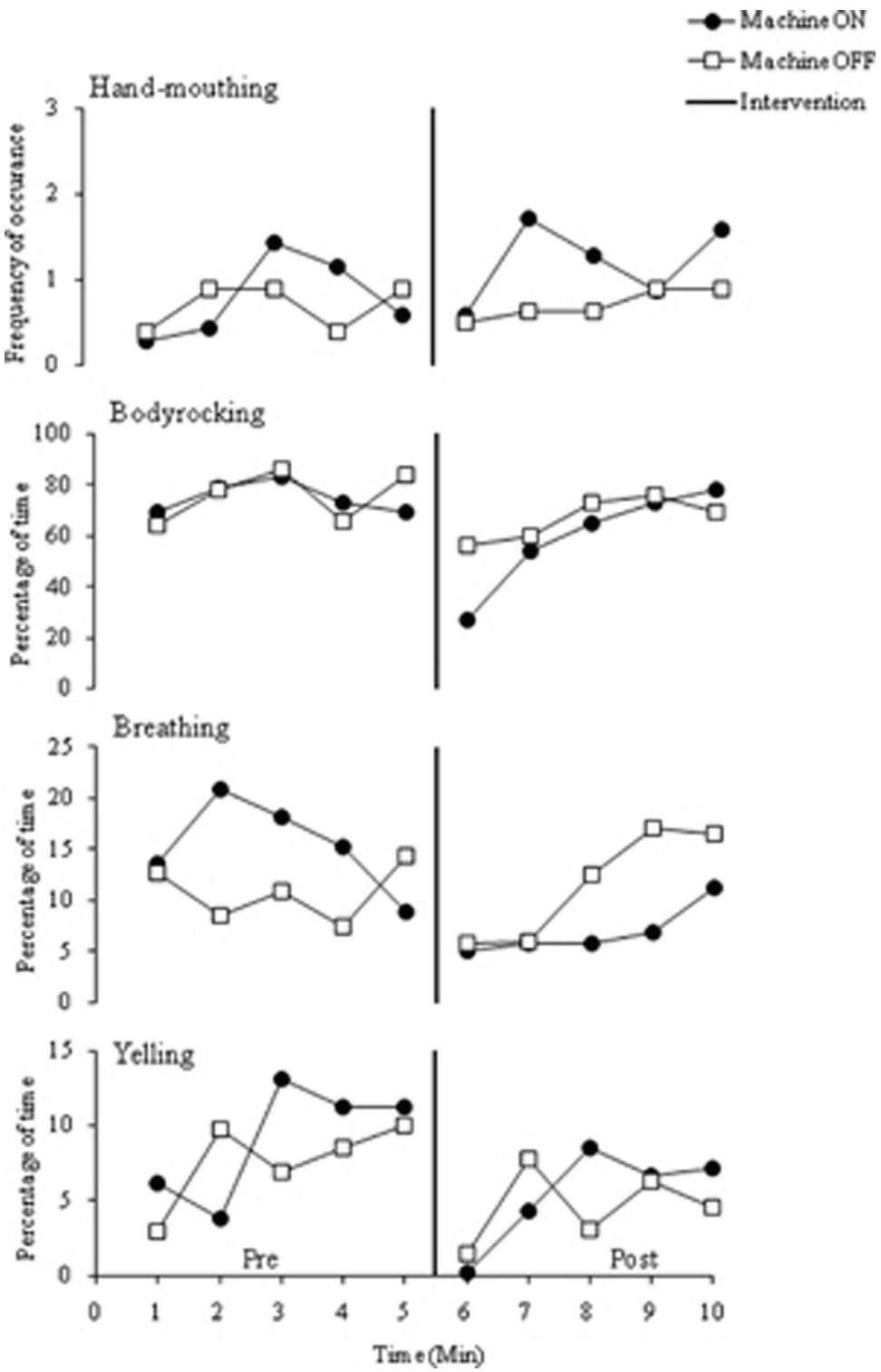

Figure 3 Stereotypy of participant two before (pre) and after (post) whole body vibration with the machine turned on (treatment) and off (control). Note that vertical axis values were scaled to improve figure resolution.

child one were 19% greater for the machine off condition (p=0.04; ES=1.6). Regarding child two, stereotypic breathing was significantly reduced (62%) in the post-test for the machine on condition (p=0.04; ES=2.1) but not when it was turned off (p=0.79; table 3). Curiously, child three displayed significantly reduced vocalisation (35%) after the vibration machine was turned on and off (p=0.03–0.04; ES=1.3–2.0; table 3). Statistical analyses for all other comparisons were not significant (p=0.07=0.98).

DISCUSSION

The unique aspect of this case report was the use of whole body vibration for treating stereotypies of young children with autism and for first demonstrating that the stereotypy

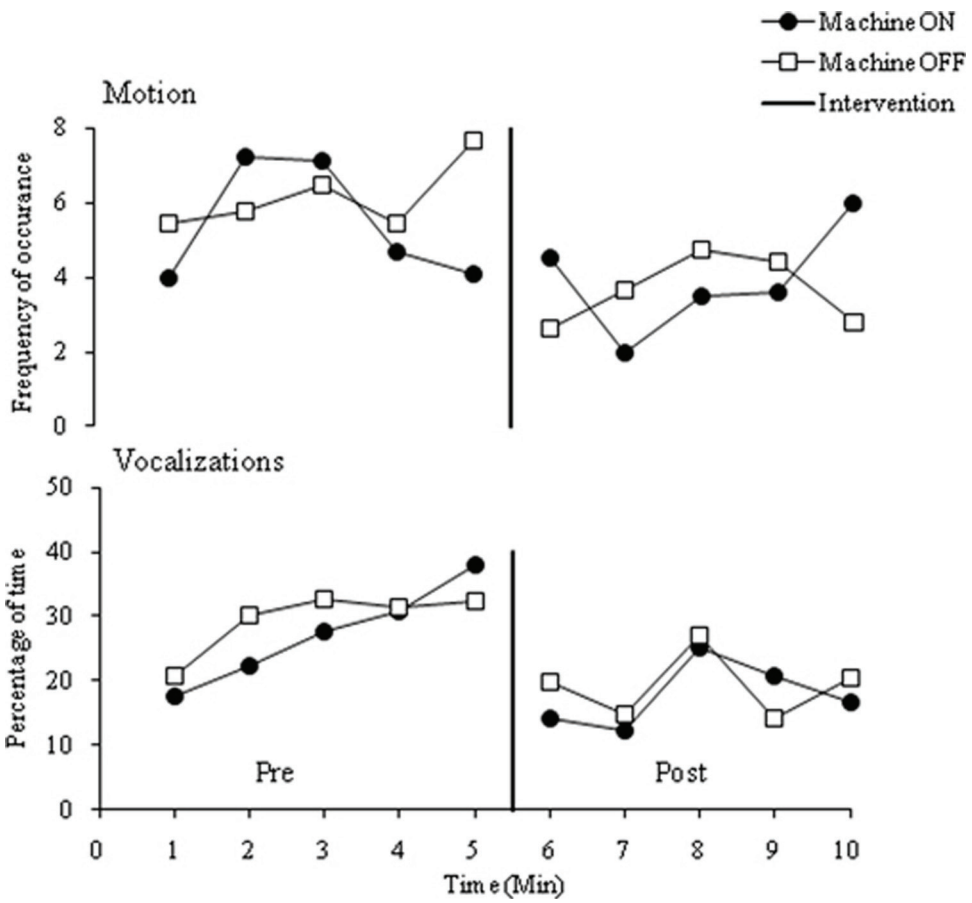

Figure 4 Stereotypy of participant three before (pre) and after (post) whole body vibration with the machine turned on (treatment) and off (control).

under examination were maintained by non-social consequences. The results revealed that whole body vibration reduced some forms of stereotypy in all children tested. However, some forms of stereotypy were not influenced and for one child simply standing on the vibration platform with it turned off reduced stereotypy (table 3).

The observation that physical oscillatory movement decreased some stereotypy is consistent with previous research using vigorous exercise protocols (jogging) to reduce stereotypy.[11 12 14–16 33–34] Curiously, mild exercise protocols (walking or ball play) have little effect on reducing stereotypy[12–13 15] suggesting that the physical movement needed to effect stereotypies should be of sufficient intensity. The intensity of whole body vibration is influenced by the platform waveform, amplitude, frequency and duration, which present a comprehensive set of controls that are likely to interact with one another. It is possible that some forms of stereotypy were not influenced in this case report (eg, child two bodyrocking) simply because the wrong intensity was chosen. Further, some stereotypies may be maintained by a unique combination of vibration characteristics (eg, longer duration and higher frequency) or a stimulus not served by whole body vibration. As this was a pilot research, we chose a common set of vibration characteristics that are effective at stimulating physiological responses in special populations.[28]

The mechanism by which whole body vibration reduces stereotypy is unknown largely because the aetiology of stereotypy is unknown.[35 36] Some have speculated that stereotypy serve as a sensory feedback[7] and whole body vibration may provide a similar sensory feedback but in a more appropriate manner. Others have suggested that stereotypy are related to abnormal dopamine levels.[36] Researchers have observed that whole body vibration influences dopamine pathways in rats[37] and hand tremors in humans with Parkinson's disease[21] suggesting vibration may influence stereotypy via the release of dopamine. Future research on this contention is clearly needed to elucidate if vibration actually affects abnormal dopamine levels in children with autism.

From a clinical perspective, it is important to note reductions in stereotypies in this case report were considered small based on ESs but that none of the children displayed a greater frequency of stereotypy after vibration. Accordingly, whole body vibration will not eliminate or decrease all stereotypies, as evidenced in table 3, and it will not statistically increase stereotypy either. To further determine if whole body vibration does more good than harm, the potential side effects of this mechanical stimulus on health-related issues should be considered. For example, young boys with autism display decreased bone health when compared to matched controls[38] which may be related to deficient nutrition and physical activity.[39] Researchers examining effects of whole body vibration on bone have observed improved bone health in young women[40] and children[24] exposed to 6–12 months

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of vibration. Accordingly, whole body vibration may have a positive effect on co-morbid health issues that adversely affect the quality of life in young children with autism. This assertion obviously needs to be researched in a systematic manner; the challenge will be in selecting the appropriate vibration parameters since the mechanism to reduce stereotypy may not be the same mechanism to stimulate bone development.

We made several subjective observations that are clinically worthy of note. First, aside from child 4 who never stepped on the vibration platform, children 1–3 enjoyed the vibration; they would smile and/or giggle when the machine was turned on. When the machine was turned off, child 3 would try to push the 'on' button suggesting that he was further seeking the sensory stimulus. Child 1 required constant tactile cues to maintain a bent knee posture. Proper knee angles are critical because they influence the amount of vibration transmitted to the head.[41] In fact, decreased knee angles (eg, no knee bend) increase the magnitude of vibration acceleration at the head.[41] Thus, to minimise damaging accelerations at the head, it is important to maintain some knee bend (≈20°) while standing on the vibration platform.[42] Child 1 may have sought a greater vibration stimulus by straightening his knees or he simply felt more comfortable in the position.

Regarding limitations of this case report, it can be observed in table 3 that frequencies of stereotypy were low in two of the three participants tested. Glasziou and Irwig[43] have argued that treatment effects of new therapies are most pronounced when given to patients with the most severe conditions. Low frequencies of stereotypy observed in two of our participants may have minimised the potential therapeutic effect of whole body vibration on reducing stereotypy. It would be of value in future research to have an inclusion criteria, where selected participants must display high rates of stereotypy based on a scale such as the Repetitive Behavior Scale-Revised.[3]

It is also important to note that stereotypies in this case report were assessed over a brief period of time and the lasting effects of the results cannot be determined. Finally, it is important to recognise that we conducted no evaluation of how the decrease in stereotypy might have improved educational outcomes. These are limitations of which future research may improve upon the design of the current study so that clinical relevance of the results may be assessed more completely.

Learning points

- Brief whole body vibration was not able to uniformly decrease the rates of all types of stereotypy. Specifically, rates of some stereotypy decreased while others were unchanged.
- From a practical perspective, whole body vibration was easy to implement in the intensive early behavioural intervention clinic and no negative side effects were observed.

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Competing interests None.

Patient consent Obtained.

REFERENCES

1. **Rice C**. Prevalence of autism spectrum disorders – autism and developmental disabilities monitoring network, United States, 2006. *MMWR* 2009;**58**:1–20.
2. American Psyciatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. Revised fourth edition. Washington, DC: American Psychiatric Association, 2000.
3. **Lam KS,** Aman MG. The Repetitive Behavior Scale-Revised: independent validation in individuals with autism spectrum disorders. *J Autism Dev Disord* 2007;**37**:855–66.
4. **Epstein LJ,** Taubman MT, Lovaas OI. Changes in self-stimulatory behaviors with treatment. *J Abnorm Child Psychol* 1985;**13**:281–93.
5. **Gabriels RL,** Cuccaro ML, Hill DE, *et al*. Repetitive behaviors in autism: relationships with associated clinical features. *Res Dev Disabil* 2005;**26**:169–81.
6. **Iwasaki K,** Holm MB. Sensory treatment for the reduction of stereotypic behaviors in persons with severe multiple disabilities. *Occup Ther J Res* 1989;**9**:170–83.
7. **Lovaas I,** Newsom C, Hickman C. Self-stimulatory behavior and perceptual reinforcement. *J Appl Behav Anal* 1987;**20**:45–68.
8. **Malone RP,** Gratz SS, Delaney MA, *et al*. Advances in drug treatments for children and adolescents with autism and other pervasive developmental disorders. *CNS Drugs* 2005;**19**:923–34.
9. **Rapp JT,** Vollmer TR. Stereotypy I: a review of behavioral assessment and treatment. *Res Dev Disabil* 2005;**26**:527–47.
10. **Smith SA,** Press B, Koenig KP, *et al*. Effects of sensory integration intervention on self-stimulating and self-injurious behaviors. *Am J Occup Ther* 2005;**59**:418–25.
11. **Petrus C,** Adamson SR, Block L, *et al*. Effects of exercise interventions on stereotypic behaviours in children with autism spectrum disorder. *Physiother Can* 2008;**60**:134–45.
12. **Kern L,** Koegel RL, Dunlap G. The influence of vigorous versus mild exercise on autistic stereotyped behaviors. *J Autism Dev Disord* 1984;**14**:57–67.
13. **Celiberti DA,** Bobo HE, Kelly KS, *et al*. The differential and temporal effects of antecedent exercise on the self-stimulatory behavior of a child with autism. *Res Dev Disabil* 1997;**18**:139–50.
14. **Elliott RO Jr,** Dobbin AR, Rose GD, *et al*. Vigorous, aerobic exercise versus general motor training activities: effects on maladaptive and stereotypic behaviors of adults with both autism and mental retardation. *J Autism Dev Disord* 1994;**24**:565–76.
15. **Levinson LJ,** Reid G. The effects of exercise intensity on the stereotypic behaviors of individuals with autism. *Adapt Phys Act Quart* 1993;**10**:255–68.
16. **Rosenthal-Malek A,** Mitchell S. Brief report: the effects of exercise on the self-stimulatory behaviors and positive responding of adolescents with autism. *J Autism Dev Disord* 1997;**27**:193–202.
17. **Rauch F**. Vibration therapy. *Dev Med Child Neurol* 2009;**51**(Suppl 4):166–8.
18. **Bosco C,** Iacovelli M, Tsarpela O, *et al*. Hormonal responses to whole-body vibration in men. *Eur J Appl Physiol* 2000;**81**:449–54.
19. **Rittweger J,** Beller G, Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin Physiol* 2000;**20**:134–42.
20. **Cochrane DJ,** Stannard SR, Sargeant AJ, *et al*. The rate of muscle temperature increase during acute whole-body vibration exercise. *Eur J Appl Physiol* 2008;**103**:441–8.
21. **Haas CT,** Turbanski S, Kessler K, *et al*. The effects of random whole-body-vibration on motor symptoms in Parkinson's disease. *NeuroRehabilitation* 2006;**21**:29–36.
22. **Semler O,** Fricke O, Vezyroglou K, *et al*. Preliminary results on the mobility after whole body vibration in immobilized children and adolescents. *J Musculoskelet Neuronal Interact* 2007;**7**:77–81.
23. **Semler O,** Fricke O, Vezyroglou K, *et al*. Results of a prospective pilot trial on mobility after whole body vibration in children and adolescents with osteogenesis imperfecta. *Clin Rehabil* 2008;**22**:387–94.
24. **Ward K,** Alsop C, Caulton J, *et al*. Low magnitude mechanical loading is osteogenic in children with disabling conditions. *J Bone Miner Res* 2004;**19**:360–9.
25. **Bressel E,** Smith G, Branscomb J. Transmission of whole body vibration in children while standing. *Clin Biomech (Bristol, Avon)* 2010;**25**:181–6.
26. **McMillan JH**. *Educational Research: Fundamentals for the Consumer*. Fourth edition. Boston, MA: Allyn and Bacon 2004.
27. **Iwata BA,** Dorsey MF, Slifer KJ, *et al*. Toward a functional analysis of self-injury. *J Appl Behav Anal* 1994;**27**:197–209.

28. **Madou K,** Cronin J. The effects of whole body vibration on physical and physiological capability in special populations. *Hong Kong Physiot J* 2008;**26**:24–38.
29. **Miltenburger R,** Rapp J, Long E. A low-tech method for conduction real-time recording. *J Appl Beh Anal* 1999;**32**:119.
30. **Cohen J**. *Statistical Power Analysis for the Behavioral Sciences*. Second edition. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc 1988.
31. **Busk P,** Serlin R. Meta-analysis for single-case research. In: Kratochwill T, Levin J, eds. *Single-Case Research Design and Analysis: New Directions for Psychology and Education*. Mahwah NJ: Lawrence Erlbaum Associates, Inc 1992;187–212.
32. **Beeson PM,** Robey RR. Evaluating single-subject treatment research: lessons learned from the aphasia literature. *Neuropsychol Rev* 2006;**16**:161–9.
33. **Kern L,** Koegel RL, Dyer K, *et al*. The effects of physical exercise on self-stimulation and appropriate responding in autistic children. *J Autism Dev Disord* 1982;**12**:399–419.
34. **Watters RG,** Watters WE. Decreasing self-stimulatory behavior with physical exercise in a group of autistic boys. *J Autism Dev Disord* 1980;**10**:379–87.
35. **Turner M**. Annotation: Repetitive behaviour in autism: a review of psychological research. *J Child Psychol Psychiatry* 1999;**40**:839–49.
36. **Lewis M,** Kim S. The pathophysiology of restricted repetitive behavior. *J Neurodev Disord* 2009;**1**:114–32.
37. **Nakamura H,** Moroji T, Nohara S, *et al*. Activation of cerebral dopaminergic systems by noise and whole-body vibration. *Environ Res* 1992;**57**:10–18.
38. **Hediger ML,** England LJ, Molloy CA, *et al*. Reduced bone cortical thickness in boys with autism or autism spectrum disorder. *J Autism Dev Disord* 2008;**38**:848–56.
39. **Pan CY,** Frey GC. Physical activity patterns in youth with autism spectrum disorders. *J Autism Dev Disord* 2006;**36**:597–606.
40. **Gilsanz V,** Wren TA, Sanchez M, *et al*. Low-level, high-frequency mechanical signals enhance musculoskeletal development of young women with low BMD. *J Bone Miner Res* 2006;**21**:1464–74.
41. **Harazin B,** Grzesik J. The transmission of vertical whole-body vibration to the body segments of standing subjects. *J Sound Vib* 1998;**215**:775–87.
42. **Griffin MJ**. *Handbook of Human Vibration*. London, UK: Academic Press 1996.
43. **Glasziou PP,** Irwig LM. An evidence based approach to individualising treatment. *BMJ* 1995;**311**:1356–9.