Asian Exercise and Sport Science Journal
2588-4832 www.aesasport.com
Vol.4 No.2
Received: March 2020 , Accepted: June 2020 , Available online: August 2020

DOI: https://doi.org/10.30472/aesj.v4i2.140

Effects of vibration on mechanical efficiency during cycling

A Hawkey[1, 2], D Robbins,[3]
[1]Faculty of Sport, Health and Social Sciences, Solent University, Southampton, UK. [2]School of Medicine, University of Dundee, UK. [3]Faculty of Health, Education, Medicine and Social Care, Anglia Ruskin University, Chelmsford, UK. ***Corresponding author***: Assoc. Professor Adam Hawkey (adam.hawkey@solent.ac.uk)

ABSTRACT
While efficiency has been identified as a key determinant of endurance cycling performance, there is limited research investigating how vibration may influence this factor. Therefore, this feasibility study aimed to assess the effects of vibration on mechanical efficiency during cycling performance. Following institutional ethics approval, 20 undergraduate students (Mean ± SD Age = 22.35 ± 2.78 yrs.; Height = 1.77 ± 0.08 m; Mass = 87.02 ±16.63 Kg) cycled for 15 minutes on a stationary Power Plate powerBIKE™ ergometer in both vibration and non-vibration conditions. During each condition, the gross mechanical efficiency (GE) was calculated. A Wilcoxon signed rank statistical test reported a significant increase (P < 0.001) in oxygen consumption during the vibration condition (24.5 ± 3.8 $ml.kg.min^{-1}$) compared to the non-vibration condition (16.9 ± 2.7 $ml.kg.min^{-1}$). Subsequently, there was a significant reduction (P < 0.001) in GE during the vibration condition (15.77 ± 2.8%) compared to the non-vibration condition (23.1 ± 3.5%). Findings therefore suggest that being exposed to vibration during cycling has the potential to significantly increase energy demand, and negatively affect an individual's efficiency. This has implications for the cyclist as increased oxygen consumption, without increased cadence or resistance, will negatively affect performance. Further investigation is now required to ascertain how vibration affects efficiency during cycling, to evaluate methods designed to dampen vibration transmission, and to better prepare cyclists for such exposure.
KEY WORDS: vibration, cycling, mechanical efficiency, gross mechanical efficiency

INTRODUCTION
Mechanical efficiency (ME), defined as external work accomplished ÷ energy input x 100 [26], is regularly used by exercise professionals to ascertain how much energy is used in relation to the minimal amount of work required to complete a task or movement [27]. While it has been reported that other variables, such as VO_{2max} and lactate threshold, can account for more of the variance in cycling power output [20], previous research has identified efficiency to be a key determinant of endurance cycling performance [5]; with approximately 30% of the power output during cycling time-trials attributed to this factor [22]. It has

been shown that exercise training can potentially enhance efficiency; with research reporting improvements over one [18] and multiple seasons [42] it has been speculated that increases in efficiency could be directly related to the volume and intensity undertaken by cyclists [22]. Interestingly, this high-intensity type training, popular in a range of sport and fitness settings [1], has been reported to be the most effective exercise intervention for improving efficiency in a cycling population [19].

In addition to research into the effectiveness of training programmes, there have been several studies investigating interactions relating to the bicycle/cyclist system. These have primarily focused on the measurement of loads transmitted to the cyclist [2,8,9], and on factors concerned with ride comfort [31,46]. Furthermore, a small number of researchers have observed the vibration transmissibility of the bicycle and its components [13,25,33]. Vibration transmission is considered important as exposure, particularly during road cycling, has been identified as a potential risk factor for overuse injuries, decreased performance, increased discomfort and physiological inefficiency [30]. This is not surprising as exposure to vibration is generally regarded as detrimental to human health; in the workplace it is tightly controlled by the International Organization for Standardization (ISO) [21]. Research into continued exposure to vibration, such as that observed with pneumatic drill workers and those who regular operate cars, boats and aircraft, has revealed deleterious effects on the musculoskeletal and nervous systems [11,23,29,38]. However, and somewhat paradoxically, vibration has also been utilised extensively in a sport and exercise context, in the form of whole body vibration training (WBVT) and hand-held vibration training (HHVT), to elicit various benefits on human health and performance. These have included increased bone density [4,40,47], improved insulin sensitivity [3], alleviation of symptoms association with rheumatoid arthritis [24], reduced lower back pain [35], greater postural control [47], improved balance [37], and enhanced grip, jumping, sprinting and flexibility performance [6,14,15,32].

While vibration training has received wide interest and popularity in sports including soccer, volleyball, basketball and judo, the majority of research in cycling has been concentrated on its possible effects on the cardiovascular system. One such study, by Sperlich *et al*. (2009), observed an increase in maximal oxygen consumption (VO_{2max}) with vibration exposure, compared to normal cycling, when performing a maximal incremental cycling test [43]. Increases in oxygen consumption from whole body exercise has been shown to increase with higher frequencies and amplitudes [7,36], with effects lasting for at least 24 hours [17]. However, to date, these effects have not been tested in cycling with vibration. Other research, conducted by Suhr et al. (2007), reported that vibration applied during cycling was effective at stimulating the angiogenesis (new blood vessel formation) process [44]. Additionally, Samuelson et al. (1989) observed that vibration reduced work capacity during an incremental cycling exercise to exhaustion test [41]. Filingeri *et al* (2012) assessed the impact of adding vibration during cycling on physiological parameters related to the cardiovascular, pulmonary and energetic systems [12]; increases in heart rate, blood lactate and rate of perceived exertion during the vibration condition, compared to traditional cycling, were all reported [12].

While these studies have contributed to the body of knowledge regarding vibration and cycling, the range of research questions addressed in a relatively small number of publications has resulted in a weak evidence base. Specifically, there is still limited data relating to the effects of vibration on ME during cycling. Therefore, considering the limitations of the restricted volume of research investigating the influence of vibration on human physiology during cycling, this investigation aims to provide fundamental data on the influence of vibration on oxygen consumption during use of a bicycle ergometer.

METHODS

Following institutional ethics approval, and in accordance with the latest delineation of the Helsinki Declaration [49], 20 (male = 17; female = 3) undergraduate students (Mean ± SD: Age = 22.35 ± 2.78 yrs.; Height = 1.77 ± 0.08 m; Mass = 87.02 ±16.63 Kg) were recruited using the convenience sampling method. Following a standardised, incremental, 5-minute warm-up on a stationary cycle ergometer, all participants cycled for a further 15 minutes in vibration and non-vibration conditions. This was standardised at a rate of 80W, which equated to 70RPM and 65RPM in the non-vibration and vibration conditions respectively. The vibration frequency at a cadence of 65 RPM equated to 21.25 Hz. The difference in RPM was necessary due to the vibration mechanism increasing resistance; therefore, in order to maintain consistent power, the RPM was reduced in the vibration condition. To allow for sufficient recovery [28,48], and to minimise any learning effects, participants completed the conditions over two days, separated by 48 hrs, in a randomised order. Sessions were completed at the same time of day (± 1 hr.) to avoid the confounding influence of circadian variation [10,45]. All exercise testing was performed on a powerBIKE^{TM} (Power Plate International Ltd, London, UK); a stationary bike allowing for both vibration and control conditions (Figure 1a-1b) used in previous pilot studies [12]. A manual switch integrated into the handlebar activated or deactivated the vibration mechanism, which was located in the bike's crank. When engaged, vibration was transmitted to the lower limbs from the crank via the pedals. When the vibration system was not engaged, the system functioned as would be the case on a normal cycle ergometer.

Figure 1a. The powerBIKE™ cycle ergometer used in the current study

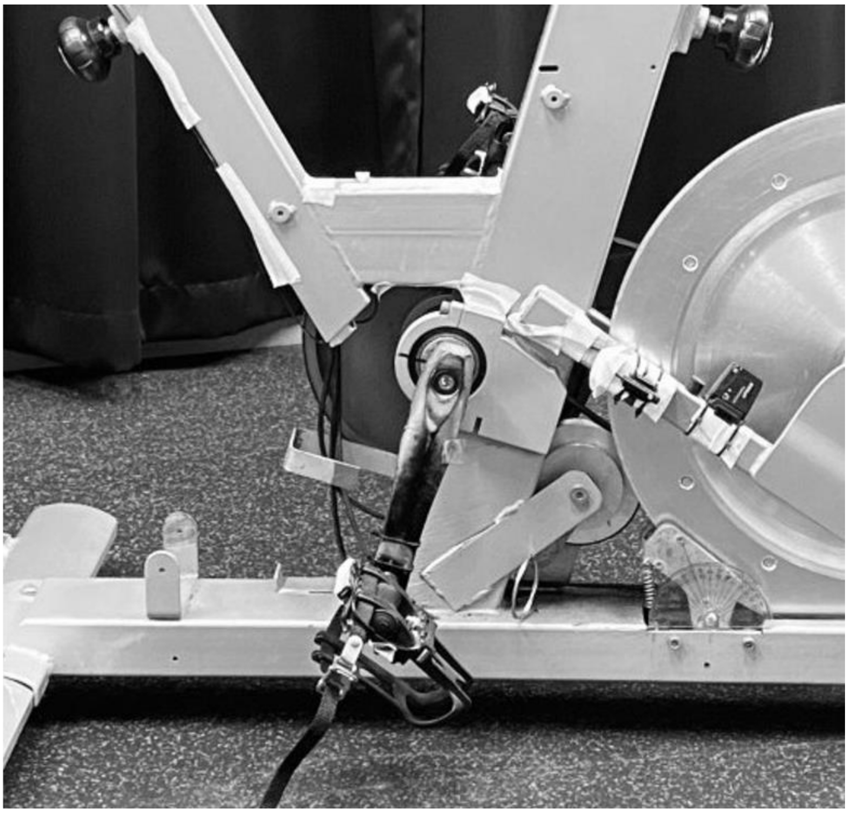

Figure 1b. Close up detail of the vibration mechanism on the powerBIKE™

During each condition, oxygen consumption was collected and measured using a Cortex Meta Control 3000 (Figure 2), from which the gross mechanical efficiency (GE: a simpler variant of ME without correction for restful oxygen intake) was calculated.

Figure 2. Equipment set-up showing participant cycling on powerBIKE™ while oxygen consumption was measured using a Cortex Meta Control 3000

RESULTS

Data from the two conditions was entered into the statistical package for social sciences (SPSS: v22). As the vibration data was not normally distributed, a Wilcoxon signed rank test was used to analyse the data to determine any mean differences. The Wilcoxon signed rank test reported a significant increase ($P < 0.001$) in oxygen consumption during the vibration condition compared to the non-vibration condition (Figure 3; Table 1). Subsequently, there was also a significant reduction ($P < 0.001$) in GE during the vibration condition compared to the non-vibration condition (Figure 4; Table 1).

	Oxygen consumption ($ml.kg.min^{-1}$)	Gross efficiency (%)
Vibration	24.5 ± 3.8	15.77 ± 2.8
Control	16.9 ± 2.7	23.1 ± 3.5

All values presented as mean ± standard deviation

Table 1. Effects of vibration on oxygen consumption and gross efficiency

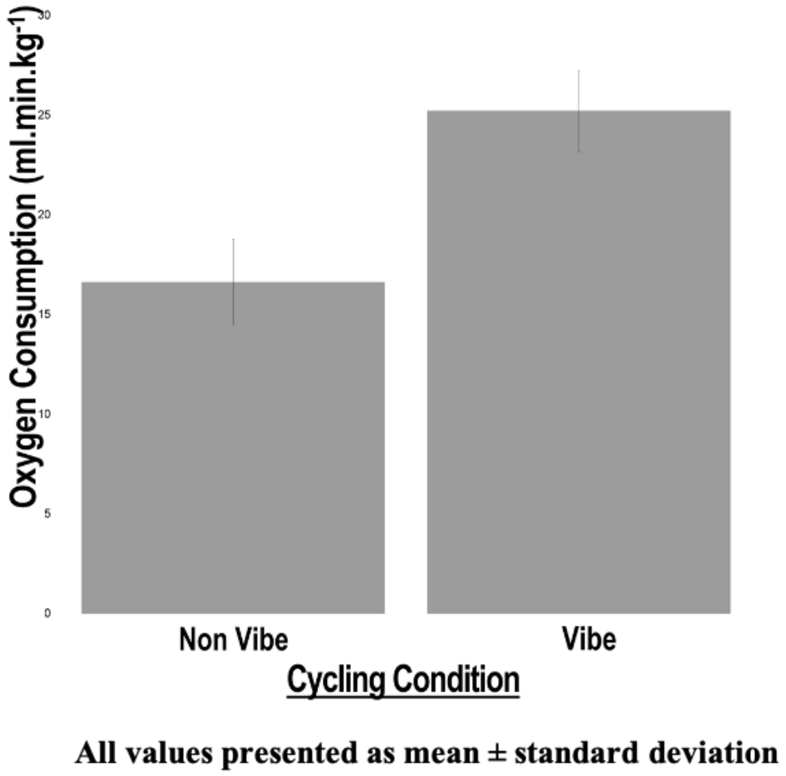

Figure 3. Graph showing increase in oxygen consumption during the vibration condition

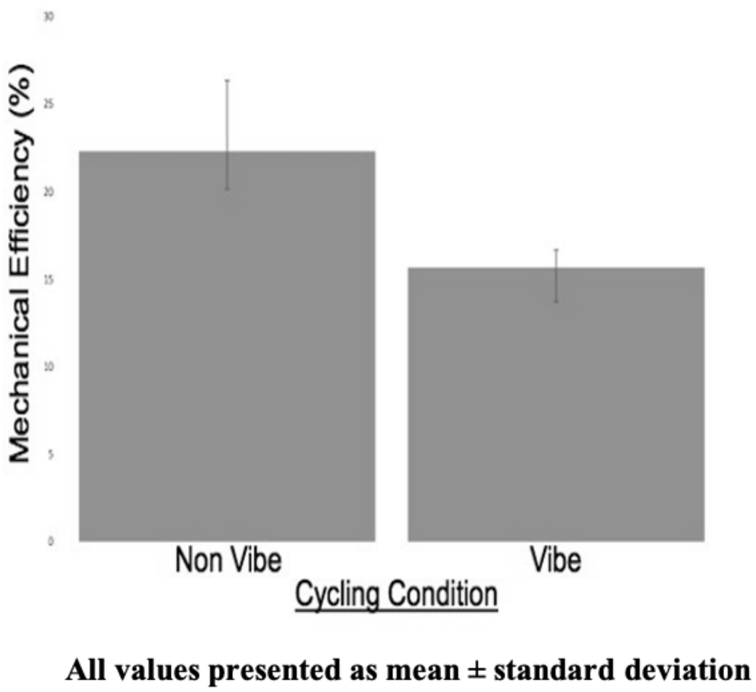

Figure 4. Graph showing reduction in gross efficiency during the vibration condition

DISCUSSION

Previous research has identified that efficiency is a key determinant of endurance performance [5] and that vibration exposure during cycling can be a potential risk factor for overuse injuries, decreased performance, increased discomfort and physiological inefficiency [30]. Despite the acknowledged importance of vibration exposure during cycling though, only a small number of researchers have investigated its direct impact on efficiency and performance. Sperlich *et al*. (2009) and Samuelson et al. (1989) observed an increase in maximal oxygen consumption [43] and reduced work capacity [41], respectively, with vibration exposure. Both of these studies employed a methodology that mounted the bike's frame on to a vibrating platform though; with only the crank connected to the vibrating source and transmitting vibration to the lower limbs. Filingeri *et al* (2012) used a specialised ergometer (powerBIKE^{TM}), which enabled vibratory signals to be better transmitted to the cyclist [12]; Filingeri *et al* (2012) assessed the impact of adding vibration during cycling on physiological parameters related to the cardiovascular, pulmonary and energetic systems; observing increases in heart rate, blood lactate and rate of perceived exertion during the vibration condition, compared to traditional cycling, were all reported [12]. However, while these studies have made a valuable contribution to the knowledge available relating to vibration and cycling, there is still limited data concerning the specific effect of vibration on efficiency during cycling. Therefore, the purpose of the current study was to examine if vibration had any influence on efficiency during cycling.

The main finding of the current study is that being exposed to vibration during cycling has an influence on oxygen consumption and efficiency. Similar to research by Sperlich et al (2009), the current study showed that vibration exposure significantly increased oxygen consumption compared to the corresponding normal cycling condition. The results are not entirely comparable though as, while the current study reported this increase at 80w, Sperlich *et al* (2009) reported no increase in oxygen uptake at lower intensities (100w, 150w and 200w); only those high intensity workloads (250w and 300w) showed any increase [43]. That the current study found a reduction in efficiency with vibration exposure also demonstrates agreement with that of Samuelson *et al* (1989), who reported that imposed vibration during incremental cycling exercise to exhaustion reduced work capacity [41]. However, it is difficult to directly compare these studies to the current investigation due to differences in experimental protocols, the different equipment used for testing, and the likely variation of performance level and training experience of the participants.

Despite this, there appears to be a very practical application for the current study that may be beneficial for cyclists. With anecdotal evidence, supported by scientific studies [13,25,33], that riding on some surfaces exposes cyclists to increased vibration, the current findings illustrate the increased demands caused by vibration during cycling and potentially serve as an advisory for cyclists to undertake specific training to counteract the negative effects these vibrations may have on performance. This familiarisation, or acclimatisation, could potentially increase individuals' tolerance to vibration and may prove to be beneficial; both for performance and health reasons.

Limitations and delimitations

While this current study clearly supports the notion that vibration exposure increases oxygen consumption and reduces efficiency during cycling, there are some limitations in study design that need to be acknowledged. Firstly, despite all participants being required to continue with their usual exercise regimes and nutritional intake throughout the duration of the testing, this was not strictly controlled outside the confines of the current study. It is, therefore, feasible that participants undertook additional training during the intervention and thus do not exclude the possibility that this influenced results. However, that the conditions were carried out in a randomised order and that sessions were completed at the same time of day, to avoid the confounding influence of circadian variation, supports the view that any changes in oxygen consumption and efficiency were largely attributable to the vibration exposure. Also, while consistent for each individual cyclist throughout the two conditions, a lack of standardisation over certain biomechanical variables, including participant positioning on the bike, seat height, and saddle position, could have had a bearing on results. Engaging the vibration mechanism introduces an increase in resistance, therefore the exact cadence could not be used for both conditions of the intervention. To minimise the impact of this cadences of 65 and 70 RPM, for vibration and traditional cycling respectively, were selected. These values are not only relatively close cadences but created a resistance which required 80 W of power during cycling. None of the participants were regular cyclists, therefore regular and/or competitive cyclists may respond differently to the vibration stimulus. At this point in time, the amplitude of vibration is not known, therefore this should be considered as a factor unaccounted for within the results.

Future research

There are some interesting areas of future research that could yield further benefits in this relatively novel field. The effects of vibration during cycling on heart rate, heart rate variability, blood pressure, and peripheral cardiovascular function all are worth considering. There is also potential to develop equipment designed to help minimise some of the unwanted effects of vibration during cycling; including gloves, padding, and handlebar grips [38]. The magnitude of the vibration is not currently known, therefore future studies should investigate the influence of cadence and mass of the rider on vibration magnitude. An opportunity also exists to conduct further electromyography (EMG) studies to evaluate the direct effect that vibration exposure has on muscle activity during cycling performance. Outside of performance cycling, exploring the benefits of vibration exposure during cycling are also possible. With research indicating that vibration exposure has the potential to increase bone mineral density [4,40,47] and to selectively target muscles [39], perhaps deliberately using cycling (which is already established as a low impact exercise intervention for maintaining cardiovascular fitness) with the addition of a vibration stimulus could be utilised in the prevention/treatment of osteoporosis and related diseases.

CONCLUSIONS

The findings of the current study suggest that being exposed to vibration during cycling has the potential to significantly increase energy demand, and negatively affect an individual's efficiency. This has implications for the cyclist as increased oxygen consumption, without increased cadence or resistance, in terms of cycling training will negatively affect performance. It is, therefore, recommended that cyclists utilise vibration exposure in a training environment for the potential benefit of increasing their tolerance to the vibration they may encounter during competition. Further investigation is now required to ascertain how vibration could affect muscle activation during cycling and evaluate methods designed to dampen such exposure.

ACKNOWLEDGEMENTS:

Thank you to Pierre Hockey and Kieran Bedford for their assistance with data collection.

REFERENCES

1. Adamson S. Lorimer R. Cobley J.N. Lloyd R. Babraj J. (2014). High intensity training improves health and physical function in middle aged adults. *Biology*, 3: 333-344.

2. Arpinar-Avsar P. Birlik G. Sezgin ÖC. Soylu AR. (2013). The Effects of Surface-Induced Loads on Forearm Muscle Activity during Steering a Bicycle. *Journal of Sports Science and Medicine* 12: 512- 520

3. Babraj J. Hawkey A. (2017). Improved insulin sensitivity following a short-term whole body vibration intervention. *Al Ameen Journal of Medical Sciences*, 10(1): 3-9.

4. Belavý DL. Beller G. Armbreicht G. Perschel FH. Fitzner R. Bock O. Börst H. Degner C. Gast U. Felsenberg D. (2011). Evidence for an additional effect of whole-body vibration above resistive exercise alone in preventing bone loss during prolonged bed rest. *Osteoporosis International*. 22(5), 1581-1591.

5. Coyle E.F. (1995). Integration of the physiological factors determining endurance performance ability. *Exercise and Sport Science Reviews*, 23: 25-64.

6. Delecluse C. Roelants M. Verschueren S.M. (2003). Strength increases after whole- body vibration compared with resistance training. *Medicine and Science in Sports and Exercise*, 35: 1033-1041.

7. Di Iorio, F., Cesarelli, M., Bifulco, P., Fratini, A., Roveda, E. and Ruffo, M. (2012) The Effect of Whole Body Vibration on Oxygen Uptake and Electromyographic Signal of the Rectus Femoris Muscle during Static and Dynamic Squat. *Journal of Exercise Physiology Online*, 15(5).

8. Drouet J. Champoux Y. Dorel S. (2008). *Development of Multi-platform Instrumented Force Pedals for Track Cycling* (P49). In: The Engineering of Sport 7. Springer: Paris. pp. 263-271.

9. Drouet J. Champoux Y. (2010). A novel dynamometric hubset design to measure wheel loads in road cycling. *Procedia Engineering*, 2: 2925-2930.

10. Drust B. Waterhouse J. Atkinson G. Edwards B. Reilly T. (2005). Circadian rhythms in sports performance: An update. *Chronobiology International*, 22: 21-44.

11. Falou W. E. Duchêne J. Grabisch M. Hewson D. Langeron Y. Lino F. (2003). Evaluation of driver discomfort during long-duration car driving. *Applied Ergonomics*, 34(3): 249-255.

12. Filingeri D. Jemni M. Bianco A. Zeinstra, E. Jimenez A. (2012). The effects of vibration during maximal graded cycling exercise: a pilot study. *Journal of Sports Science and Medicine*, 11: 423-429.

13. Giubilato F. Petrone, N. (2012). A method for evaluating the vibrational response of racing bicycles wheels under road roughness excitation. *Procedia Engineering*, 34: 409-414

14. Hawkey A. (2019). Short-term hand-held vibration training benefits handgrip strength in competitive judokas. *Journal of Sport and Human Performance*, 7(2): 1-11.

15. Hawkey A. Morrison D. (2017). In-season whole-body vibration training enhances vertical jump performance in professional soccer goalkeepers. *Turkish Journal of Sport and Exercise*, 19(2): 143-149.

16. Hawkey A. Rittweger J. Rubin C. (2016). Vibration exercise: evaluating its efficacy and safety on the musculoskeletal system. *The Sport and Exercise Scientist*, 50: 26-27.

17. Hazell, T.J. Lemon, P.W.R. (2012) Synchronous whole-body vibration increases VO 2 during and following acute exercise. *European Journal of Applied Physiology*, 112(2): 413-420.

18. Hopker J. Coleman D. Passfield L. (2009). Changes in cycling efficiency during a competitive season. *Medicine and Science in Sports and Exercise*, 41: 912–919.

19. Hopker J.G. Coleman D.C. Passfield L. Wiles J.D. (2010). The effect of training volume and intensity on competitive cyclists' efficiency. *Applied Physiology, Nutrition and Metabolism*, 35: 17-22.

20. Hopker JG. Jobson SA. Coleman D. Passfield L. (2012). Inverse relationship between VO2max and gross efficiency. *International Journal of Sports Medicine*, 33(10): 789-94.

21. International Organization for Standardization (ISO) (1997). *ISO. 2361-1*. In Organization IS (ed). Mechanical vibration and shock: evaluation of human exposure to whole body vibration. Geneva, Switzerland.

22. Jobson S. Hopker JG. Korff T. Passfield L. (2012). Gross efficiency and cycling performance: a review. *Journal of Science and Cycling*, 1(1): 3-8.

23. Keith SE. Brammer AJ. (1994). Rock drill handle vibration: measurement and hazard estimation. *Journal of Sound and Vibration*, 174(4): 475-491.

24. Kumari R. Wyon M. Hawkey A. Metsios G. (2011). Effects of vibration on disease activity scores in patients with rheumatoid arthritis: a case study. *Journal of Sports Therapy*, 4(1): 30-33.

25. Lépine J. Champoux Y. Drouet J-M. (2013). Road bike comfort: on the measurement of vibrations induced to cyclist. *Sports Engineering*, 17: 113-122.

26. McArdle W.D. Katch F.I. Katch V.L. (2015). *Essentials of Exercise Physiology (5th Edition). Wolters Kluwer: Philadelphia*.

27. McBride J.M. Davis J.A. Alley J.R. Knorr D.P. Goodman C.L. Snyder J.G. Battista, R.A. (2015). Index of mechanical efficiency in competitive and recreational long distance runners. *Journal of Sports Sciences*, 33(13): 1388-1395.

28. McLester J.R. Bishop P.A. Smith J. Wyers L. Dale B. Kozusko J. Richardson M. Nerett M.E. Lomax R. (2003) A series of studies – A practical protocol for testing muscular endurance recovery. *Journal of Strength and Conditioning Research*, 17(2): 259-273.

29. Mester J. Spitzenfeil P. Schwarzer J. Seifriz F. (1999) Biological reaction to vibration-implications for sport. *Journal of Science and Medicine in Sport*, 2(3): 211-226.

30. Munera M. Chiementin X. Crequy S. Bertucci W. (2014). Physical risk associated with vibration at cycling. *Mechanics and Industry*, 15(6): 535-540.

31. Olieman M, Marin-Perianu R, Marin-Perianu M (2012). Measurement of dynamic comfort in cycling using wireless acceleration sensors. *Procedia Engineering*, 34: 568-573

32. Paradisis G. Zacharogiannis E. (2007). Effects of whole-body vibration on sprint running kinematics and explosive strength performance. *Journal of Sports Science and Medicine*, 6(1): 44-49.

33. Petrone N. Giubilato F. (2011). Comparative Analysis of Wheels Vibration Transmissibility after Full Bicycle Laboratory Tests. *AIAS*: 147.

34. Ratamess N.A. Alvar B.A. Evetoch T.K. Housh T.J. Kibler W.B. Kraemer W.J. Triplet N.T. (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise*, 41: 687-708.

35. Rittweger J. Just K. Kautzsch K. Reeg P. Felsenberg D. (2002). Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: a randomized controlled trial. *Spine*, 27(17): 1829-34.

36. Rittweger, J., Ehrig, J., Just, K., Mutschelknauss, M., Kirsch, K.A. and Felsenberg, D. (2002) Oxygen uptake in whole-body vibration exercise: influence of vibration frequency, amplitude, and external load. *International Journal of Sports Medicine*, 23(6): 428-432.

37. Ritzmann R. Kramer A. Bernhardt S. Gollhofer A. (2014). Whole body vibration training – improving balance control and muscle endurance. *PLoS ONE*, 9(2): e89905.

38. Robbins D. Zeinstra, E. Jimenez A. Goss-Sampson M. (2012) Does whole body vibration have clinically significant neurophysiological and neurovascular implications? *International Journal of Prevention and Treatment*, 1(2): 18-26.

39. Robbins, D. Goss-Samspon M. (2013) The influence of whole body vibration on the plantarflexors during heel raise exercise. *Journal of Electromyography and Kinesiology* 23 614-618.

40. Rubin C. Turner AS. Bain S. Mallinckrodt C. McLeod K. (2001). Anabolism: Low mechanical signals strengthen long bones. *Nature*, 412: 603-604.

41. Samuelson B. Jorfeldt L. Ahlborg B. (1989). Influence of vibration on work performance during ergometer cycling. *Upsala Journal of Medical Sciences*, 94(1): 73-79.

42. Santalla A. Naranjo J. Terrados N. (2009). Muscle efficiency improves over time in world-class cyclists. *Medicine and Science in Sports and Exercise*, 41: 1096–1101.

43. Sperlic B. Kleinoeder H. de Marees M. Quarz D. Linville J. Haegele M. Mester J. (2009). Physiological and perceptual responses of adding vibration to cycling. *Journal of Exercise Physiology*, 12(2): 40-46.

44. Suhr F. Brixius K. de Marees M. Bolck, B. Kleinoder H. Achtzehn S. Bloch, W Mester J. (2007). Effects of short-term vibration and hypoxia during high-intensity cycling exercise on circulating levels of angiogenic regulators in humans. *Journal of Applied Physiology*, 103: 474-483.

45. Teo W. Newton M.J. McGuigan M.R. (2011) Circadian rhythms in exercise performance: implications for hormonal and muscular adaptation. *Journal of Sports Science and Medicine*, 10(4): 600-606.

46. Thite AN. Gerguri S. Coleman F. Doody M. Fisher N. (2013). Development of an experimental methodology to evaluate the influence of a bamboo frame on the bicycle ride comfort. *Vehicle System Dynamics*, 51(9): 1-18.

47. Verschueren S.M.P. Roelants M. Delecluse C. Swinnen S. Vanderschueren D. Boonen S. (2004). Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: A randomized controlled pilot study. *Journal of Bone and Mineral Research*, 19: 352–359.

48. Westcott W.L. (2010). How often should clients perform strength training? *ACSM's Certified News*, 20(2): 10-11.

49. World Medical Association. (2013) World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *Journal of the American Medical Association*, 310: 2191-2194.