UNIVERSITI PUTRA MALAYSIA

PREDICTING SEAT TRANSMISSIBILITY OF SEATED HUMAN BODY ON SUSPENSION SEAT EXPOSED TO VERTICAL WHOLE-BODY VIBRATION

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FK 2021 37

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By

SITI AISYAH BINTI ADAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

September 2020

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chair : Nawal Aswan bin Abdul Jalil, PhD, PEng
Faculty : Engineering

Exposure to a whole-body vibration is an occupational risk factor, which leads to research interests in biodynamic responses of a human body. The knowledge of biodynamic responses of a seated human body on a suspension seat are limited as previous studies were merely focused on the rigid and conventional seats. The main objective of this thesis is to predict the seat transmissibility of a seated human body on the agriculture suspension seat. In addition, factors affecting the seat transmissibility and the apparent mass, such as postures and vibration magnitudes are also investigated. In the first experiment, the vertical seat transmissibility and the Seat Effective Amplitude Transmissibility (SEAT) values were measured. Eleven healthy male subjects aged between 21 to 35 years old, with a mean weight and height of 61.5 kg, and 1.68 m, respectively participated in the study. All the subjects were exposed to random vertical vibration in the range of 1 to 20 Hz, at three vibration magnitudes (0.5, 1.0 and 2.0 m/s^2 r.m.s.) for 60 s. For each exposure, four postures were investigated (“relax”, “slouch”, “tense”, and “backrest”). The results showed that the primary resonance frequency of the seat transmissibility for every posture was pronounced between 1.7 and 2.5 Hz. The transmissibility at the resonance was the highest for the “backrest” condition. The results of SEAT values revealed that “slouch” posture showed the highest value (64.7%). In the second experiment, the apparent mass of a seated human body on a rigid and suspension seat were measured. Two sitting conditions were investigated – i) without the backrest and ii) with the vertical rigid backrest. The experimental measurement revealed a lower peak magnitude and resonance frequency of apparent mass without the backrest for a suspension seat (4.0 to 5.2 Hz), as compared to those measured with a rigid seat (4.5 to 5.4 Hz). For both seats, there was a reduction in the peak of apparent mass when in contact with a backrest. In both experiments, there was a reduction in the primary resonance frequency of the seat transmissibility and the apparent mass with an increase in the vibration magnitude, suggesting a non-linearity in the suspension seat-human system. Using the measured apparent mass of the seated human body on suspension seat, a two-degree-of-freedom lumped parameter model was developed. The model was able to fit the measured responses of the body in various sitting conditions (with and without the backrest). The modelling found that when a human body was in contact with the backrest, the mass decreased and the stiffness increased, resulting in an increase in the derived damped natural frequency. A combined three-degree-lumped-parameter of suspension seat-human body model was developed to predict the suspension seat transmissibility. The model was capable in predicting the seat transmissibility by minimizing the sum-of-least-squares error between the experimental measurements and the model prediction. It was found that the performance of the suspension seat did not depend on the suspension mechanism alone, but rather on the combination of the seated human body with the suspension seat. This research shows that the vibration transmission of a suspension seat can be predicted. Such predictions will assist the optimization of the suspension seat, and thus reduce the time needed to assess the suspension seat performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MERAMAL KEBOLEHPINDAHAN GETARAN MENEGAK SELURUH BADAN PADA MANUSIA KETIKA DUDUK DIKERUSI PENGGANTUNGAN

Oleh

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Pendedahan kepada getaran seluruh badan merupakan risiko pekerjaan, yang menjadi tumpuan dalam penyelidikan respon biodinamik badan manusia. Pengetahuan mengenai respon biodinamik manusia ketika duduk dikerusi sistem penggantungan adalah terhad, kerana kajian terdahulu banyak memberi fokus kepad kerusi rigid dan konvensional. Objektif utama tesis ini adalah untuk menjangka kebolehpindahan getaran kerusi terhadap manusia ketika duduk dikerusi penggantungan pertanian. Selain itu, faktor-faktor yang mempengaruhi kebolehpindahan getaran kerusi dan jisim nyata, seperti postur dan magnitud getaran turut dikaji. Dalam eksperimen pertama, kebolehpindahan getaran kerusi secara menegak dan nilai Kebolehpindahan Efektif Amplitud Kerusi (SEAT) diukur. Sebelas subjek lelaki yang sihat, berumur sekitar 21 hingga 35 tahun, dengan min berat 61.5 kg dan min tinggi 1.68 m mengambil bahagian dalam kajian. Kesemua subjek didedahkan kepada getaran rawak menegak dalam julat 1 hingga 20 Hz, pada tiga magnitude getaran (0.5, 1.0 and 2.0 m/s^2 punca min kuasa dua) selama 60 saat. Pada setiap pendedahan getaran, empat postur diselidik (“mengendur”, “membongkok”, “menegang” dan “bersandar”). Keputusan menunjukkan resonan frekuensi pertama, kebolehpindahan kerusi untuk setiap postur adalah ketara antara frekuensi 1.7 hingga 2.5 Hz. Kebolehpindahan ketika diresonan adalah tertinggi ketika postur “bersandar”. Keputusan SEAT menunjukkan postur “membongkok” mencatat nilai tertinggi (64.7%). Dalam eksperimen kedua, jisim nyata badan manusia ketika duduk dikerusi rigid dan kerusi penggantungan diukur. Dua kedudukan duduk dikaji – i) tanpa sandar dan ii) dengan sandaran rigid menegak. Keputusan ujikaji menunjukkan puncak magnitud dan resonan frekuensi yang lebih rendah pada jisim nyata untuk kerusi penggantungan (4.0 hingga 5.2 Hz), jika dibandingkan dengan kerusi rigid (4.5 hingga 5.4 Hz). Untuk kedua-dua eksperimen, terdapat pengurangan pada resonan frekuensi yang pertama untuk kebolehpindahan kerusi dan jisim nyata apabila magnitud getaran ditambah, menimbulkan cadangan tidak linear dalam sistem kerusi penggantungan-manusia. Dengan menggunakan jisim nyata yang telah didapati dari badan manusia ketika duduk dikerusi penggantungan, dua darjah kebebasan model parameter bergabung dibangunkan. Model berkenaan berpadanan dengan respon badan yang telah diukur dalam pelbagai kondisi duduk (dengan dan tanpa tempat bersandar). Model menunjukkan apabila badan manusia bersentuhan dengan tempat bersandar, jisim berkurang, manakala unsur kekakuan meningkat, menyebabkan peningkatan dalam unsur teredam frekuensi semula jadi. Kombinasi model parameter bergabung kerusi penggantungan-badan manusia dibangunkan untuk menjangka kebolehpindahan getaran kerusi penggantungan. Model tersebut berjaya menjangka kebolehpindahan getaran kerusi penggantungan dengan meminimumkan ralat jumlah kuasa dua terkecil antara keputusan eksperimen dan model jangkaan. Keputusan menunjukkan prestasi kerusi penggantungan tidak hanya bergantung kepada mekanisma penggantungan sahaja, malah ianya disebabkan oleh gabungan pengaruh badan manusia ketika duduk di atas kerusi penggantungan. Kajian ini membuktikan getaran penghantaran dari kerusi penggantungan boleh dijangka. Jangkaan tersebut dapat membantu mengoptimumkan kerusi penggantungan dan seterusnya mengurangkan masa yang diperlukan untuk menilai prestasi kerusi penggantungan.

ACKNOWLEDGEMENTS

Alhamdulillah. I would like to take this opportunity to convey my heartfelt thanks and sincere appreciation to all those who have made this journey possible.

First and foremost, praise to Allah the Almighty for making this possible. I would like to express the deepest appreciation to my supervisor, Assoc. Prof. Ir. Dr. Nawal Aswan Abdul Jalil, who truly broadens my knowledge and interest in the world of science and technology through his passion for research. Dr Nawal continuously provided encouragement and was always willing and enthusiastic to assist in any way he could throughout the research project. His much needed guidance and support were perfectly balanced with the freedom he allowed me to discover my own strengths and capabilities.

Special thanks to my supervisory committee members, Dr Khairil Anas Md Rezali and Assoc. Prof. Dr. Ng Yee Guan, who were willing to share their knowledge and advice to answer my questions regarding the experiment works, journal publications and my thesis. Their continuous supports are much appreciated. I would also like to thank Dr. Shamsul and Ir. Adam from the Science and Technology Research Institute for Defence (STRIDE), Malaysia who allowed me to work in their lab.

My sincere appreciation is extended to Dr. Azizan As'aary, Mr. Tajul Ariffin, Mr. Mohd. Saiful, Mr. Muhammad Wildan and Mr. Mohd Zafri for helping me with the experimental preparation and fabrication. I am also appreciative of all my lab buddies for their support during the experimental works.

Most importantly, I would like to thank my family and friends for their love, prayers, supports and encouragements, without whom I would never have enjoyed so many opportunities. Lastly, I would like to express my sincere thanks who have directly and indirectly contributed to my research work. Thank you all.
.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AM	Apparent Mass
CSD	Cross Spectral Density
DOF	Degree-of-Freedom
FE	Finite Element
FFT	Fast Fourier Transform
FRF	Frequency Response Function
GOF	Goodness-of-Fit
IEPE	Integrated Electronics Piezo-Electric
LBP	Lower Back Pain
MSD	Musculoskeletal Disorders
OSHA	Occupational Safety and Health Administration
PSD	Power Spectral Density
SD	Standard Deviation
SEAT	Seat Effective Amplitude Transmissibility
WBV	Whole-Body Vibration

CHAPTER 1

INTRODUCTION

This chapter describes a brief introduction to the background of this research. Subsequently, the objectives and the corresponding hypotheses are explained, and the necessity of the research is being justified. Next, the scope and the limitations of the study are highlighted. Finally, an overview of the thesis is discussed at the end of the chapter.

1.1 Research Background

Exposure to a whole-body vibration (WBV) in transports during a daily life is common. The WBV occurs when a human body is supported by a vibrating surface. It is generally transmitted through the floor, the seat surfaces and the backrests, such as through driving a car or commuting using trains. Humans' exposure to the WBV is an extensive occupational risk factor, which is commonly associated with the lower back pain (LBP). It also affects the performance and the comfort of professional drivers (Bovenzi, 2010; Mayton *et al.*, 2008).

Previous studies found that higher exposures to the WBV were associated to an off-road rather than an on-road conditions (Scarlett *et al*., 2002; Darby *et al.,* 2010; Kim *et al*., 2018). Thus, it is likely to exceed the health guidance caution zone of 8 hours exposure in 24 hours span, which is in accordance to ISO 2631–1 (1997) standard. WBV can cause muscle lengthening and shortening which could potentially increase the muscle tension due to a stretch reflex (Ritzmann *et al*., 2010). Furthermore, it was reported that muscle activities were higher under the conditions with vibrations in comparison to the conditions without vibrations (Li *et al.*, 2015).

The term biodynamic is widely used in human vibration engineering practice, as mentioned in the ISO 8727 (1997). Biodynamic can be defined as the mechanical properties or responses of the body, parts and systems either with reference to impressed forces or motion, or in the relation to the body's own mechanical activity (Griffin, 2012). The most common way to describe the biodynamic response is by studying the dynamic characteristics of the human body from a measurement of the apparent mass.

According to the ISO 5982 (2001), apparent mass is the force and motion at the point of input of vibration to the body ("to the body" transfer functions). Griffin (2012) defined the apparent mass as the complex ratio of force to acceleration during simple harmonic motion, or also called as "effective mass". Current laboratory procedures for evaluating seat performances can benefits from this transfer function (apparent mass) under conditions similar while driving vehicles (ISO 5982, 2001). Apparent mass of the human body is commonly used as it gives insight into the dynamic behavior of the human body, representing frequencies at which the human body is most sensitive to acceleration. (Mansfield, 2005). The apparent mass has not only been used to derive models for seats assessment (Pang *et al*., 2005; Wu and Qiu, 2019), but to identify resonance for exposure risk assessment (Rakheja *et al*., 2008; Pranesh *et al.,* 2010) as well.

The exposure to the WBV can be reduced with a conventional or suspension seat. The conventional seat does not have its own suspension mechanism, and consist of standard foam cushion. Suspension seat has its own suspension mechanism and designed to isolate vibration at lower frequencies than normal seat (conventional seat). It is common for off-road vehicles, such as agricultural tractors to be equipped with the suspension seat. The suspension seat is aimed to reduce the effect of excessive vibration and shock to the human body. The suspension seat's efficiency depends on (i) the seat transmissibility, (ii) the input vibration at the seat base and (iii) the sensitivity of the human body to the input vibration on the seat surface (Griffin, 2012). The excitation sources such as road roughness, engine, tyres and dynamic working load are referred to input vibration.

The most common way to analyse the characteristics of a suspension seat is to measure its magnitude transmissibility. Seat transmissibility can be defined as the ratio between vibrations on the seat surface to the seat base and it is dimensionless. The characteristics of the seat and the human body are both important. The combination of the seat and the human body formed a coupled system and it is affected by each other (Lo *et al.,* 2013; Kim *et al.*, 2017). Thus, in order to predict the suspension seat performance, it is necessary to include the human response in the model as well.

The apparent mass of the human body is usually measured on a rigid seat, with less attention given for the suspension seat. However, there are evidences that type of seat could affect the apparent mass of human body (Toward and Griffin, 2011; Dewangan *et al.,* 2018). The use of suspension seat is common for agricultural tractors. Research on the contribution factors of the apparent mass of a human body seated on the suspension seat will not only improve the knowledge of the dynamic mechanisms of the human body when exposed to the WBV, but can be used to develop biodynamic models of the human body as well.

The conceptual framework of this study is shown in the Figure 1.1.

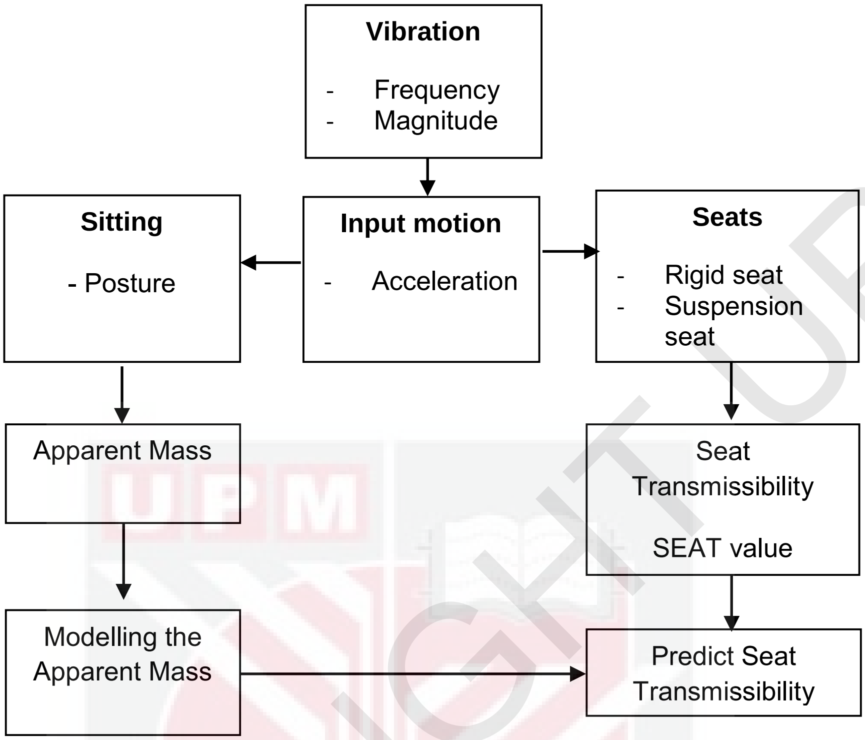

Figure 1.1: Conceptual framework of the study

1.2 Problem Statement

1.2.1 Effect of Sitting Postures and Vibration Magnitudes on the Vibration Transmission.

Standards have been proposed to test the seat transmissibility by using the inert mass or human subject (ISO 7096, 2000). According to the standard, the test person shall adopt a natural upright posture. However, in a normal working condition, human body adopted various postures depending on the farm activities. In addition, the variation in vibration magnitudes also been influenced by the work surface and the speed of the tractors. These variables may affect the performance of the suspension seat, and thus affect the vibration transmission through the suspension seat. Nevertheless, it’s remained unclear on how these factors affecting the suspension seat performance.

1.2.2 Influence of the Suspension Seat on the Apparent Mass of a Seated Human Body

Seated human bodies on the rigid seat and exposed to the WBV have been extensively investigated in various experimental conditions. (Matsumoto, 2002, Rakheja *et al*., 2010; Dewangan *et al*., 2018). Changes in the seating condition will influence the human responses (Griffin, 2012). A suspension system introduces a degree of freedom between the subject's ischial tuberosity when in contact with the seat pan, which allows the relative movement of the hip. However, to date, limited studies have been reported on the apparent mass of the seated human body on a suspension seat.

1.2.3 Modelling the Apparent Mass of a Seated Human Body on the Suspension Seat.

Both suspension seat and a human subject have close natural frequency. Suspension seat and a human body form a combined dynamic system that affect the seat transmissibility. The human body introduces another degree-of-freedom to the system. The influence of the human body to the seat transmissibility may be caused by the seat dynamics or the response of a human body, or may be caused by the combined effect of both the seat dynamics and the response of a human body. The influence of these factors on the relative contributions of variations in the biodynamic response and variations in the seat transmissibility are not known. Thus, this research seeks to find the mechanics underlying the non-linearity of the human body to develop a mathematical model of the apparent mass. The modelling from the apparent mass will help to understand the dynamic response of seated human body seated on suspension seat.

1.2.4 Incorporating Human Response with Suspension Seat for the Prediction of Seat Transmissibility

Off-road vehicles are usually driven on rough surfaces, which cause severe vibrations. These vibrations are usually low in frequency, ranging below 5 Hz (Zhou, 2014; Yan *et al.*, 2015). Vibrations at low excitation frequencies (1 - 20 Hz) are the main risk factors for the musculoskeletal disorders, which can reduce the work efficiency of drivers and passengers (Burström *et al.*, 2015; Scarlett *et al*., 2007; Smets, 2010). Thus, such vibrations require isolation.

Previous researchers have noted that the human body cannot be simply replaced with a rigid mass (Toward, 2010; Panta *et al.,* 2014). However, limited studies on the modelling of the agriculture suspension seat have considered the human responses. Thus, the need of a suspension seat-human body model is crucial to predict the dynamic performance of the suspension seat when exposed to the WBV.

1.3 Objectives

1.3.1 Main Objective

The main objective of the thesis is to predict the suspension seat transmissibility when exposed to the vertical WBV. The objective can be achieved by investigating the seat transmissibility and the apparent mass of a seated human body on the suspension seat. The specific objectives are described below.

1.3.2 Specific Objectives

i. To investigate the effects of sitting postures and vibration magnitudes on the vibration transmission of a suspension seat.

ii. To investigate the apparent mass of a seated human body on the rigid and suspension seat.

iii. To develop a mathematical model of the apparent mass of a seated human body on the suspension seat.

1.4 Research Questions and Hypotheses

This thesis aims to answer four main questions:

i. Is the sitting postures and vibration magnitudes affect the vibration transmission of a suspension seat?

ii. How the apparent mass of a seated human body is different from rigid and suspension seat?

iii. How to develop a mathematical model of the apparent mass of a seated human body on the suspension seat?

iv. Can the response of human body be included in the modelling to predict the seat transmissibility?

It was hypothesized that:

i. The sitting postures and vibration magnitudes would affect the vibration transmission of a suspension seat.

ii. The resonance frequency of the apparent mass of the seated human body would reduce when seated on the suspension seat.

iii. The apparent mass of a seated human body can be represent by the lumped parameter models.

iv. The response of the human body is combined with the response of the suspension seat by using lumped parameter model to predict the seat transmissibility.

1.5 Significance of the Study

The present study is important to advance the understanding on the response of a human body when seated on the suspension seat. The suspension seat is an important component of the agricultural machineries for isolating the vibration transmitted to the driver and for reducing the discomfort and health risk. An in-depth understanding in the characteristics of suspension seats and biodynamic responses of a human body seated on the suspension seat can assist manufacturers in optimising the seat design.

In addition, the study proposed the method of prediction of seat transmissibility. Thus, it is useful for the industry to identify the performance of the suspension seat that meets their usage and consequently improves the safety of the workers from an excessive exposure to the WBV.

1.6 Scope and Limitation of the Study

1.6.1 Scope of the Study

The scope of the study is simplified as in Figure 1.2. Three main categories are explored, which includes factors affecting biodynamic responses of the seated human body, seats, and vibration input. The apparent mass measurement leads to the development of a lumped parameter model of a seated human body on a suspension seat. In addition, the suspension seat transmissibility are investigated. Both the data will be used to predict the suspension seat transmissibility.

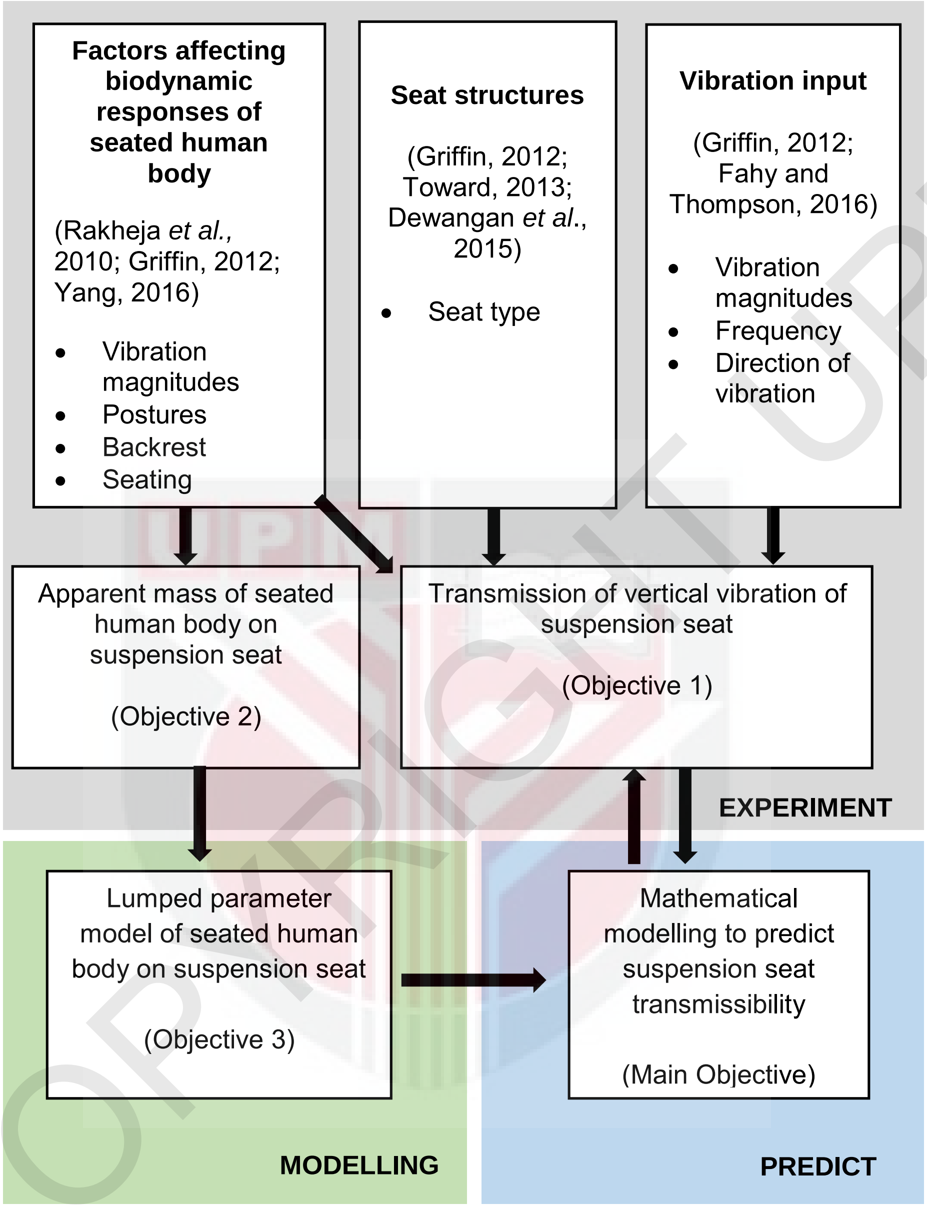

Figure 1.2: Simplified diagram representing the scope of the study

1.6.2 Limitation of the Study

The suspension seat used in the study is limited to a passive suspension seat. The reason for such a suspension seat is studied is because it is commonly used in the agriculture industry in Malaysia. Hence, it would be helpful to use the suspension seat that is commonly used in the industry. Nevertheless, the contribution of the knowledge gain from this research can be applied to different types of suspension seats.

1.7 Thesis Layout

Overall, the thesis comprises of five chapters.

Chapter 1 introduces the research. An overview of the research background is presented.

Chapter 2 describes the related studies of a human response to the WBV, the suspension seat transmissibility and the existing models of a seated human body. The knowledge gap is highlighted at the end of the chapter.

Chapter 3 specifies the equipment, material, methodology and data analysis used in the thesis. The flow and experimental design of the research are presented in this chapter.

Chapter 4 investigates the vibration transmission and the human responses on the suspension seat. The effect of the vibration magnitudes, postures and the backrest support are explored. Then, mathematical models are proposed to predict the suspension seat transmissibility. A general discussion of the findings are reported at the end of the chapter.

Chapter 5 concludes the main findings of the study, along with the recommendation for future research.

REFERENCES

Abdul Jalil, N.A. and Griffin, M.J., 2007. Fore-and-aft transmissibility of backrests: Variation with height above the seat surface and non-linearity. *Journal of Sound and Vibration*, *299*(1-2), 109-122.

Adam, S.A. and Abdul Jalil, N.A., 2017. Vertical suspension seat transmissibility and SEAT values for seated person exposed to whole-body vibration in agricultural tractor preliminary study. *Procedia Engineering*, *170*, 435-442.

Alfadhli, A., Darling, J. and Hillis, A.J., 2018. The Control of an Active Seat Suspension Using an Optimised Fuzzy Logic Controller, Based on Preview Information from a Full Vehicle Model. *Vibration*, *1*(1), 20-40.

Amiri, S., Naserkhaki, S., & Parnianpour, M., 2019. Effect of whole-body vibration and sitting configurations on lumbar spinal loads of vehicle occupants. *Computers in Biology and Medicine*, *107*, 292-301.

Anna, D. H., 2011. *The Occupational Environment: Its Evaluation, Control and Management*, American Industrial Hygiene Association.

Bai, X.X., Xu, S.X., Cheng, W. and Qian, L.J., 2017. On 4-degree-of-freedom biodynamic models of seated occupants: Lumped-parameter modeling. *Journal of Sound and Vibration*, *402*, 122-141.

Basri, B. and Griffin, M.J., 2013. Predicting discomfort from whole-body vertical vibration when sitting with an inclined backrest. *Applied Ergonomics*, *44*(3), pp.423-434.

Bennett, D.L., Gillis, D.K., Portney, L.G., Romanow, M. and Sanchez, A.S., 1989. Comparison of integrated electromyographic activity and lumbar curvature during standing and during sitting in three chairs. *Physical therapy*, *69*(11), 902-913.

Blüthner, R., Seidel, H. and Hinz, B., 2002. Myoelectric response of back muscles to vertical random whole-body vibration with different magnitudes at different postures. *Journal of Sound and Vibration*, *253*(1), 37-56.

Bovenzi, M. and Hulshof, C.T.J., 1998. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain. *Journal of Sound and Vibration*, *215*(4), 595-611.l

Bovenzi, M., 2010. A longitudinal study of low back pain and daily vibration exposure in professional drivers. *Industrial Health*, *48*(5), 584-595.

Braun, S. G., Ewins, D., Rao, S. S., and Leissa, A., 2002, “Encyclopedia of Vibration: Volumes 1, 2, and 3,” *Applied Mechanics, 55*(3), B45.

British Standards Institution, 1987. BS 6841, Measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock. London: British Standards Institution.

British Standard,1999. *BS 7085:1999*. Guide to safety aspects of experiments in which people are exposed to mechanical vibration and shock.

Bureau of Labor Statistics, 2016.

Burström, L., Nilsson, T. and Wahlström, J., 2015. Whole-body vibration and the risk of low back pain and sciatica: a systematic review and meta-analysis. *International archives of Occupational and Environmental Health*, *88*(4), 403-418.

Cho, H.Y., Han, M., Hirao, A. and Matsuoka, H., 2017, July. Virtual Occupant Model for Riding Comfort Simulation. In *Proceedings of the 12th International Modelica Conference, Prague, Czech Republic, May 15-17, 2017* (No. 132, pp. 27-34). Linköping University Electronic Press.

Cho, Y. and Yoon, Y.S., 2001. Biomechanical model of human on seat with backrest for evaluating ride quality. *International Journal of Industrial Ergonomics*, *27*(5), 331-345.

Coggins, M.A., van Lente, E., Mccallig, M., Paddan, G. and Moore, K., 2010. Evaluation of hand-arm and whole-body vibrations in construction and property management. *Annals of Occupational Hygiene*, *54*(8), 904-914.

Corbridge, C., Griffin, M.J. and Harborough, P.R., 1989. Seat dynamics and passenger comfort. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, *203*(1), 57-64.

Cvetanovic, B. and Zlatkovic, D., 2013. Evaluation of whole-body vibration risk in agricultural tractor drivers. *Bulgarian Journal of Agricultural Science*, *19*(5), 1155-1160.

Darby, A.M., Heaton, R. and Mole, M., 2010. Whole-body vibration and ergonomics of driving occupations. Road haulage industry.

Dewangan, K.N., Rakheja, S. and Marcotte, P., 2018. Gender and anthropometric effects on whole-body vibration power absorption of the seated body. *Journal of Low Frequency Noise, Vibration and Active Control*, *37*(2), 167-190.

Dewangan, K.N., Rakheja, S., Marcotte, P. and Shahmir, A., 2015. Effects of elastic seats on seated body apparent mass responses to vertical whole body vibration. *Ergonomics*, *58*(7), 1175-1190.

Dewangan, K.N., Rakheja, S., Marcotte, P., Shahmir, A. and Patra, S.K., 2013. Comparisons of apparent mass responses of human subjects seated on rigid and elastic seats under vertical vibration. *Ergonomics*, *56*(12), 1806-1822.

Dolan, K. J., & Green, A., 2006. Lumbar spine reposition sense: the effect of a ‘slouched’posture. *Manual Therapy*, *11*(3), 202-207

Dong, R.C., He, L., Du, W., Cao, Z.K. and Huang, Z.L., 2019. Effect of sitting posture and seat on biodynamic responses of internal human body simulated by finite element modeling of body-seat system. *Journal of Sound and Vibration*, *438*, 543-554.

Eamcharoenying, P., 2015. *Hybrid Numerical-Experimental Testing of Active and Semi-Active Suspensions* (Doctoral dissertation, University of Bath).

Ebe, K., 1998. Predicting overall seat discomfort from static and dynamic Characteristics of seats. *PhD thesis, University of Southampton, England*.

Fahy, F. and Thompson, D. eds., 2016. *Fundamentals of Sound and Vibration*. CRC Press.

Fairley, T.E. and Griffin, M.J., 1989. The apparent mass of the seated human body: vertical vibration. *Journal of Biomechanics*, *22*(2), 81-94.

Fethke, N.B., Schall, M.C., Merlino, L.A., Chen, H., Branch, C.A. and Ramaswamy, M., 2018. Whole-body vibration and trunk posture during operation of agricultural machinery. *Annals of Work Exposures and Health*, *62*(9), 1123 1133.

Futatsuka, M., Maeda, S., Inaoka, T., Nagano, M., Shono, M. and Miyakita, T., 1998. Whole-body vibration and health effects in the agricultural machinery drivers. *Industrial Health*, *36*(2), 127-132.

Gan, Z., Hillis, A.J. and Darling, J., 2015. Biodynamic modelling of seated human subjects exposed to uncouples vertical and fore-and-aft whole-body vibration. *Journal of Vibration Engineering and Technologies*, *3*(3), 301-314.

Gatchel, R.J. and Schultz, I.Z. eds., 2014. *Handbook of Musculoskeletal Pain and Disability Disorders in the Workplace*. New York, NY: Springer.

Gobbi, M. and Mastinu, G., 2001. Analytical description and optimization of the dynamic behaviour of passively suspended road vehicles. *Journal of Sound and Vibration*, *245*(3), 457-481.

Goswami, D. Y., 2004, *The CRC Handbook of Mechanical Engineering*, CRC press.

Griffin, M.J., 2012. *Handbook of Human Vibration*. Academic press.

Grujicic, M., Pandurangan, B., Arakere, G., Bell, W.C., He, T. and Xie, X., 2009. Seat-cushion and soft-tissue material modeling and a finite element investigation of the seating comfort for passenger-vehicle occupants. *Materials & Design*, *30*(10), 4273-4285.

Guglielmino, E., Sireteanu, T., Stammers, C.W., Ghita, G. and Giuclea, M., 2008. *Semi-active suspension control: improved vehicle ride and road friendliness*. Springer Science & Business Media.

Gunston, T., 1998, September. The development of suspension seat dynamic model. In *Human Response to Vibration Meeting, Buxton, Derbyshire, England, 16-18 September*.

Harcombe, H., Herbison, G.P., McBride, D. and Derrett, S., 2014. Musculoskeletal disorders among nurses compared with two other occupational groups. *Occupational Medicine*, *64*(8), 601-607.

Hinz, B., Rützel, S., Blüthner, R., Menzel, G., Wölfel, H. P., and Seidel, H. 2006. Apparent mass of seated man—First determination with a soft seat and dynamic seat pressure distributions. *Journal of Sound and Vibration, 298*(3), 704-724.

Hinz, B., Seidel, H., Menzel, G., Blüthner, R., 2002. Effects related to random whole-body vibration and posture on a suspended seat with and without backrest. *Journal of Sound and Vibration, 253*(1), 265-282.

Holmlund P, Lundström R and Lindberg L (2000). Mechanical impedance of the human body in vertical direction. *Applied Ergonomics 31*, 415-422.

Huang, Y. and Griffin, M.J., 2006. Effect of voluntary periodic muscular activity on nonlinearity in the apparent mass of the seated human body during vertical random whole-body vibration. *Journal of sound and vibration*, *298*(3), 824-840.

Huang, Y., 2008. *Mechanism of nonlinear biodynamic response of the human body exposed to whole-body vibration* (Doctoral dissertation, University of Southampton).

International Organization for Standardization, 1997. Mechanical vibration and Shock- Evaluation of human exposure to whole-body vibration. Part 1: General Requirements. *ISO 2631-1: 1997.*

International Organization for Standardization, 1997. Mechanical vibration and shock- Human exposure: Biodynamic coordinate systems. *ISO 8727: 1997*.

International Organization for Standardization, 2000. Earth-moving machinery- Laboratory evaluation of operator seat vibration. *ISO 7096: 2000.*

International Organization for Standardization, 2001. Mechanical vibration and shock - Range of idealized values to characterize seated-body biodynamic response under vertical vibration. *ISO 5982: 2001.*

Jalili, N., 2002. A comparative study and analysis of semi-active vibration-control systems. *Journal of Vibration and Acoustics*, *124*(4), 593-605.

Joshi, G., Bajaj, A.K. and Davies, P., 2010. Whole-body vibratory response study using a nonlinear multi-body model of seat-occupant system with viscoelastic flexible polyurethane foam. *Industrial Health*, *48*(5), 663-674.

Kazarian, L., 1972. Dynamic response characteristics of the human vertebral column: an experimental study on human autopsy specimens, *Acta Orthop. Scand. 43,* 1–188.

Kim, E., Fard, M. and Kato, K., 2017. Characterisation of the human-seat coupling in response to vibration. *Ergonomics*, *60*(8), 1085-1100.

Kitazaki S. and Griffin, M.J., 1998. Resonance behaviour of the seated human body and effects of posture. *Journal of Biomechanics 31*, 143–149.

Kitazaki, S. and Griffin, M.J., 1997. A modal analysis of whole-body vertical vibration, using a finite element model of the human body. *Journal of Sound and Vibration*, *200*(1), 83-103.

Kittusamy, N.K. and Buchholz, B., 2004. Whole-body vibration and postural stress among operators of construction equipment: A literature review. *Journal of Safety Research*, *35*(3), 255-261.

Krajnak, K., 2018. Health effects associated with occupational exposure to hand-arm or whole body vibration. *Journal of Toxicology and Environmental Health, Part B*, *21*(5), 320-334.

Li, L., Lamis, F., Wilson, S. E., 2008. Whole-body vibration alters proprioception in the trunk. *International Journal of Industrial Ergonomics 38*(9-10), 792-800.

Li, W., Zhang, M., Lv, G., Han, Q., Gao, Y., Wang, Y., Tan, Q., Zhang, M., Zhang, Y., Li, Z., 2015. Biomechanical response of the musculoskeletal system to whole body vibration using a seated driver model. *International Journal of Industrial Ergonomics (45)*, 91-97.

Liang, C. C., & Chiang, C. F., 2006. A study on biodynamic models of seated human subjects exposed to vertical vibration. *International Journal of Industrial Ergonomics*, *36*(10), 869-890.

Liang, C.C. and Chiang, C.F., 2008. Modeling of a seated human body exposed to vertical vibrations in various automotive postures. *Industrial Health*, *46*(2), 125-137.

Liu, C., Qiu, Y. and Griffin, M.J., 2015. Finite element modelling of human-seat interactions: vertical in-line and fore-and-aft cross-axis apparent mass when sitting on a rigid seat without backrest and exposed to vertical vibration. *Ergonomics*, *58*(7), 1207-1219.

Liu, C., Qiu, Y. and Griffin, M.J., 2017. Dynamic forces over the interface between a seated human body and a rigid seat during vertical whole-body vibration. *Journal of Biomechanics*, *61*, 176-182.

Lo, L., Fard, M., Subic, A. and Jazar, R., 2013. Structural dynamic characterization of a vehicle seat coupled with human occupant. *Journal of Sound and Vibration*, *332*(4), 1141-1152.

Mansfield, N. J. and Maeda, S., 2007. The apparent mass of the seated human exposed to single-axis and multi-axis whole-body vibration. *Journal of Biomechanics*, *40*(11), 2543-2551.

Mansfield, N.J. and Griffin, M.J., 2000. Non-linearities in apparent mass and transmissibility during exposure to whole-body vertical vibration. *Journal of Biomechanics*, *33*(8), 933-941.

Mansfield, N.J. and Griffin, M.J., 2002. Effects of posture and vibration magnitude on apparent mass and pelvis rotation during exposure to whole-body vertical vibration. *Journal of Sound and Vibration*, *253*(1), 93-107.

Mansfield, N.J. and Maeda, S., 2005. Effect of backrest and torso twist on the apparent mass of the seated body exposed to vertical vibration. *Industrial Health 43,* 413–420.

Mansfield, N.J., 2004. *Human Response to Vibration*. CRC press.

Mansfield, N.J., 2005. Impedance methods (apparent mass, driving point mechanical impedance and absorbed power) for assessment of the biomechanical response of the seated person to whole-body vibration. *Industrial Health*, *43*(3), 378-389.

Matsumoto, Y. and Griffin, M.J., 2001. Modelling the dynamic mechanisms associated with the principal resonance of the seated human body. *Clinical Biomechanics*, *16*, S31-S44.

Matsumoto, Y. and Griffin, M.J., 2002. Effect of muscle tension on non-linearities in the apparent masses of seated subjects exposed to vertical whole-body vibration. *Journal of Sound and Vibration*, *253*(1), 77-92.

Matsumoto, Y. and Griffin, M.J., 2002. Non-linear characteristics in the dynamic responses of seated subjects exposed to vertical whole-body vibration. *Journal of Biomechanical Engineering*, *124*(5), 527-532.

Matsumoto, Y. and Griffin, M.J., 2003. Mathematical models for the apparent masses of standing subjects exposed to vertical whole-body vibration. *Journal of Sound and Vibration 260*, 431 – 451.

Matsumoto, Y. and Griffin, M.J., 2005. Nonlinear subjective and biodynamic responses to continuous and transient whole-body vibration in the vertical direction. *Journal of Sound and Vibration*, *287*(4-5), 919-937.

Mayton, A.G., Kittusamy, N.K., Ambrose, D.H., Jobes, C.C., Legault, M.L., 2008. Jarring/jolting exposure and musculoskeletal symptoms among farm equipment operators. *International Journal of Industrial Ergonomics 38*, 758-766.

McManus, S.J., Clair, K.S., Boileau, P.E., Boutin, J., Rakheja, S., 2002. Evaluation of vibration and shock attenuation performance of a suspension seat with a semi-active magnetorheological fluid damper. *Journal of Sound and Vibration, 253*(1), 313-327.

Mertens, H., 1978. Nonlinear behavior of sitting humans under increasing gravity. *Aviation, Space and Environmental Medicine 49*: 287–98.

Nawayseh, N. and Griffin, M.J., 2003. Non-linear dual-axis biodynamic response to vertical whole-body vibration. *Journal of Sound and Vibration*, *268*(3), pp.503-523.

Nawayseh, N. and Griffin, M.J., 2004. Tri-axial forces at the seat and backrest during whole-body vertical vibration, *Journal of Sound and Vibration, 277*, 309-326.

Nawayseh, N. and Griffin, M.J., 2009. A model of the vertical apparent mass and the foreand-aft cross-axis apparent mass of the human body during vertical whole-body vibration. *Journal of Sound and Vibration 319*, 719-730.

Nawayseh, N., 2016. A mathematical model of the apparent mass of the human body under fore-and-aft whole-body vibration*. International Journal of Automotive and Mechanical Engineering 13*(3): 3613 – 27.

Okunribido, O.O., Magnusson, M., Pope, M. H. 2008. The role of whole body vibration, posture and manual materials handling as risk factors for low back pain in occupational drivers. *Ergonomics, 51*(3), 308-329

Oliveira, C.G., Simpson, D.M. and Nadal, J., 2001. Lumbar back muscle activity of helicopter pilots and whole-body vibration. *Journal of Biomechanics*, *34*(10), 1309-1315.

Paddan, G.S. and Griffin, M.J., 2002. Evaluation of whole-body vibration in vehicles. *Journal of Sound and Vibration*, *253*(1), 195-213.

Pang, J., Qatu, M., Dukkipati, R., and Sheng, G., 2005. Nonlinear seat cushion and human body model. *International Journal of Vehicle Noise and Vibration*, *1*(3-4), 194-206.

Pankoke, S. and Wölfel, H.P., 2003. *Determination of the Deflected Contact Surface between Human Body and Seat under Realistic Individual Sitting Conditions–A Mixed Experimental and Numerical Approach* (No. 2003-01-2209). SAE Technical Paper.

Panta, S.R., Avasarala, R. and Koona, R., 2014. Ride dynamic behaviour of coupled human-vehicle vibratory model. *International Journal of Human Factors Modelling and Simulation*, *4*(3-4), 250-265.

Patra, S.K., Rakheja, S., Nelisse, H., Boileau, P.É. and Boutin, J., 2008. Determination of reference values of apparent mass responses of seated occupants of different body masses under vertical vibration with and without a back support. *International Journal of Industrial Ergonomics*, *38*(5-6), pp.483-498.

Petit, A. and Roquelaure, Y., 2015. Low back pain, intervertebral disc and occupational diseases. *International Journal of Occupational Safety and Ergonomics*, *21*(1), 15-19.

Pheasant, S. Haslegrave, C.M., 2005. *Bodyspace: Anthropometry, Ergonomics and the Design of Work*, CRC Press.

Pranesh, A.M., Rakheja, S., and Demont, R., 2010. Influence of support conditions on vertical whole-body vibration of the seated human body. *Industrial Health, 48*(5), 682-697.

Qiu, Y., 2017. Dynamic Characteristics of a Suspension Seat Determined in Laboratory Study. *Journal of Ergonomics, 7*(220), 2.

Qiu, Y., Griffin, M.J., 2004. Transmission of vibration to the backrest of a car seat evaluated with multi-input models. *Journal of Sound and Vibration, 274*(1-2), 297 321.

Qiu, Y., Griffin, M.J., 2011. Modelling the fore-and-aft apparent mass of the human body and the transmissibility of seat backrests, *Vehicle System Dynamics 49*(5), 703–722.

Qiu, Y., Griffin, M.J., 2012. Biodynamic response of the seated human body to single-axis and dual-axis vibrations: effect of backrest and non-linearity, *Industrial Health, 50*, 37-51.

Raffler, N., Ellegast, R., Kraus, T. and Ochsmann, E., 2016. Factors affecting the perception of whole-body vibration of occupational drivers: an analysis of posture and manual materials handling and musculoskeletal disorders. *Ergonomics*, *59*(1), 48-60.

Rahman, N.I.A., Dawal, S.Z.M., Yusoff, N., Kamil, N.S.M., 2018. Anthropometric measurements among four Asian countries in designing sitting and standing workstations. *Sādhanā, 43*(1), 10.

Rakheja, S., Dong, R. G., Patra, S., Boileau, P. É., Marcotte, P., and Warren, C., 2010. Biodynamics of the human body under whole-body vibration: Synthesis of the reported data. *International Journal of Industrial Ergonomics*, *40*(6), 710-732.

Rakheja, S., Haru, I. and Boileau, P.É., 2002. Seated occupant apparent mass characteristics under automotive postures and vertical vibration. *Journal of Sound and Vibration*, *253*(1), 57-75.

Rakheja, S., Mandapuram, S., and Dong, R. G., 2008. Energy absorption of seated occupants exposed to horizontal vibration and role of back support condition. *Industrial Health, 46*(6), 550-566.

Ritzmann, R., Kramer, A., Gruber, M., Gollhofer, A. and Taube, W., 2010. EMG activity during whole body vibration: motion artifacts or stretch reflexes? *European Journal of Applied Physiology*, *110*(1), 143-151.

Rohlmann, A., Hinz, B., Blüthner, R., Graichen, F. and Bergmann, G., 2010. Loads on a spinal implant measured in vivo during whole-body vibration. *European Spine Journal*, *19*(7), 1129-1135.

Sandover, J., 1978. Modelling human responses to vibration. *Aviation, Space, and Environmental Medicine*, *49*(1 Pt. 2), 335-339.

Savaresi, S.M., Poussot-Vassal, C., Spelta, C., Sename, O. and Dugard, L., 2010. *Semi-active suspension control design for vehicles*. Elsevier.

Scarlett, A.J., Price, J.S. and Stayner, R.M., 2002. Whole-body vibration: Initial evaluation of emissions originating from modern agricultural tractors. *HSE Contract Research Report*.

Scarlett, A.J., Price, J.S. and Stayner, R.M., 2007. Whole-body vibration: evaluation of emission and exposure levels arising from agricultural tractors. *Journal of terramechanics*, *44*(1), 65-73.

Seidel, H. and Griffin, M.J., 2001. Modelling the response of the spinal system to whole-body vibration and repeated shock. *Clinical Biomechanics, 16*, Supplement No.1, S3 – S7.

Shao, X., Xu, N., & Liu, X., 2018. Investigation and application on the vertical vibration models of the seated human body. *Automotive Innovation*, *1*(3), 263-271.

Siefert, A., Pankoke, S. and Wölfel, H.P., 2008. Virtual optimisation of car passenger seats: Simulation of static and dynamic effects on drivers' seating comfort. *International Journal of Industrial Ergonomics*, *38*(5-6), pp.410-424.

Siegel, S. and John Jr, N., 6. Castellan. 1988. Nonparametric Statistics for the Behavioral Sciences. *New York*.

Smets, M.P., Eger, T.R. and Grenier, S.G., 2010. Whole-body vibration experienced by haulage truck operators in surface mining operations: a comparison of various analysis methods utilized in the prediction of health risks. *Applied Ergonomics*, *41*(6), 763-770.

Smith, S.D., 1994. Non-linear resonance behaviour in the human exposed to whole-body vibration. *Shock and Vibration, 5*, 439–450.

Stein, G.J., Múčka, P., Gunston, T.P. and Badura, S., 2008. Modelling and simulation of locomotive driver's seat vertical suspension vibration isolation system. *International Journal of Industrial Ergonomics*, *38*(5-6), 384-395.

Subashi, G.H.M.J., Matsumoto, Y. and Griffin, M.J., 2006. Apparent mass and cross-axis apparent mass of standing subjects during exposure to vertical whole-body vibration. *Journal of Sound and Vibration*, *293*(1-2), 78-95.

Toward, M.G. and Griffin, M.J., 2009. Apparent mass of the human body in the vertical direction: Effect of seat backrest. *Journal of Sound and Vibration, 327*, 657-669.

Toward, M.G. and Griffin, M.J., 2010. A variable parameter single degree-of-freedom model for predicting the effects of sitting posture and vibration magnitude on the vertical apparent mass of the human body. *Industrial health*, *48*(5), 654-662.

Toward, M.G. and Griffin, M.J., 2010. Apparent mass of the human body in the vertical direction: Effect of a footrest and a steering wheel. *Journal of Sound and Vibration 329,* 1586–1596.

Toward, M.G. and Griffin, M.J., 2011. Apparent mass of the human body in the vertical direction: Inter-subject variability. *Journal of Sound and vibration*, *330*(4), 827-841.

Toward, M.G. and Griffin, M.J., 2011. The transmission of vertical vibration through seats: Influence of the characteristics of the human body. *Journal of Sound and Vibration 330*(26), 6526-6543.

Tufano, S. 2011. *Dynamic response of the coupled human body and seat in vertical and fore-and-aft direction* (Doctoral dissertation, Universita'degli Studi di Catania).

Tufano, S., Griffin, M.J., 2013. Nonlinearity in the vertical transmissibility of seating: the role of the human body apparent mass and seat dynamic stiffness. *Vehicle System Dynamics, 51*(1), 122-138.

Valeev, A., 2018. Dynamics of a group of quasi-zero stiffness vibration isolators with slightly different parameters. *Journal of Low Frequency Noise, Vibration and Active Control*, *37*(3), 640-653.

Wang, W., Bazrgari, B., Shirazi-Adl, A., Rakheja, S. and Boileau, P.E., 2010. Biodynamic response and spinal load estimation of seated body in vibration using finite element modeling. *Industrial health*, *48*(5), 557-564.

Wang, W., Rakheja, S. and Boileau, P.É., 2004. Effects of sitting postures on biodynamic response of seated occupants under vertical vibration. *International Journal of Industrial Ergonomics*, *34*(4), pp.289-306.

Wei, L. and Griffin, M.J., 1998. Mathematical models for the apparent mass of the seated human body exposed to vertical vibration. *Journal of Sound and Vibration*, *212*(5), 855-874.

Wei, L. and Griffin, M.J., 1998. The prediction of seat transmissibility from measures of seat impedance. *Journal of Sound and Vibration, 214*, 121-37.

Wu, J., and Qiu, Y., 2019. Modelling of a train seat with subject exposed to lateral, vertical and roll vibration. *Journal of Physics: Conference Series* (Vol. 1264, No. 1, p. 012018). IOP Publishing.

Wu, X., Griffin, M. J., 1996. Towards the standardization of a testing method for the end-stop impacts of suspension seats. *Journal of Sound and Vibration, 192*(1), 307-319

Yan, Z., Zhu, B., Li, X. and Wang, G., 2015. Modeling and analysis of static and dynamic characteristics of nonlinear seat suspension for off-road vehicles. *Shock and Vibration*, Article ID 938205: 1-13.

Yang, M., 2016. *Effects of sitting posture and seat backrest on the biodynamic response of the human body and the prediction of spinal forces during vertical whole-body vibration* (Doctoral dissertation, University of Southampton).

Yang, M., Qiu, Y. and Griffin, M., 2015. Effect of backrest inclination on apparent mass at seat and the backrest during vertical whole-body vibration. Presented at the 50th UK Conference on Human Responses to Vibration, Southampton, UK, 9th - 10th September.

Yoshimura, T., Nakai, K. and Tamaoki, G., 2005. Multi-body dynamics modelling of seated human body under exposure to whole-body vibration. *Industrial Health*, *43*(3), 441-447.

Zhang, X., Qiu Y., Griffin M.J., 2015. Transmission of vertical vibration through a seat: Effect of thickness of foam cushions at the seat pan and the backrest. *International Journal of Industrial Ergonomics 48*, 36-45.

Zhang, X., Qiu, Y. and Griffin, M.J., 2015. Developing a simplified finite element model of a car seat with occupant for predicting vibration transmissibility in the vertical direction. *Ergonomics*, *58*(7), 1220-1231.

Zheng, G., 2012. *Biodynamics of the seated human body with dual-axis excitation: nonlinearity and cross-axis coupling* (Doctoral dissertation, University of Southampton).

Zheng, G., Qiu, Y. and Griffin, M.J., 2011. An analytic model of the in-line and cross-axis apparent mass of the seated human body exposed to vertical vibration with and without a backrest. *Journal of Sound and Vibration*, *330*(26), 6509-6525.

Zhou, Z., 2014. *Subjective and biodynamic responses of seated subjects exposed to whole-body vertical vibration at low frequency* (Doctoral dissertation, University of Southampton).

Zimmermann, C.L., Cook, T.M., 1997. Effects of vibration frequency and postural changes on human responses to seated whole-body vibration exposure. *International Archives of Occupational and Environmental Health, 69* (3), 165-179.