RAE2026

Design and Development of an Anti-Vibration Glove: Integrating Ergonomics and Materials Fabrication

MCO2

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UoA38

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Contents

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Project Descriptor

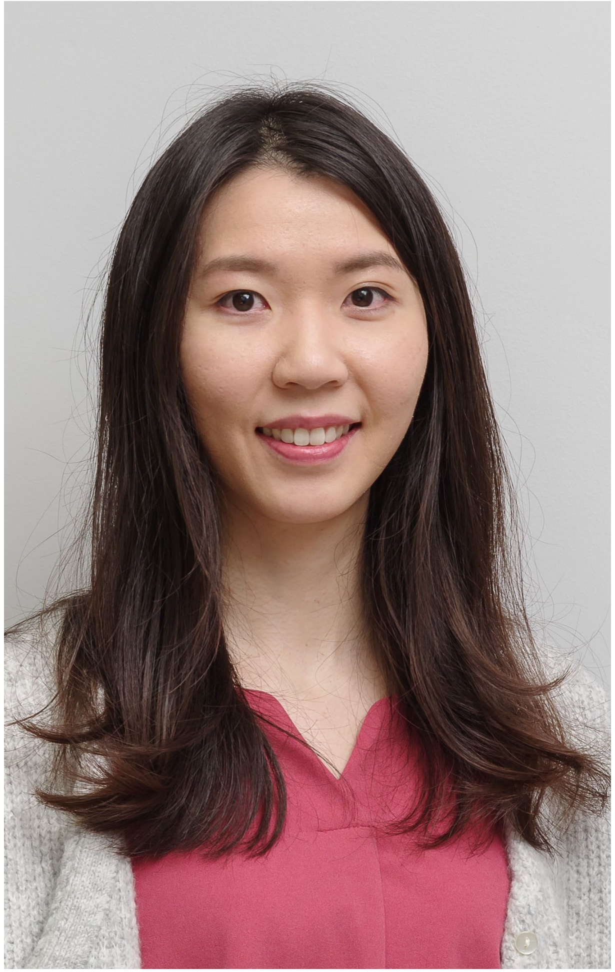
Anti-vibration gloves have been developed to protect hands from excessive vibration. The materials commonly used in current anti-vibration gloves to reduce the effects of vibration include chloroprene rubber, foam, urethane air bladders, resilient gels, or combinations of these materials. While it is important and also critical that such gloves effectively reduce the transmission of vibrations to the hand, they should not inhibit hand dexterity or coordination during use. Some people choose to forgo wearing gloves because they may reduce work efficiency. Wearing comfort is another factor that influences user compliance. However, few studies have examined the effects of anti-vibration glove materials and designs. There is limited knowledge regarding how different glove designs impact hand movement and wearing comfort.

With three years of funding support (1 April 2020 to 31 March 2023) from the Japan Society for the Promotion of Science, this study aimed to develop an anti-vibration glove that provides both high perceived comfort and good hand dexterity, based on hand and finger ergonomics and the design of textile materials for vibration isolation.

The outcomes of this study not only provide workers with a better anti-vibration glove that protects against hand–arm vibration syndrome and enhances compliance with glove use, but also demonstrate that the development of 3D-structured fabrics can be applied to other product innovations in fields such as architecture, automotive design, and medicine

The research findings were disseminated through peer-reviewed journal papers and conference presentations, highlighting the potential for further development of work gloves and vibration isolation materials.

Personal Profile: Dr. Annie YU – Assistant Professor



Dr. Yu's research focuses on the design and development of novel knitted fabrics and functional textiles. Her expertise spans knitting technologies, apparel production techniques, experimental design, and the evaluation of clothing fit and comfort. She also investigates the physiological and psychological responses of human participants to different types of textiles and clothing products and develops simulation models to predict garment–skin pressures.

Dr. Yu is the sole Principal Investigator (PI) of the following funded projects: "Effect of Inlaid Yarns and Inlaid Method on Compression Behaviour of Weft-knitted Spacer Fabric" funded by the Kinugasa Fiber Research Centre (1 April 2020 to 31 March 2021); "Development of a 3D-Shaped Knitted Composite for Wearable Cushioned Products" funded by the Kyoto Technoscience Centre (1 April 2022 to 31 March 2023); and "Breathable Cushioning Created by Novel Multi-layer Sandwich Knitted Structure" funded by The Hong Kong Polytechnic University (1 November 2023 to 31 October 2026). The last study is ongoing and was developed as MCO1. She is also the sole PI of "Development of Anti-vibration Glove with 3D Structured Weft-knitted Fabric", funded by the Japan Society for the Promotion of Science (1 April 2020 to 31 March 2023), which contributed to MCO2. She also collaborated with Prof. Ishii Yuya from the Kyoto Institute of Technology on research related to knitted capacitance sensors, delivered as MCO3.

Dr. Yu began her academic research career at PolyU in 2023, conducting studies related to textiles and knitting design. In the same year, she received the Kinugasa Textile Award (Academic Category) from the Kinugasa Textile Research Foundation for Textile Science.

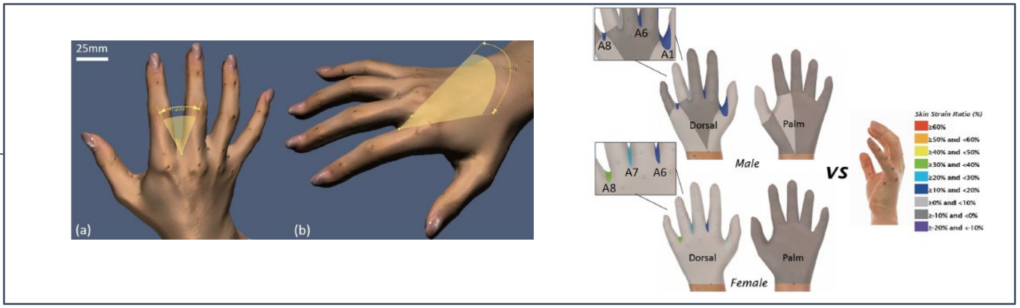
Research Questions

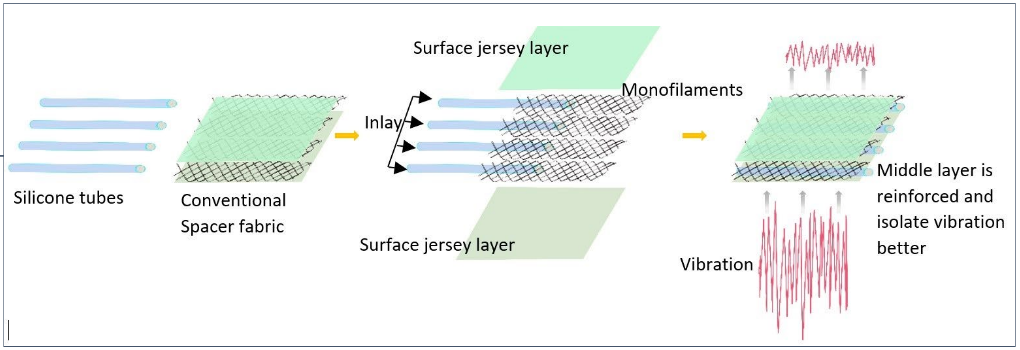
An anti-vibration glove is an effective protective device when using vibrating hand tools, such as chainsaws, impact drivers, road breakers, and ballast machines. However, there is still room for improvement in glove design and material selection to enhance comfort and hand dexterity. The 3D knitted spacer fabrics with silicone inlays developed in MCO1 are lightweight and breathable and show potential for vibration isolation. The research questions of this project include:

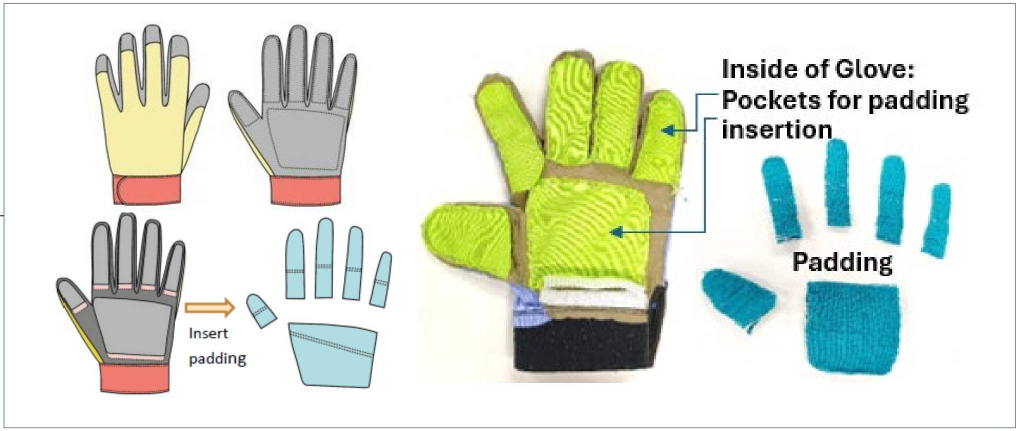
1. How do the current designs and materials of anti-vibration gloves affect hand performance and wearing comfort?
2. What are the hand and finger proportions and skin strain changes during dynamic motions, and how can these findings be applied to glove design for improved fit and dexterity?
3. How do specific material combinations, such as spacer fabrics with elastic or silicone inlays, enhance vibration isolation, air permeability, and compression behaviour?
4. How do different spacer structures (e.g. tuck stitches, miss stitches) and inlay patterns affect vibration transmissibility, compression stiffness, and ergonomic fit?
5. How do gloves made with advanced materials compare to commercially available anti-vibration gloves in terms of vibration isolation, thermal comfort, and wearability?
6. What are the design directions for the next generation of anti-vibration gloves?

Research Outputs

- Variations in hand measurements and finger segment proportions during different motions
- Knitted padding materials suitable for use in anti-vibration gloves for vibration isolation
- Development of an anti-vibration glove prototype incorporating the knitted padding
- Seven journal papers were published
- Three conference presentations were delivered







Research Field & Key References

- An increase in the thickness and softness of anti-vibration gloves can improve their effectiveness in reducing vibration transmission [1, 2]. However, thicker gloves can also make it more difficult to grasp and control hand tools, resulting in reduced work efficiency and, consequently, lower compliance with glove use [3–5]. Prolonged use of gloves made from air- and moisture-impermeable materials or those with substantial thickness can lead to heat and moisture accumulation, hand fatigue, and discomfort for the wearer. Therefore, balancing glove thickness, softness, and vibration isolation properties is crucial to ensure both comfort and functionality.

- To improve glove fit, extensive research has been conducted on hand anthropometry, measurement techniques, and their association with various hand postures [6–9]. However, most previous studies focused primarily on the back of the hand, neglecting the palm side, web space area, and finger segments. This limited scope has led to ambiguity in understanding how hand measurements change with posture, resulting in inconclusive findings and challenges in improving glove fit.

- Previous studies have shown that spacer fabrics can effectively isolate vibrations due to their deformability and damping capacity. Compared with elastomeric materials, spacer fabrics offer better breathability, moisture transfer, and air permeability, which enhance wearer comfort. Blaga et al. evaluated various spacer fabrics and demonstrated their ability to absorb vibration energy [10–13]. Chen et al. investigated the negative stiffness effect and vibration isolation performance of warp-knitted spacer fabrics incorporating spandex yarns knitted together with surface yarns [14, 15]. An evaluation of weft-knitted spacer fabrics has also been reported [16]. The degree and range of vibration isolation provided by spacer fabrics are influenced by factors such as spacer structure, fabric thickness and density, and the diameter of filament connective yarns. Although numerous studies have evaluated the vibration transmissibility of different types of conventional spacer fabrics, there remains a lack of research focused on designing new 3D knitted fabric structures to significantly enhance vibration isolation performance.

Research Field & Key References

Knowledge Gap

- A solution that effectively balances glove thickness, softness, and vibration isolation properties – while maintaining comfort and not hindering work efficiency – is lacking.
- A comprehensive understanding of hand and finger proportions, as well as the variations in hand measurements across different postures, is also still incomplete.
- The specific design elements or structural integrations that could be incorporated into spacer fabrics to enhance vibration isolation performance are yet to be identified.

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[12] Blaga, M., et al., *Evaluation of the knitted fabrics stiffness through dynamic testing.* IOP Conference Series: Materials Science and Engineering, 2018. **459**: p. 012033.

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[14] Chen, C., et al., *Analysis of the damping property of warp-knitted spacer fabrics under damped free vibration.* Textile Research Journal, 2018. **88**(7): p. 790–799.

[15] Chen, C., et al., *Study of the vibration transmission property of warp-knitted spacer fabrics under forced sinusoidal excitation vibration.* Textile Research Journal, 2018. **88**(8): p. 922–931.

[16] Chen, F., Y. Liu, and H. Hu, *An experimental study on vibration isolation performance of weft-knitted spacer fabrics.* Textile Research Journal, 2016. **86**(20): p. 2225–2235.

Research Methods, Prototypes & Materials

Phase 1a
Hand evaluation
Analyse the geometry and ergonomics of the hand and fingers

Phase 1b
Current product evaluation
Examine the advantages and disadvantages of existing glove designs and materials to define the direction for further development

Phase 2
Innovative fabric development
Design and create 3D structured weft-knitted fabrics specifically for vibration reduction

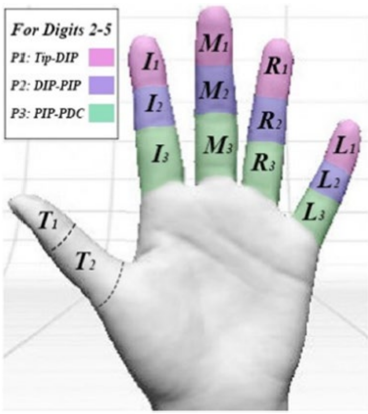
Phase 3
Glove prototyping
Develop glove prototypes using the newly designed fabrics to achieve significant improvements in both vibration isolation performance and wearing comfort

Phase 4
Performance evaluation
Evaluate and compare the physical and mechanical properties of the developed fabrics and glove prototypes

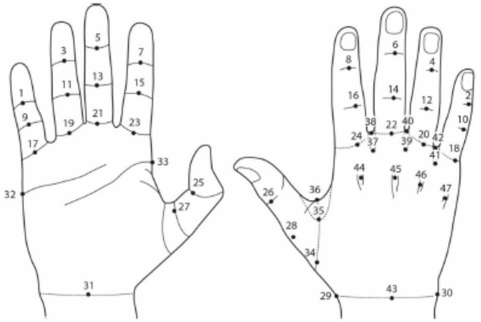
Feedback

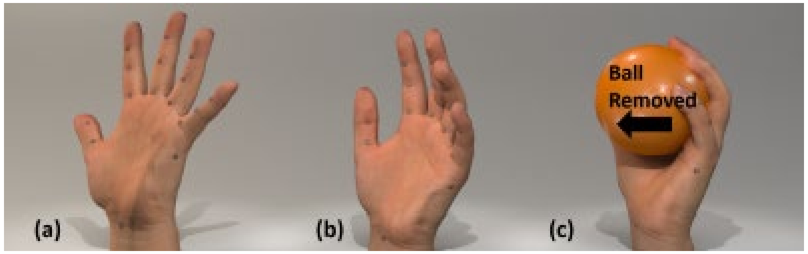
Research Methods, Prototypes & Materials

Phase 1a: Analyse the geometry and ergonomics of the hand and fingers under different postures

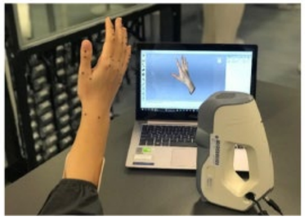


Measure and analyse the proportions of finger segments in splayed and gripping postures



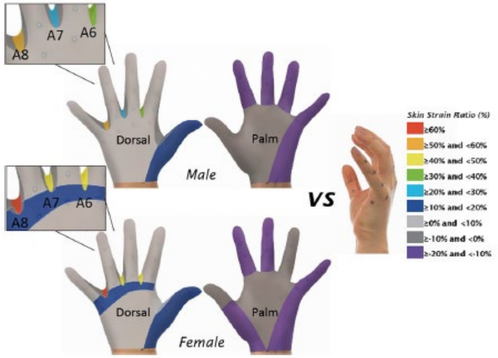


Evaluate the impact of glove finger segment proportions on displacement and comfort



(Please refer to https://doi.org/10.1016/j.apergo.2021.103409)

Take 57 dimensional measurements across three different hand postures and assess the changes in skin strain between these postures



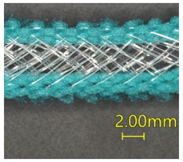
(Please refer to https://doi.org/10.1371/journal.pone.0250428)

Research Methods, Prototypes & Materials

Phase 1b: Current anti-vibration glove evaluation through materials testing and wear trial experiments

Buy from market – vibration isolation material: chloroprene rubber and foam

Made by conventional spacer fabrics

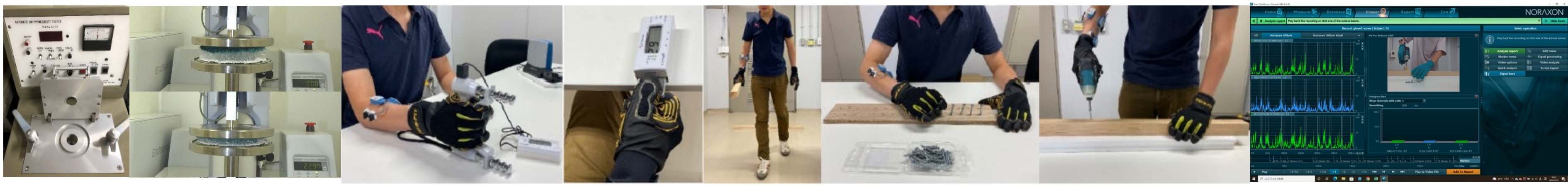


Glove materials evaluation

1) Thermal conductivity
2) Water vapour transmissibility
3) Air permeability
4) Compression properties

Impact of anti-vibration gloves on

1) Hand dexterity
2) Forearm muscle activity
3) Temperature and humidity inside the glove
4) Subjective sensations



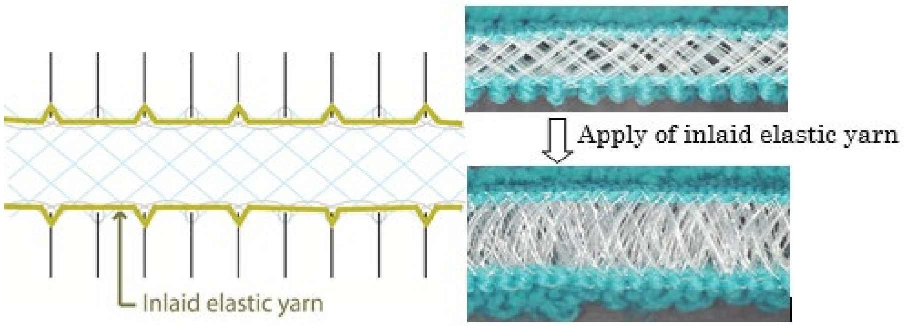
(Please refer to: https://doi.org/10.1016/j.apergo.2021.103572 and https://doi.org/10.1186/s40691-023-00340-0)

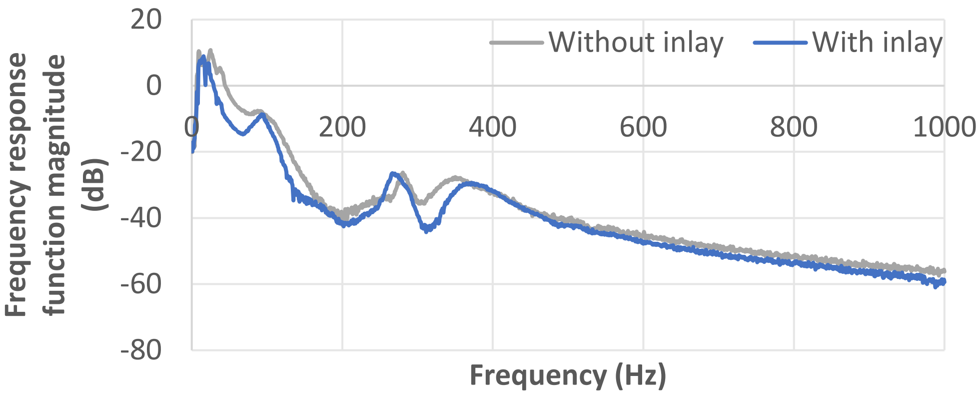
Research Methods, Prototypes & Materials

Phase 2: Innovative fabric is developed to increase vibration isolation properties

A **bulk and soft structure** made with longer linking distance is found to provide a higher degree and range of vibration isolation.

Based on the development in MCO1:
When an elastic yarn is inlaid on the fabric surface:
- → The fabric contracts in the course direction.
- → The fabric becomes thicker.
- → The structure becomes more compact.
- → The fabric exhibits slightly improved vibration isolation performance.





When magnitude of frequency response < 0 dB → vibration reduction ;
> 0 dB → vibration amplification

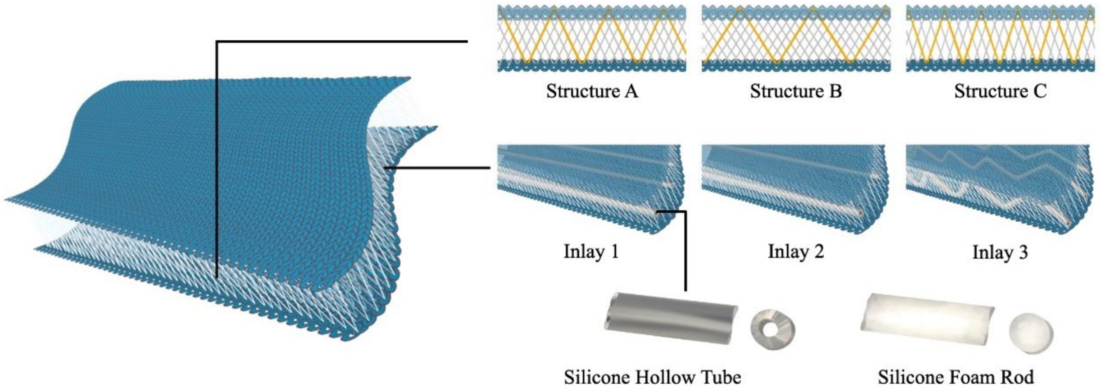
(Please refer to https://doi.org/10.4188/jte.66.65)

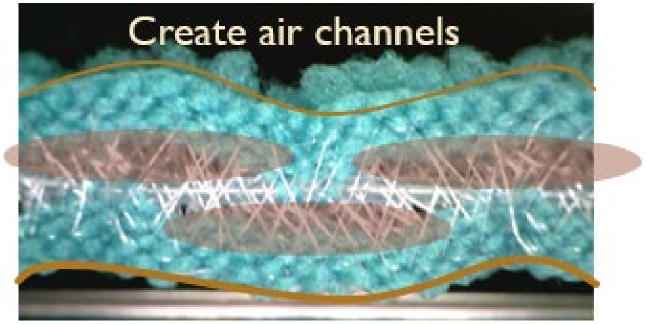
Research Methods, Prototypes & Materials

Phase 2: Innovative fabric is developed to increase vibration isolation properties

Silicone tube is flexible, elastic, and an effective vibration damping material.

Based on the development in MCO1:
When a silicone tube is inlaid in the connective layer:
→ The fabric thickness further increases, and the surface becomes wavy.
→ The vibration isolation performance improves.





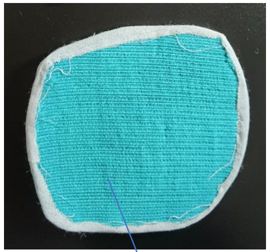
(Please refer to https://doi.org/10.3390/polym15051089 and https://doi.org/10.1177/15280837251315943)

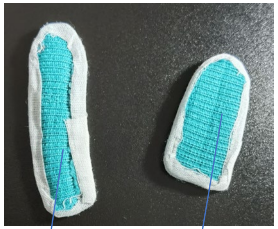
Research Methods, Prototypes & Materials

Developed vibration isolation fabric used as a padding

Phase 3: Glove prototypes

Based on commercial anti-vibration gloves, glove prototypes are produced with inner pockets to insert the paddings.





Inside of the glove

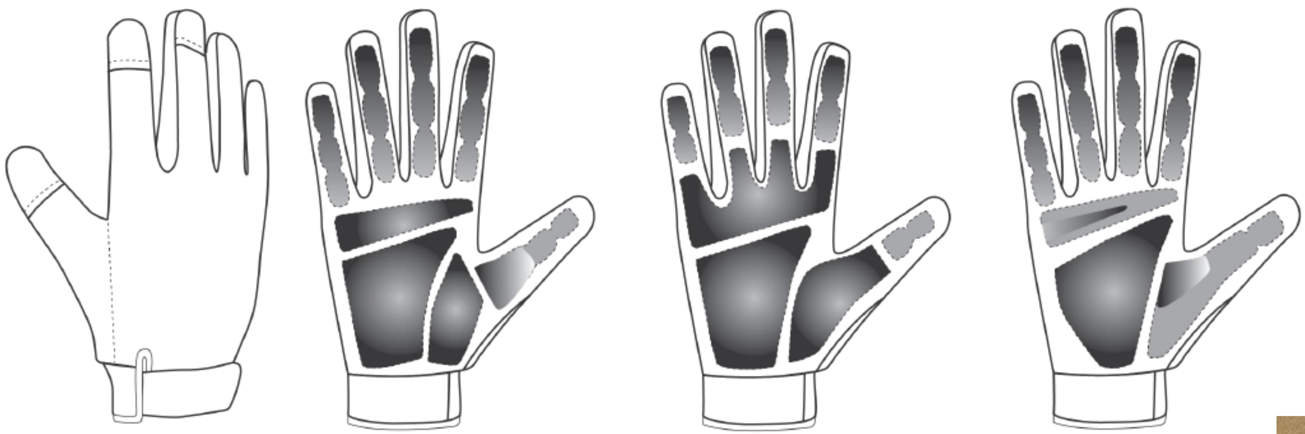
Outer appearance

(Please refer to https://doi.org/10.1177/15280837251315943)

Research Methods, Prototypes & Materials

Phase 3: Glove prototypes

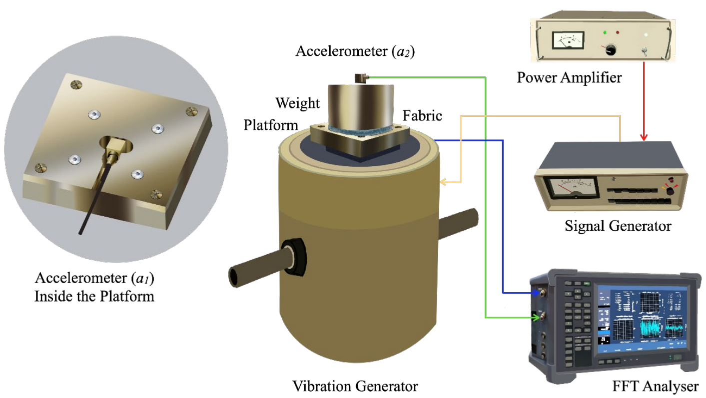
Padding and pattern arrangement design



All padding layouts maintain a similar total coverage area but differ in the way the materials are cut, shaped, and adjusted in thickness to accommodate specific hand movement zones.

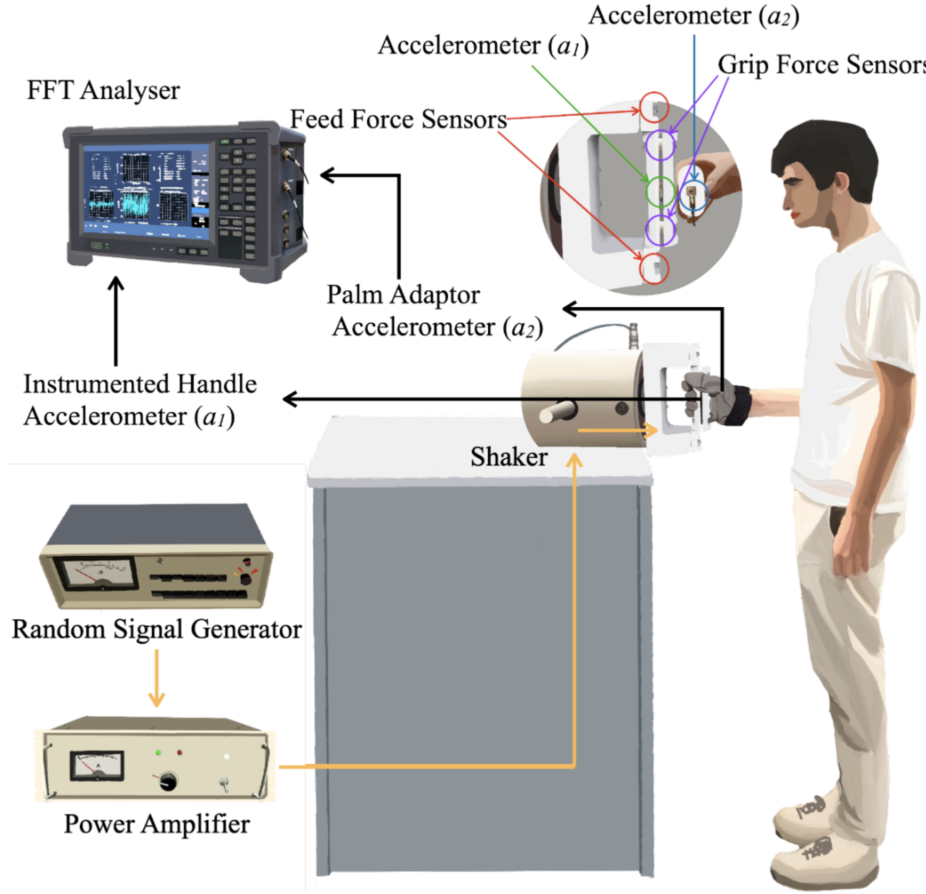
Research Methods, Prototypes & Materials

Phase 4: Evaluation



Set-up for vibration transmissibility for fabric samples according to ISO13753:2008

Objective tests on mechanical properties of fabric and glove samples were also conducted.



Set-up for vibration transmissibility for glove samples according to ISO 10819:2013

(Please refer to https://doi.org/10.1177/15280837251315943)

Research Outcomes, Findings & Further Research

- The hand measurement evaluation found that the slant of the web space, dorsal length, and surface area should be increased, while the angles of the web space and palm length should be reduced to improve glove patterns.
- Two finger segment ratios – the fingertip-to-proximal interphalangeal/full digit ratio and fingertip-to-distal interphalangeal/full digit ratio – were found to enable precise identification of the proximal and distal interphalangeal joints and should be considered to enhance glove fit.
- In comparison with commercial anti-vibration gloves, gloves made of traditional spacer fabric without ergonomic design features showed no advantage in hand dexterity or performance.
- 3D structured knitted fabrics can provide effective vibration isolation while exhibiting better air and water permeability than conventional elastomeric materials.
- A thicker spacer structure with a larger number of needles between the tuck stitches, inlaid with silicone hollow tubes, can further improve vibration isolation.

The study will be continued:

- Further glove design and development, considering finger segment proportions and skin strain variations during dynamic motions, will be carried out.
- Modification and design of 3D knitted fabric will be undertaken to achieve greater improvements in vibration isolation performance.

Research Dissemination

Journal Papers

Yu, A., Sukigara, S. & Masuda, A. (2020). Investigation of vibration isolation behaviour of spacer fabrics with elastic inlay. Journal of Textile Engineering, 66(5), 65–69. doi: 10.4188/jte.66.65

Yu, A., Yick, K. L. & Wong, S. T. (2021). Analysis of length of finger segments with different hand postures to enhance glove design. Applied Ergonomics, 94, 103409. doi: 10.1016/j.apergo.2021.103409

Kwan, M. Y., Yick, K. L., Chow, L., **Yu, A.**, Ng, S. P. & Yip, J. (2021). Impact of postural variation on hand measurements: Three-dimensional anatomical analysis. PLOS ONE, 16(4), e0250428. doi: 10.1371/journal.pone.0250428

Yu, A. & Sukigara, S. (2021). Evaluation of the design and materials of anti-vibration gloves: Impact on hand dexterity and forearm muscle activity. Applied Ergonomics, 98, 103572. doi: 10.1016/j.apergo.2021.103572

Yu, A. & Sukigara, S. (2023). Investigation of materials for palm and dorsal of anti-vibration gloves for thermal comfort. Fashion and Textiles, 10, 21. doi: 10.1186/s40691-023-00340-0

Yu, A., Sukigara, S. & Masuda, A. (2023). Vibration isolation properties of novel spacer fabric with silicone inlay. Polymers, 15(5), 1089. doi: 10.3390/polym15051089

Wang, Y. L., Chen, H. R., **Yu, A.**, Masuda, A. & Takeuchi, S. (2025). Evaluation of anti-vibration properties in work gloves using novel 3D knitted padding. Journal of Industrial Textiles, 55. doi: 10.1177/15280837251315943

Research Dissemination

Conference Presentations

Yu, A., Masuda, A., Sukigara, S., Yick, K. L. & Li, P. L. Vibration isolation and softness of knitted spacer fabric with silicone inlay. Textile Bioengineering and Informatics Society Symposium 2022 (TBIS 2022), held online, 6–8 September 2022 (Medal speaker, with peer-reviewed paper proceeding).

Yu, A. & Wang, Y. Investigation of anti-vibration glove made of silicone inlaid spacer fabric. International Conference on Advances in Design, Materials and Manufacturing Technologies 2022 (ICADMMT 2022), Hong Kong, China, 6–7 October 2022.

Wang, Y. & **Yu, A.** Development of spacer fabric as isolation material for anti-vibration glove. The 76 Annual conference of The Textile Machinery Society of Japan, Osaka Science and Technology Center, Osaka, Japan, 1–2 June 2023.

Poster Presentations

Yu, A. Design and development of anti-vibration glove – integrating ergonomics and materials. 2025 Design research impact and global insights - Exhibition. Hong Kong, China, 25 August –29 September 2025.