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RESEARCH ARTICLE

REVISED Driving-induced lower back pain: Investigation of causes and recommendations with TRIZ [version 2; peer review: 1 approved, 1 approved with reservations, 1 not approved]

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Abstract

Background: Driving-induced lower back pain (DLBP) is associated with long driving times and awkward postures. Nonetheless, its actual causes and solutions remain unclear due to intervening causes from activities of daily living and traumatic injuries. This study investigated the causes and recommendations for DLBP using the theory of inventive problem solving (TRIZ).

Methods: A cause-and-effect chain analysis (CECA) was conducted based on discussions with 19 ergonomics experts from Malaysia. Engineering contradictions were formulated according to the causes and associated with the parameters of the TRIZ system. These parameters were then intersected in the contradiction matrix to extract the inventive principles. Finally, recommendations were made based on these principles.

Results: CECA uncovered the design- and posture-related causes of DLBP. It was implied that missing seat adjustment controls might cause drivers to sit with their knees positioned higher than their hips. This issue causes an excessive posterior pelvic tilt, resulting in DLBP. To address this issue, an inert atmosphere involving the addition of inflatable bubble wraps to elevate the posterior position was recommended.

Conclusion: While there have been studies on DLBP, the present study demonstrated originality by using TRIZ to preliminarily but systematically investigate and resolve DLBP. Further triangulations, prototyping, experimentations, and verifications were not possible due to time and budgetary constraints. Nevertheless, this research uncovered the TRIZ-integrated perspectives on ergonomic solutions to DLBP that are more cost-effective than medical treatments or

Open Peer Review

Approval Status

	1	2	3
version 2			
(revision)
15 Sep 2021	view	view	view

version 1

31 Aug 2021

1. **Chandrakantan Subramaniam** ,
Universiti Utara Malaysia, Changlun, Malaysia
2. **Markus Hartono** , University of Surabaya,
Surabaya, Indonesia
3. **Anca Draghici** , Politehnica University of
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Any reports and responses or comments on the article can be found at the end of the article.

design overhauls.

Keywords

TRIZ, lower back pain, driving, posterior pelvic tilt, ergonomics, awkward posture, inventive principles, engineering contradiction

This article is included in the **Research Synergy** Foundation gateway.

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Author roles: **Ng PK:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Writing – Original Draft Preparation, Writing – Review & Editing; **Mohamed MSS:** Conceptualization, Investigation, Project Administration, Writing – Original Draft Preparation, Writing – Review & Editing; **Yeow JA:** Methodology, Project Administration, Writing – Review & Editing

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REVISED Amendments from Version 1

The original article was updated to this version just to include the latest ethics approval number. There were no other changes.

Any further responses from the reviewers can be found at the end of the article

Introduction

Lower back pain (LBP) involves pain felt below the costal margin and above the inferior gluteal folds.¹ In Australia, the healthcare cost for LBP varies if the patient is admitted to the hospital (AUD\$ 14,949) or discharged from an emergency department (AUD\$ 584).² In addition, LBP also radically changes one's life and identity over time.^{3,4}

Driving-induced lower back pain (DLBP)

While there are findings on the risk factors for DLBP, there is limited evidence supporting that whole-body vibrations directly increase DLBP risks.⁵ DLBP is attributable to accelerated muscle fatigue due to the upright driving posture that is maintained for a long time.^{6,7}

Although improving seat designs limits the effects of DLBP,^{8–11} the causes and solutions for DLBP remain ambiguous due to the presence of outliers from daily living activities. For example, the causes may be complicated due to trauma effects. If a driver sustains injuries from an accident, factors such as airbag deployment and the vehicles involved can affect the pain location.¹² Therefore, it is important to create proper exclusion criteria before exploring the causes and recommendations for DLBP. While DLBP is often researched using surveys,^{13–16} these alone may not sufficiently provide the information needed to address the issue.¹⁷

The theory of inventive problem solving (TRIZ) is an algorithmic problem-solving approach used in various areas, such as technology and business.^{18–21} The use of such a systematic yet adaptable approach in the context of DLBP has not been explored. Hence, this study aimed to investigate the causes and recommendations for DLBP using TRIZ.

Methods

The exclusion criteria were established first because DLBP is a specific kind of LBP. These criteria were determined through a focus group discussion among three medical doctors who were selected using purposive sampling. Each doctor has had at least 10 years of experience in treating LBP. Based on the discussion, the following criteria should be excluded when deliberating the causes of DLBP:

- Pre-existing back injuries (e.g. herniated disc, prolapsed disc);
- Fractures;
- Overweight or obesity;
- Congenital spine abnormalities (e.g. ankylosing spondylitis, seronegative spondylarthritis);
- Limb deformities (e.g. talipes equinovarus, congenital polio)
- Other health issues (e.g. spinal stenosis, prostate issues);
- Pregnancy;
- Pain from activities besides driving (e.g. sports, sitting in front of a work desk)

These exclusion criteria were referenced in the main focus group discussion. A cause-and-effect chain analysis (CECA) was used, with the causes extracted from the main focus group comprising 19 ergonomics experts from Malaysia who were selected using purposive sampling. Each expert has had at least 10 years of experience in ergonomics and DLBP.

The experts suggested that drivers commonly complain about temporary LBP around the L5–S1 region after driving for 10–15 min due to increased disc pressure caused by a slouched driving posture. This posture is attributable to a posterior pelvic tilt from an increased hip flexion angle when sitting with the hips positioned below the knees. The experts added

Figure 1. Cause-and-effect chain analysis diagram for DLBP.

that this condition occurs if there are no seat adjustment controls for the posterior position. These causes are summarised in the CECA diagram (see Figure 1).

Results

From the posture-related causes, the first engineering contradiction (EC1) was formulated.

EC1: If the hip is positioned lower than the knees, then the driver sinks his/her weight into the seat (#2: Weight of stationary object), but the increased disc pressure causes LBP (#11: stress or pressure).

The “then” and “but” phrases were linked to two system parameters^{22,23} and intersected in the contradiction matrix²⁴ to obtain four inventive principles:

13: The other way around

29: Pneumatics and hydraulics

10: Preliminary action

18: Mechanical vibration

Preliminary action (essential change on the object before needed) was found to be suitable for resolving EC1. Specifically, seat controls can be used to elevate the posterior portion before driving²⁵ for the hips to be positioned above the knees, thereby preventing the risk for LBP. However, some vehicles do not have this type of seat control. For this design-related cause, the EC2 was formulated.

EC2: If the seat controls are omitted, then the cost is reduced (#39: Productivity), but a compromised sitting posture causes LBP (#13: Stability of the object's composition).

Similarly, the parameters were intersected in the matrix to obtain these four principles:

35: Parameter changes

3: Local quality

22: Blessing in disguise

39: Inert atmosphere

An inert atmosphere (adding neutral parts or “nothing” into a system) is suitable for resolving EC2. Adding “nothing” can include adding air (e.g. inflatable bubble wraps to elevate the posterior position and alleviate disc pressure).

Meanwhile, a hard object is not suitable because it causes discomfort and pain around the waist and buttocks.^{26,27} Conversely, a soft object is not suitable as the driver will sink into the seat, negating the original purpose of the solution.

Apart from that, a soft high-density foam is also an option.²⁸ The object should be hard enough to prevent drivers from sinking back into the original posture and soft enough to maintain cushioning.

Conclusions

This study preliminarily investigated the causes and recommendations for DLBP using TRIZ. This aim was achieved using the CECA and inventive principles. Although DLBP has been studied previously, the present study demonstrated originality by using TRIZ to preliminarily but methodically investigate and resolve DLBP.

CECA revealed that DLBP arises from sitting with the hips positioned lower than the knees or without seat controls. The preliminary action principle proposed that seat controls should be included in the seat design to allow the lumbar region to be elevated and reduce the posterior pelvic tilt. Considering that not all cars have these seat controls, the inert atmosphere principle was recommended by adding inflatable bubble wraps to elevate the seat's posterior portion. In summary, rapidly-synthesised and cost-effective solutions for DLBP were successfully proposed using TRIZ.

Limitations and future directions

This was a preliminary study. Triangulation, prototyping, and experimentation were not possible due to time and budgetary constraints. In the future, further apparatus development and testing should be considered.

Acknowledgements

The authors would like to thank the Faculty of Engineering and Technology, Multimedia University (MMU) for allowing this study to be conducted. The authors thank the organising committee of MECON 2021 and DIFCON 2021 for facilitating the review and submission of the works related to this study. Special thanks go to the anonymous medical doctors and ergonomics experts who participated in the focus group discussion sessions. Lastly, the authors are exceptionally grateful to Ms. Chiew Fen Ng for the constructive criticism of the manuscript.

Author contributions

Poh Kiat Ng

Roles: Conceptualisation, data curation, formal analysis, investigation, methodology, project administration, writing – original draft preparation, writing – review, and editing

Muhammad Syafiq Syed Mohamed

Roles: Conceptualisation, investigation, project administration, writing – original draft preparation, writing – review and editing

Jian Ai Yeow

Roles: Project administration, methodology, writing – review and editing

Ethical approval

Ethics approval for this study was granted by the Technology Transfer Office of Multimedia University (approval number EA3172021).

Consent

Written informed consent was obtained from the participants in the preliminary and main focus group discussions.

Data availability

Figshare: Driving-induced lower back pain: Investigation of causes.

DOI: <http://doi.org/10.6084/m9.figshare.14754150>.²⁹

This project contains the following underlying data:

- Summary of Focus Group Discussion Data.docx. (This contains data on the points, opinions, and information from the preliminary focus group discussion meant to establish the exclusion criteria and from the focus group discussion that aimed to establish the causes of driving-induced lower back pain).

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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Reviewer Report 04 January 2022

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Anca Draghici

¹ Faculty of Management in Production and Transportation, Politehnica University of Timisoara, Timisoara, Romania

² President, Romanian Ergonomics and Workplace Management Society, Timisoara, Romania

I would like to see how the TRIZ method has been applied because it is the first time that I see such an application connected with driving-induced lower back pain!

So, I suggest extending the "Methods" chapter with relevant information on how the TRIZ method has been used (including the specific software tool for this) and how the results were achieved and interpreted. Thus, in the Conclusions part... may be added some recommendations (or limits) of using the research approach described in the paper.

This is a really innovative approach...congratulations on your creativity.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: industrial ergonomics, occupational health and safety

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 16 November 2021

<https://doi.org/10.5256/f1000research.77604.r98546>

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Markus Hartono

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- This study lacks the details of research urgency, research gaps, and state-of-the-art. It is unclear to see what the rationales of this study are, why DLBP has been investigated, what the urgency of this study was, and why TRIZ was proposed to solve the problem.
- There were no literature reviews of physical problems (such as musculoskeletal disorders/MSD or DLBP), methods used for product design and development (such as TRIZ or similar methods), ergonomics principles.
- It's unfortunate that the rationale of DLBP being studied was insufficient.
- Also, why TRIZ was being applied seems to be insufficient in explanation. Let say, we have many similar potential methods, they should have been reviewed, and how the TRIZ has been focused. Unfortunately, they were unavailable.

Overall, this article lacks the details and critical points (in terms of method/approach and research gap).

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

No

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Kansei Engineering, Ergonomics, New Product & Service Design, Service Quality.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 16 Nov 2021

Poh Kiat Ng, Multimedia University, Malaysia

I understand the comments of the reviewer. However, this article (through RSF) was meant to be a short report (less than 1000 words). Therefore it was not possible to summarise all the details, research gaps, and literature review since the authors were trying to fulfil the word limit. Nonetheless, we still thank the reviewer for his comments.

Competing Interests: No competing interests were disclosed.

Reviewer Report 20 September 2021

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Chandrakantan Subramaniam

School of Business Management, College of Business, Universiti Utara Malaysia, Changlun, Malaysia

The area of examination is seen as important and needs immediate attention. However, the background of the study needs to be improved as it needs to show some evidence or statistics from valid sources that the issue is rampant or important to be investigated. This will very much help future readers to understand the issue from a practical viewpoint.

The methodological section could be further improved to show the rigorousness of how the data was obtained. This is a qualitative study and many would like to understand the methodology better. This will help to demonstrate the scientific part of this present study.

Finally, The results section needs some improvement as readers must understand the results easily. How were the findings derived? What was the technique used? How was the inference made? Who were the respondents? Any inclusion or exclusion criteria?. These are some of the important things that were missing in this paper. The authors(s) could also probably present a simpler way to explain the results.

The Vinodkumar and Bhasi (2010)¹ article is a suggested reference as it also studies safety behaviour from the human factors angle thus would be helpful inclusion to explain the current phenomenon too.

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Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Occupational Safety and Health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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