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To cite this version:
Madelyn Rojas Castro, Marina Travanca, Marta Avalos, David Valentin Conesa, Emmanuel Lagarde. Usefulness of Bayesian modeling in risk analysis and prevention of Home Leisure and Sport Injuries (HLIs). III Jornadas Científicas de Estudiantes de la Sociedad Española de Biometría, Jan 2018, Bilbao, Spain. hal-01964484

HAL Id: hal-01964484
https://hal.archives-ouvertes.fr/hal-01964484
Submitted on 22 Dec 2018

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Usefulness of Bayesian modeling in risk analysis and prevention of Home Leisure and Sport Injuries (HLIs)

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18 January 2018
Home Leisure and Sport Injuries (HLIs)

Injuries

- Intentional
  - Agressions
  - Suicides
  - Violence

- Non Intentional
  - Work accidents
  - Road traffic accidents

Activities
- Domestic
- Scholar
- Pratique sportive
- Holiday and Leisure
- Falls
- Intoxication
- Burns
- Suffocations
- Drowning
- Minor injury
- Hospitalisation
- Death
- Handicap

Mechanisms

Consequences

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Bayesian Modeling of HLIs

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Injuries Epidemiological Context

World Health Organization (WHO)

- **Injuries** are the 4th cause of mortality in the EU.
- **230 thousand** annual deaths (EU), 58 % are HLIs.

In France:

- **HLIs are the 3th cause of mortality.**
- **Leading cause of childhood mortality.**

Each year:

- **20 thousand** deaths, 5 times more than traffic accidents.
- **5 million** emergencies.
- **11 million** injuries
L’ Observatoire MAVIE

- Prospective online cohort study of HLIs
- Currently, MAVIE has more than **26 thousand** volunteers in France during 3 years of recruitment (target sample **100 thousand** volunteers).

Objectives

- Identify the **risk factors** associated with the HLIs occurrence and severity.
- Implement **prevention measures** to reduce the number of victims.
MAVIE-Lab (mHealth)

- **Mobile app** including a **DSS (Decision Support System)**
- To self-management of HLIs risks (Evaluation).
- To experience personalized **prevention solutions** to reduce the risk of injury (Mitigation).
Modeling Problems MAVIE data

1. Reduced number of injuries declared by each activity.
2. Missing values.
3. Under-representation between injuries reported and those occurred.
4. Complex relationships between risk factors.
Bayesian Generalized Linear Models (Logistic Regression)

\[ p(\theta \mid X, y) \propto p(\theta) \ l(\beta, \sigma \mid X, y) \]

*posterior \propto prior \times likelihood*
Bayesian Generalized Linear Models (Logistic Regression)

+No Prior Information

+Prior Information

+elicitation

Hierarchical analysis

General Information

Published literature

Results Previous Studies

Experts Information

+Raw Data: Similar Studies

Current study information

Bayesian Approach

Prior no informative

Distr. Normal

Jeffrey's Priors

Weakly Informative

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Bayesian Modeling of HLIs
Methodological Proposal

Priors experts elicitation

Reason for using Bayesian experts elicitation

1. The knowledge is limited or incomplete.
2. The evidence is inconsistent missing or ambiguous.
3. The questions are complex and the relations between variables.
4. To deal with bias and uncertainties.
5. To integrate different sources of knowledge.

(A. B. Knol et al. 2010)
Bayesian experts elicitation (MAVIE-Lab)

Exerts Information

Model A
Injury Risk

++ Information Cohorte MAVIE

++ Volunteers

Model X
Better Forecasting Injury Risk

Integral Prevention Advice

+Prevention Experts Advice

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Bayesian Modeling of HLIs
Exploratory analysis objectives

Principal Objective

To explore **Bayesian modeling methodologies** for being used in MAVIE-Lab development

- To explore *experts elicitation* to improve the estimation of model parameters.
- To explore the use of automatic *selection models methods* since the Bayesian approach.
Model Selection  BMA Bayesian Model Averaging

The BMA is a weighted average of the posterior distributions for each parameter for all possible models.

Figure taken from (FitzGerald et al. 2014).
• **Sample of MAVIE Cohort:** N = 4,345 (March 2017). Volunteers over 18 years old, who had completed and validated the questionnaire.

• **Injuries:** 603 Reported Injuries (13.87 %).

• **Variables:** Explanatory variables: 20 categorical or categorized variables (Factors associated with HLIs occurrence).
  
  • **Demographic:** Age and sex.
  • **Previous Injuries.**
  • **Physical and mental health:** BMI, Health problems, depression, anxiety, hyperactivity, drowsiness and concentration.
  • **Consumption:** Medicines, alcohol, tobacco and cannabis.
  • **Sport Practice:** Sports, use of compression and maintenance accessories.
Methodology

MAVIE Data

Multiple Imputation

BY Logistic Model (Non informative priors)

Model Selection (BMA Bayesian Model Averaging)

Elicitation Prior Distributions

BY Logistic Model (Informative priors)
Results

BY Logistic Model (non informative priors)

(a) CI 95%
(b) ROC (AUC=0.58)
(c) Separation Graphic
Model Selection BMA: Better models according to BIC criteria

Selected Variables: Sex, Health Prob., Previous HLIs, Sports.
Model BMA Variables:
BY Logistic Model (Non informative priors)

(d) CI 95%
(e) ROC (AUC=0.64)
(f) Separation Graphic

<table>
<thead>
<tr>
<th>Variables</th>
<th>OR</th>
<th>Mean $\beta$</th>
<th>Variance $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (F)</td>
<td>0.44</td>
<td>-0.36</td>
<td>0.04</td>
</tr>
<tr>
<td>Age 50-60</td>
<td>1.20</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Age 40-50</td>
<td>1.40</td>
<td>0.15</td>
<td>0.04</td>
</tr>
<tr>
<td>Age 30-40</td>
<td>1.40</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>Age 18-30</td>
<td>2.10</td>
<td>0.32</td>
<td>0.04</td>
</tr>
<tr>
<td>Health Prob.</td>
<td>1.74</td>
<td>0.24</td>
<td>0.07</td>
</tr>
<tr>
<td>Smoker</td>
<td>1.64</td>
<td>0.21</td>
<td>0.03</td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>1.34</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td>Alcohol</td>
<td>5.72</td>
<td>0.76</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Informative Prior Distributions

(g) CI 95%

(h) ROC (AUC=0.6)

(i) Separation Graphic
### Results BY model: (BMA, Prior Information)

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>Devest</th>
<th>2.5%</th>
<th>97.5%</th>
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<tr>
<td>Intercept</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Age (50-60)</td>
<td>0.95</td>
<td>0.035</td>
<td>0.883</td>
<td>1.020</td>
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<tr>
<td>Age (40-50)</td>
<td>0.93</td>
<td>0.037</td>
<td>0.855</td>
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<tr>
<td>Age (30-40)</td>
<td>0.89</td>
<td>0.043</td>
<td>0.812</td>
<td>1.973</td>
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<tr>
<td>Age (18-30)</td>
<td>1.29</td>
<td>0.076</td>
<td>1.154</td>
<td>1.443</td>
</tr>
<tr>
<td>Sex (F)</td>
<td>0.80</td>
<td>0.024</td>
<td>0.760</td>
<td>0.851</td>
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<tr>
<td><strong>Sport</strong></td>
<td><strong>1.58</strong></td>
<td><strong>0.065</strong></td>
<td><strong>1.467</strong></td>
<td><strong>1.719</strong></td>
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<tr>
<td>Health Prob.</td>
<td>1.57</td>
<td>0.050</td>
<td>1.476</td>
<td>1.668</td>
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<tr>
<td>Smokers</td>
<td>1.54</td>
<td>0.074</td>
<td>1.397</td>
<td>1.688</td>
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<tr>
<td>Ex-smokers</td>
<td>1.44</td>
<td>0.060</td>
<td>1.331</td>
<td>1.567</td>
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<tr>
<td>Physic Health</td>
<td>1.35</td>
<td>0.052</td>
<td>1.252</td>
<td>1.453</td>
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<td>Psc.Medic.</td>
<td>1.22</td>
<td>0.038</td>
<td>1.146</td>
<td>1.294</td>
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<td>Mantenim. Acc.</td>
<td>1.29</td>
<td>0.072</td>
<td>1.150</td>
<td>1.434</td>
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<tr>
<td>Comp. Acc.</td>
<td>1.31</td>
<td>0.065</td>
<td>1.188</td>
<td>1.440</td>
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<tr>
<td><strong>Previous HLIs</strong></td>
<td><strong>2.41</strong></td>
<td><strong>0.095</strong></td>
<td><strong>2.236</strong></td>
<td><strong>2.605</strong></td>
</tr>
<tr>
<td>Alcohol</td>
<td>1.18</td>
<td>0.037</td>
<td>1.112</td>
<td>1.254</td>
</tr>
</tbody>
</table>
Discussion

- The model does not allow separating profiles of greater or lesser injury risk.

- The variables included *do not explain* the occurrence of injuries.

**Bayesian approach remains appropriate for the development of MAVIE-Lab.**
Solutions and ongoing work

1. To make **more specific models by type of injury**, including the most important variables in each case (Example: *Sport Injuries PhD Project*).

2. To perform a **formal elicitation** (Devilee & A. Knol 2011):
   - Experts selection
   - Uncertain evaluation
   - Elicitation protocol

3. To perform **Bayesian Network models** including besides the relationships between variables (*probabilistic and graphical modeling*) (Mujalli *et al.* 2016).
Variables relations in Running Injuries (DAG)
In conclusion, **Bayesian statistic** and the expert’s **elicitation** are powerful tools for the construction of **expert system** to be included in mHealth. This methodology makes possible to combine **statistical data** and experts information as for example **medical advice**.

**Figure:** mHealth (Figure taken from web-site UNC Gillinds School of Global Public Health)


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