Development of a Tool to Reduce Sports-related Concussions in Sports Organizations (Using Ice Hockey as a Model Sport)

Vrinda Munjal[1], Arnold Yeung[2], Naznin Virji-Babul[3,4]

[1]Department of Integrated Science, University of British Columbia, Vancouver, BC, Canada; [2]Department of Mechanical Engineering, University of British Columbia, Vancouver, BC, Canada;
[3]Department of Physical Therapy, University of British Columbia, Vancouver, BC, Canada, [4]Child and Family Research Institute, Vancouver, BC, Canada

Djavad Mowafaghian CENTRE FOR BRAIN HEALTH

INTRODUCTION

- It has been estimated that up to 3.8 million concussions occur annually[1], many of which occur in sports context.
- By high school, half of all student athletes will have sustained a concussion. By college, one third of athletes will have sustained multiple concussions[2].
- Currently, concussion prevention focuses on protective equipment, amendments to rules and regulations and information about recognizing concussions[3]. There is a critical need for a tool to evaluate the risk of concussions.
- We have developed a tool which incorporates individual risk factors of sports-related concussions to assess the risk of concussions in sports organizations. We have used ice hockey as a model sport to design this tool.

RISK FACTORS FOR CONCUSSIONS IN ICE HOCKEY

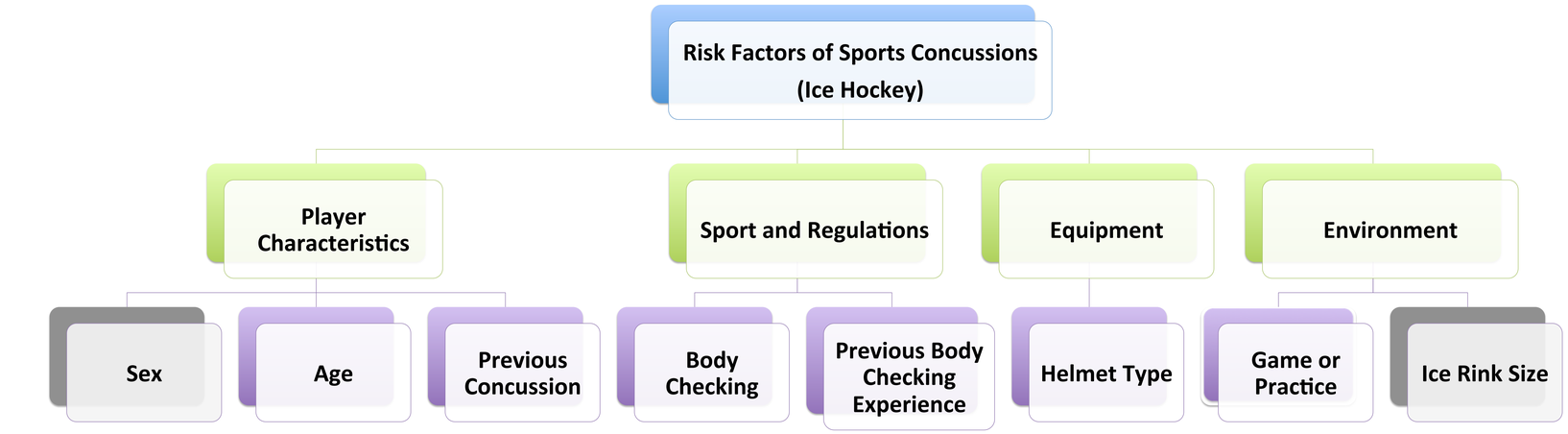

Fig 1. The four categories of risk factors included in the Sports Organization Concussion Assessment Tool (SOCRAT). The risk factors that are greyed-out are not included in the ice hockey model.

APPLICATION OF THE ASSESSMENT TOOL

Pre-Assessment
- Risk factors and parameters of associated functions must be determined using epidemiology data or expert opinion.

Assessment
- Determine the value of O_j by assigning values ranging from 0 to 1 (0 indicates that the risk factor is not present, 1 indicates that the risk factor is present).

Post-Assessment
- The parameter O_j is assigned a numerical score and S, E_j, and F_j are calculated based on derived functions.
- Calculate the RPN for each risk factor and assign the risk factors with higher RPNs as being critical.

Re-Assessment
- Reduce the risk of critical risk factors by removing/reducing their presence to lower the score of parameter O_j (and therefore E_j *and* F_j).
- Recalculate the RPN of individual risk factors and the overall RPN to determine if further action is required.

Sports Organization Concussion Assessment Tool (SOCRAT)

The SOCRAT has been modified from a common engineering application tool, the Failure Mode and Effect Analysis (FMEA), to account for:

1. Probability of different mutually exclusive effects of the same failure mode by using Bayesian Probability.
2. The assumption that the occurrence of a failure mode always results in an effect.

The output value of the algorithm, Risk Priority Number (RPN), indicates the measure of associated risk. It can be represented as:

$$RPN_j = \sum_{i=1}^{N} S_i \times E_{ij} \times F_j$$

S_i = Severity of effect *i* that could result from failure mode.

E_{ij} = Probability of effect *i* given the occurrence of failure mode due to risk factor *j*.

F_j = Probability of the failure mode (i.e. concussion) occurring.

O_j = Measure of occurrence of risk factor *j* (0 to 1).

EXAMPLE OF PROPOSED ALGORITHM (Ice Hockey Model)

Risk Factor	Severity (S)	Effect (E)	Failure probability (F)	Occurrence (O)	RPN	Source
Age (11.5 to 20 y/o)	All (2)	1	1.57 x o – 0.57			[4,5]
Previous concussion history	Severe (3) Non-severe (1)	0.07 x o + 0.24 -0.07 x o + 0.76	0.87 x o +1			[6]
Body checking allowance	Severe (3) Non-severe (1)	-0.01 x o + 0.39 0.01 x o + 0.61	2.88 x o + 1			[7]
Previous body checking experience	Severe (3) Non-severe (1)	0.11 x o + 0.28 -0.11 x o + 0.72	0.19 x o + 1			[6]
Use of helmet face shield	Severe (3) Non-severe (1)	-0.29 x o + 0.32 0.29 x o + 0.68	1			[8]
Game v. practice - M **Game v. practice - FM**	All (2) All (2)	1 1	8.92 x o + 1 5.70 x o +1			[9]

CONCLUSION

- By using the SOCRAT, sports organizations will be able to estimate the associated risk of each identified risk factor to determine their overall risk of concussion.
- Sports Organizations can use this tool to reduce their risk of concussion by modifying the identified critical risk factors through an iterative process.
- The algorithm can be modified as new research becomes available.
- This tool needs to be validated with real data.

REFERENCES

1. Langlois, J. A., Rutland-brown, W. & Wald, M. M. The Epidemiology and Impact of Traumatic Brain Injury A Brief Overview. 11–14 (2006).
2. Field, M., Collins, M. & Lovell, M. Does age play a role in recovery from sports-related concussion? (2003).
3. McCrory P. *et al.* Consensus Statement on Concussion in Sport — the 4th International Conference on Concussion in Sport. **23,** (2013).
4. Emery, C. A. & Meeuwisse, W. H. Injury rates, risk factors, and mechanisms of injury in minor hockey. *Am. J. Sports Med.* **34,** 1960–1969 (2006).
5. Willer, B., Kroetsch, B., Darling, S., Hutson, A. & Leddy, J. Injury rates in house league, select, and representative youth ice hockey. *Med Sci Sport. Exerc.* **37,** 1658–1663 (2005).
6. Emery, C. A., Kang, J., Shrier, I. & Claude, G. Risk of injury associated with body checking among youth ice hockey players. *JAMA* **303,** 2265–2272 (2010).
7.Yang, J., Phillips, G., Xiang, H., Allareddy, V. & Heiden, E. Hospitalisations for sport-related concussions in US children aged 5 to 18 years during 2000 – 2004. 664–669 (2008)
8. Stuart, M. J., Smith, A. M., Malo-ortiguera, S. A., Fischer, T. L. & Larson, D. R. A Comparison of Facial Protection and the Incidence of Head , Neck , and Facial Injuries in Junior A Hockey Players A Function of Individual Playing Time. **30,** 39–44 (2002).
9. Black, A. M. *et al.* Policy change eliminating body checking in non-elite ice hockey leads to a threefold reduction in injury and concussion risk in 11- and 12-year-old players. 55–61 (2016).