SELF-ORGANISING MAP ANALYSIS OF RUGBY PLACEKICKING BIOMECHANICS

Kim Hébert-Losier[1], Peter Lamb[2], and C. Martyn Beaven[1]

Faculty of Health, Sport and Human Performance, University of Waikato, Tauranga, New Zealand[1]
School of Physical Education, Sport and Exercise Sciences, University of Otago, Dunedin, New Zealand[2]

Our aim was to use a self-organising map (SOM) to examine key biomechanical variables previously identified to discriminate best from worst placekicking attempts. Placekicker and ball 3D biomechanics were acquired from three competitive placekickers who performed 10 kicks outdoors, 35-m from the posts. Seven key variables were extracted for SOM analysis and kicks were categorised into "best", "typical", and "worst" for each placekicker based on kick outcomes and player and coach ratings. SOM output indicated that three clusters best explained intra-cluster similarities and inter-cluster differences. The three clusters highlighted differences between the biomechanical variables of the three placekickers rather than the best, typical, and worst kicks. Within-clusters, however, the best and worst kicks tended to be represented by nodes in separate map regions.

KEYWORDS: artificial neural network, rugby union, sport performance.

INTRODUCTION: Forty-five percent (45%) of points scored during international Rugby Union matches are from placekicks, with 6% of match outcomes reliant on placekicking attempts (Quarrie & Hopkins, 2015). In fact, the ability to score points from kicks is a trait discriminating between winning and losing teams participating in Rugby Union World Cup (van Rooyen, Lambert, & Noakes, 2006), Super Rugby (Lim, Lay, Dawson, Wallman, & Aanderson, 2009), and Rugby Sevens (Hughes, Jones, Reilly, Cabri, & Araújo, 2005) matches. Clearly, improving the success rate of placekickers can alter match outcomes and should be a key focus in training and coaching of rugby skills.

To date, coaching placekicking technique has mainly relied upon practical experience or scientific findings from other sports, such as American football, soccer, and Australian Rules, rather than rugby-specific empirical data. Indeed, there are few published papers available on technical and biomechanical models for Rugby Union players (Atack, Trewartha, & Bezodis, 2018; Padulo, Granatelli, Ruscello, & D'Ottavio, 2013). The few 3D biomechanical studies available on Rugby Union placekicking are based on a limited number of non-elite players kicking in laboratory environments (Baktash, Hy, Muir, Walton, & Zhang, 2009; Bezodis, Trewartha, Wilson, & Irwin, 2007; Flemmer & Flemmer, 2015; Sinclair et al., 2014). These studies have provided limited real-world guidance for placekickers and their coaches.

Recently, we sought to identify the biomechanical variables related to successful rugby placekicking in an ecologically valid environment. We identified a subset of seven variables that consistently and meaningfully delineated the best from the worst placekicks in three competitive male placekickers using a magnitude-based inferential process (Hébert-Losier & Beaven, 2017). A self-organizing map (SOM) is an unsupervised neural network that is useful for clustering high-dimensional data and visualizing those clusters on a low-dimensional output map according to overall relatedness. SOM analyses have the potential to enhance our understanding of human movement and sports performance (Croft, Willcox, & Lamb, 2017; Lamb, Mundermann, Bartlett, & Robins, 2011). Hence, the aim of this study was to use SOM analysis to confirm whether the key biomechanical variables, previously identified to discriminate best from worst placekicking attempts, explain kicking outcomes. The rationale being that SOM has the potential to enhance our understanding of placekicking performance at an elite level.

METHODS: Three competitive male placekickers performed 10 kicks outdoors, 35 m from the goalposts. Placekicker and ball 3D biomechanics were collected at 300-Hz using an 8-camera 3D motion capture system (Qualisys AB, Sweden). Coach and player perceptions or kicking performance and placekick outcomes were recorded to define the three “best” and three “worst” kicks for each player. The remaining kicks were deemed to represent “typical” placekicking attempts.
Seven key biomechanical variables relating to placekicking success were extracted from all placekicking trials using the Visual3D software (C-Motion, USA). These seven variables were selected as they consistently and meaningfully delineated the best from the worst placekicking performances according to previous magnitude-based inferential analyses performed on these data (Hébert-Losier & Beaven, 2017). The biomechanical variables of interest were: centre of mass (CoM) forward speed at ball contact; CoM resultant speed at ball contact; CoM resultant speed maintenance at ball contact; knee flexion angle at ball contact; hip flexion angle at ball contact; maximal knee flexion angle during swing; and trunk rotational alignment in relation to the kicking direction during the swing phase.
The SOM analysis performed on the data set provided maps consisting of a lattice of nodes, each of which has an associated prototype vector with values that are attained through an iterative process. The dimensionality of the prototype vectors matches that of the input data – that is, the number of biomechanical variables used. The competitive learning algorithm and the neighbourhood function dictate that similar nodes and their prototype vectors are located in similar map regions, thus preserving the topology of the input data. The SOM clustering algorithm that produces a number of clusters with the smallest Davies–Bouldin index is considered to reflect the most representative algorithm given that this index is defined as a function of the ratio of the intra-cluster scatter to the inter-cluster separation.

RESULTS: The SOM output indicated that there was a strong three-cluster solution (i.e., minimum Davies-Bouldin index), which best explained intra-cluster similarities and inter-cluster differences (Figure 1). Further inspection of the data showed that the three-cluster solution separated the three placekickers rather than the best, typical, and worst kicking performances (Figure 2). Within-clusters, however, the best kicks tended to be represented by nodes located in the left side of the cluster, whereas the worst kicks were further represented by nodes on the opposite side of each cluster [Figure 2 (A) and (B)]. The differences between individuals can be observed by considering the separate biomechanical variables across the three clusters (Figure 3).

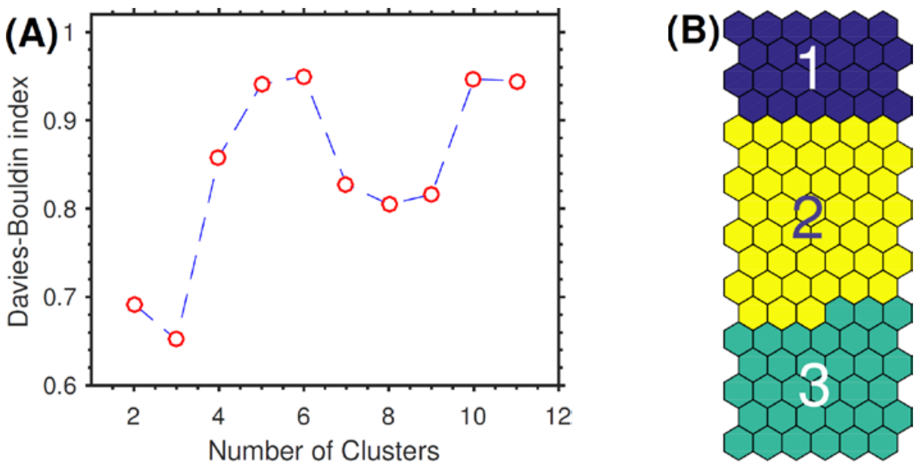

Figure 1. (A) Davies-Bouldin index for clusters *k* = 2, …, 11; (B) SOM output grid visualisation. The respective clusters are identified by numbers.

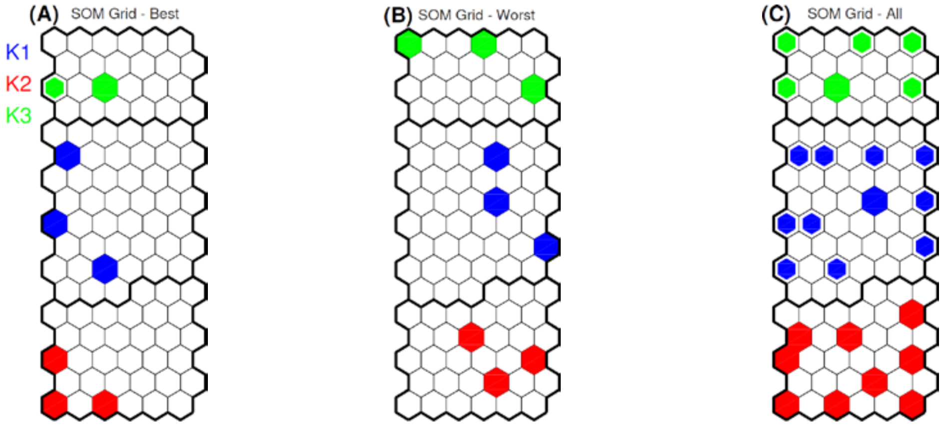

Figure 2. Self-organizing map (SOM) grids locating the three kickers (K1, K2, K3) in the (A) best, (B) worst, and (C) all (best, worst, and typical) placekicking trials.

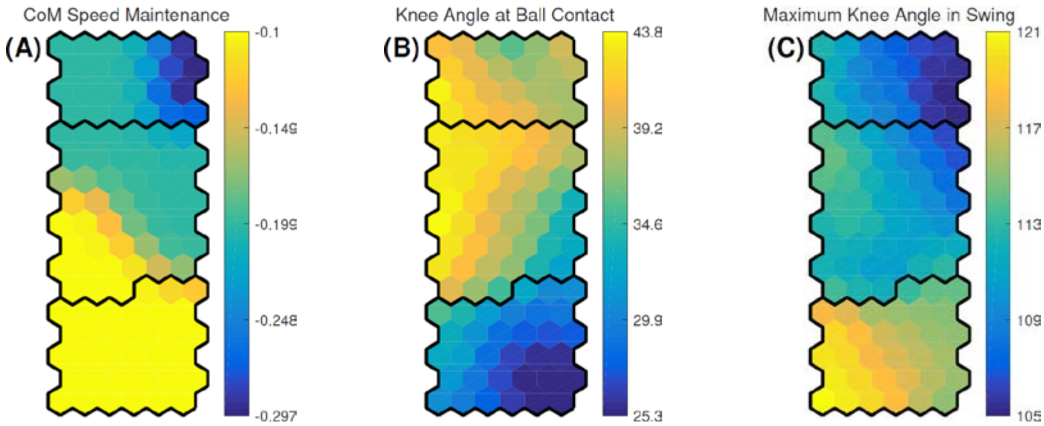

Figure 3. Self-organizing map (SOM) components corresponding to selected biomechanical variables. Variables shown are: (A) centre of mass (CoM) speed maintenance during ball contact; (B) knee flexion angle at ball contact; and (C) maximal knee flexion angle during swing.

DISCUSSION: The SOM clusters separated the placekickers rather than the best, typical, and worst placekicking attempts. This finding suggests that for the seven biomechanical variables examined, the majority of the variability in placekicking biomechanics resulted from inter-individual variation in placekicking technique rather than from placekicking outcome. Indeed, there was no overlap between kickers in the SOM, which suggests that the previously identified key biomechanical variables relating to placekicking success were driven by specific placekickers rather than from the cohort of placekickers. However, within-clusters, there was a tendency for the best kicks to congregate to one region of the map, suggesting similar relative biomechanical responses between players when kicking performances were at their best; but different biomechanical performances in absolute terms. The relationship between placekicking outcome and biomechanics in this group of players is a non-linear one, which implies that placekicking technique development or training needs to be on an individual level rather than at a group level. The current SOM results go against optimal movement template approaches in placekicking skill acquisition and coaching. Rather, the results appear to indicate that different kickers use idiosyncratic ways to optimise kicking performance, although the SOM findings might simply reflect the small sample size.

Indeed, the current study is limited by its small sample size, and more data are needed to confirm our results and to make practical recommendations. The addition of more placekicking trials and players may better enable the identification of best and worst trials through SOM analyses, or of subgroups who perform similarly from a biomechanical perspective. Numerous effective movement templates may be identified that can be used by different players to enhance placekicking outcomes. Performing SOM analyses on the biomechanical variables expressed in relative rather than absolute terms might also provide additional insight given the within-cluster distributions here noted.

CONCLUSION: The SOM on key biomechanical variables clustered placekickers rather than best, typical, and worst placekicking attempts. There was no overlap between kickers, indicating that the optimisation of placekicking success needs to be individual-specific for this particular group of players. The feasibility and effectiveness of using individualised SOM in coaching needs further research.

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