# A data-driven approach to select the best compositions of a wheelchair basketball team

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**Abstract.** This paper explores optimising team line-ups in wheelchair basketball, a sport governed by the International Wheelchair Basketball Federation (IWBF) and its Player Classification Points System (PCPS). It focuses on evaluating players' performances using metrics like the efficiency rating (EFF), performance index rating (PIR), and Win score. The study employs Bayesian longitudinal modelling alongside an optimisation programming respecting game constraints, including players' gender, classification, and match location, to predict the best team compositions. This methodology is applied to the Doneck Dolphins Trier team from the German Rollstuhlbasketball-Bundesliga (RBB), highlighting the effectiveness of these models in preparing for the 2022-2023 season matches. The study demonstrates a novel approach to team optimisation in wheelchair basketball, considering both player performance and game regulations.

**Keywords.** Bayesian statistics, Longitudinal data, Sport analytics

# 1 Introduction

The present work is based on Calvo et al. (2023) and it is motivated by sports, specifically wheelchair basketball, regulated by the International Wheelchair Basketball Federation (IWBF). This sport employs a Player Classification Points System (PCPS) that assigns a rating to each player ranging from 1 to 4.5, reflecting the spectrum from the player with the least physical capacity to the one in excellent condition. The sum of the scores of the five players on the court must never exceed 14. We introduce an innovative methodology for selecting the best line-ups for a wheelchair basketball team for a future game, based on performance metrics of different players in previous games. We combine Bayesian modeling, analysing players' performance data throughout the season, with an integer linear programming scenario to determine line-ups that maximise the team's performance subject to game constraints. One key feature of this proposal is the incorporation of uncertainty, introducing variability into the optimal solution.

# 2 Methodology and application

## 2.1 General framework

The methodology in this work is general and consists of three stages: 1) Approximating the posterior distribution of the parameters of the Bayesian longitudinal model that analyses players' performance metrics. 2) Computing predictions for a new game using the posterior predictive distribution associated to each player. 3) Obtaining the posterior distribution of the solutions to the integer linear programming optimisation problem that seeks to maximise the sum of predictions under certain constraints.

## 2.2 Methodology

In this study, we model the performance of players in basketball games using a longitudinal variable $y_{ij}$, which represents the performance of player $i$ in game $j$. The sampling model is a mixed linear model:

$$\begin{aligned}(y_{ij} \mid \boldsymbol{\theta}, \boldsymbol{b}) &\sim \mathrm{N}(\mu_{ij}, \sigma^2),\\ (\mu_{ij} \mid \boldsymbol{\theta}, \boldsymbol{b}) &= \beta_0 + b_{0i} + b_{0j} + \beta_W I_W(i) + \beta_C C_i + \beta_H I_H(j) + (\beta_1 + b_{1i})j,\end{aligned} \tag{1}$$

where $\boldsymbol{\theta}$ and $\boldsymbol{b}$ include model parameters and random effects, respectively. Parameters consist of the measurement error standard deviation $\sigma$, common coefficients ($\beta_0$, $\beta_W$, $\beta_C$, $\beta_H$, and $\beta_1$), and the standard deviations of random effects ($\sigma_{0b}$, $\sigma_{0m}$, $\sigma_{1b}$) which are assumed to be normally distributed. Covariates include a gender indicator $I_W(i)$, the functional classification $C_i$ of each player $i$, and a home indicator $I_H(j)$ for each match $j$.

For Bayesian modelling, non-informative and independent prior distributions are chosen. Wide normal distributions are used for coefficients, while uniform distributions are selected for standard deviation parameters.

The study further explores the prediction of player performance in future games using the posterior predictive distribution:

$$f(y_i^{(pre)} \mid \mathcal{D}) = \int f(y_i^{(pre)} \mid \boldsymbol{\theta}, \boldsymbol{b})\, \pi(\boldsymbol{\theta}, \boldsymbol{b} \mid \mathcal{D})\, \mathrm{d}(\boldsymbol{\theta}, \boldsymbol{b}). \tag{2}$$

Finally, the study proposes a stochastic integer linear programming optimisation problem to select the optimal team composition, maximising combined team performance while adhering to constraints. The objective function to be maximised is:

$$\max \sum_{i=1}^{N} z_i y_i^{(pre)}, \tag{3}$$

subject to player inclusion in the team lineup and functional classification constraints, ensuring compliance with the IWBF's rules.

### 2.3 Application

To illustrate this procedure, data from the 18 games in the 2022-2023 season of the Doneck Dolphins Trier wheelchair basketball team in the German 1st division are analysed. We followed nine players throughout the 18 games of the season, three of whom are female, reflecting the mixed-gender nature of the competition. All player information is summarised in Table 1. Moreover, three individual performance metrics are considered: player efficiency (EFF), performance index rating (PIR), and Win Score. The Bayesian longitudinal model is separately fitted for each metric. Player Dirk Passiwan stands out in the team, with somewhat irregular but exceptionally good performance. Due to the constraints of the Player Classification Points System (PCPS), high individual performance does not necessarily always lead to inclusion in the line-up.

Table 1: Name, functional classification value and sex of the players of the Doneck Dolphins Trier team who play more than 40 minutes during the 2022-2023 season.

| Player | Classification | Sex | Index |
|---|---|---|---|
| Annabel Breuer | 1.5 | Woman | 1 |
| Correy Rossi | 2 | Man | 2 |
| Dejon Green | 3.5 | Man | 3 |
| Dirk Passivan | 4.5 | Man | 4 |
| Lucas Jung | 1 | Man | 5 |
| Natalie Passivan | 4.5 | Woman | 6 |
| Patrick Dorner | 3.5 | Man | 7 |
| Svenja Erni | 3.5 | Woman | 8 |
| Walter Vlaanderen | 4.5 | Man | 9 |

## 3 Results

The results clearly identify compositions with the highest probability of being optimal. The probabilities of each player being included in the optimal line-up are also estimated (see Figure 1). Annabel Breuer, Correy Rossi, Dirk Passivan, and Walter Vlaanderen stand out. This demonstrates valuable information derived from the results.

Additionally, as we can observe in Figure 2, the methodology allows for calculating compatibility probabilities between players on the court. Looking at this figure, it becomes evident that Patrick Dorner is the player who best completes the group composed by {Annabel Breuer, Correy Rossi, Dirk Passivan, Walter Vlaanderen}.

Finally, it is also possible to estimate outcomes in the absence of a player due to suspension or injury, specifically considering line-ups without that player.

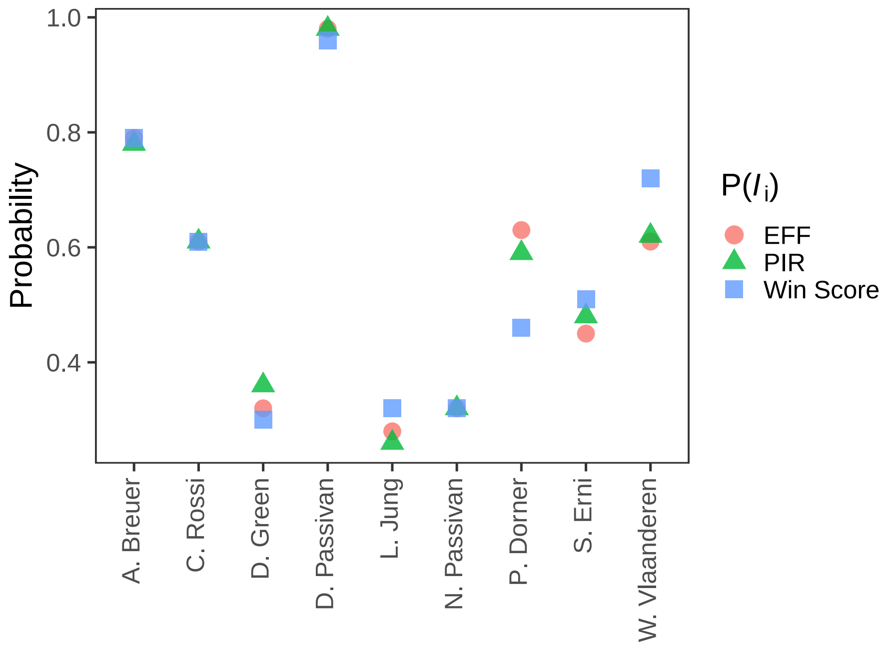


Figure 1: Estimated probabilities $P(I_i \mid \mathcal{D})$ of player $i$ being included in the optimal line-up team based on EFF, PIR and Win Score metrics.

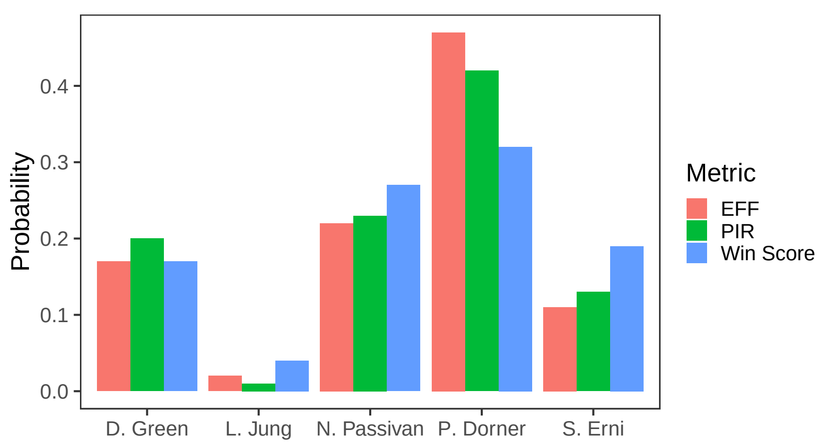


Figure 2: Estimated probabilities of the inclusion of players Dejon Green, Lucas Jung, Natalie Passivan, Patrick Dorner and Svenja Erni in the line-up team given that players Annabel Breuer, Correy Rossi, Dirk Passivan and Walter Vlaanderen have already been chosen, based on EFF, PIR and Win Score metrics.

# 4 Conclusions

This work focuses on combined metrics of positive and negative actions, but it can be easily complemented with other types of metrics. Our proposal is directly applicable to other sports for people with physical disabilities using the PCPS, such as powerchair football, powerchair hockey, or wheelchair rugby. It can even be adapted to sports without PCPS by replacing these constraints with specific limitations to each discipline. In conclusion, this methodology has great potential for use by coaches and technical staff, providing valuable insights into ideal compositions for upcoming games, evaluating both own and opposing players, and identifying strengths and weaknesses of different strategies.

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