# Optimising pre-season training loads in Australian Football

**David Carey**
Justin Crow, Kok-Leong Ong, Peter Blanch, Meg Morris, Ben Dascombe, Kay Crossley

@david_carey1

# Using optimisation to *help* plan training loads

I do not claim to be able to find,

or that there even exists,

a truly ***"optimal"*** training plan

But the task of planning training is real –

and I think some of the methods I will present can **help**

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# **Optimisation** in applied mathematics

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Take a real world problem that has **decisions** and **consequences**

↓

Write out the problem in **equations**

↓

Use **maths + computer science** to find the **best solution**

- A factory produces bicycles (B) and tricycles (T) that profit $30 and $50 respectively.
- There are 40 hours in a working week
- Can make maximum 25 bikes and 15 tricycles per hour
- Enough materials to make maximum 500 of each
- The factory would like to maximise their profit

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$$maximise: 30 \cdot B + 50 \cdot T$$

*Such that:* $$\frac{B}{25} + \frac{T}{15} \leq 40$$

$$0 \leq B, T \leq 500$$

$B$ and $T$ are our **decision variables**

(represent the choices we have to make)

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**Objective function**

(thing we want to maximise or minimise)

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**Constraints**

(rules that we cannot break)

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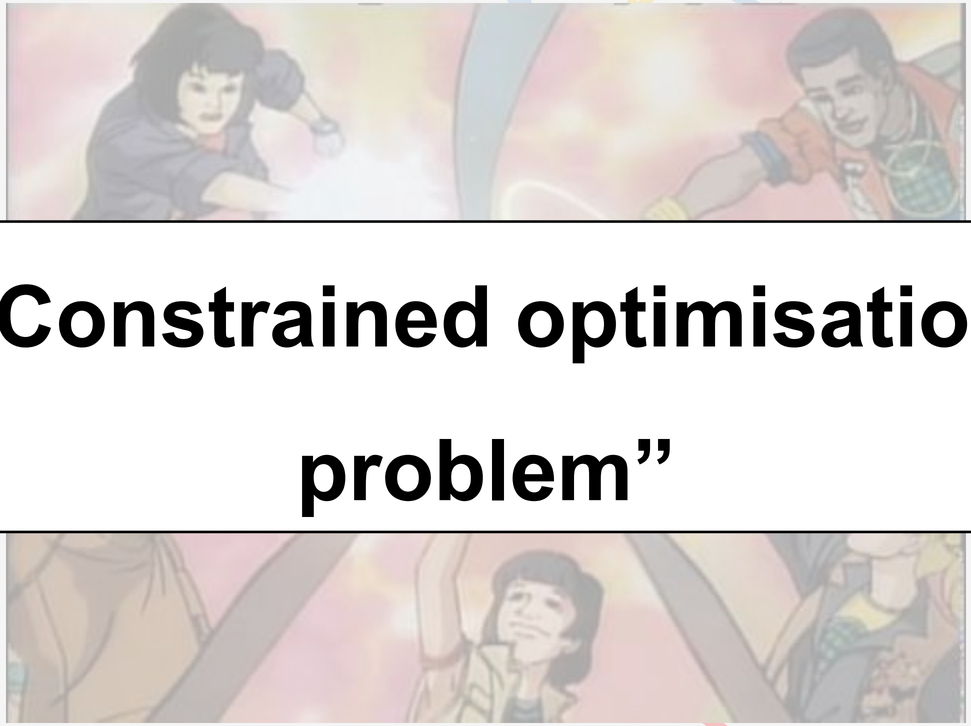


**"Constrained optimisation problem"**

**Constraints**

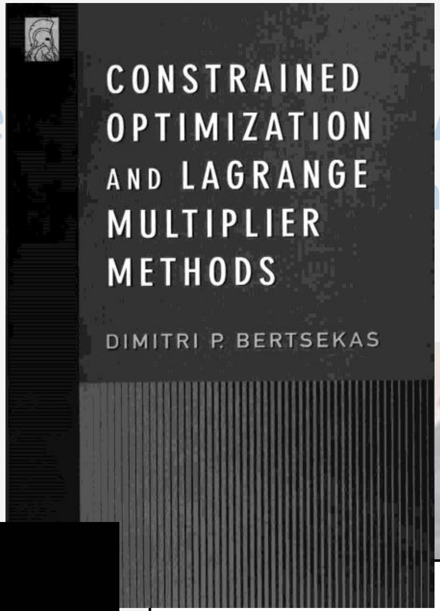
(rules that we cannot break)

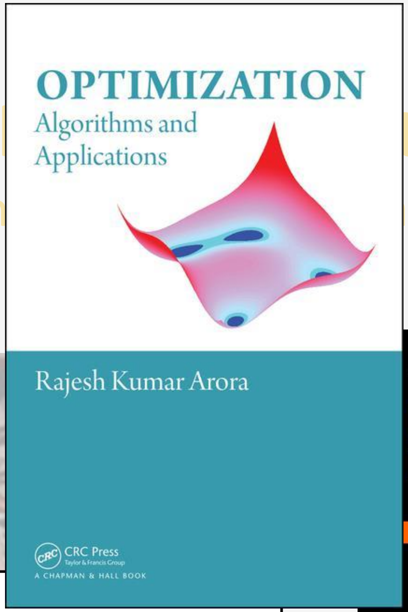
$B$ and $T$ are ... variables

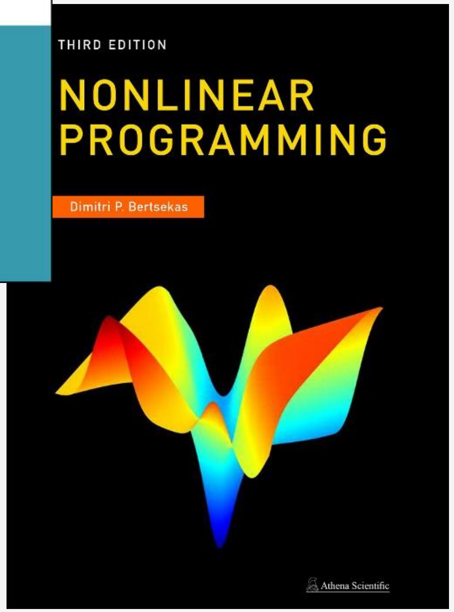
(represent the c... ...ake)

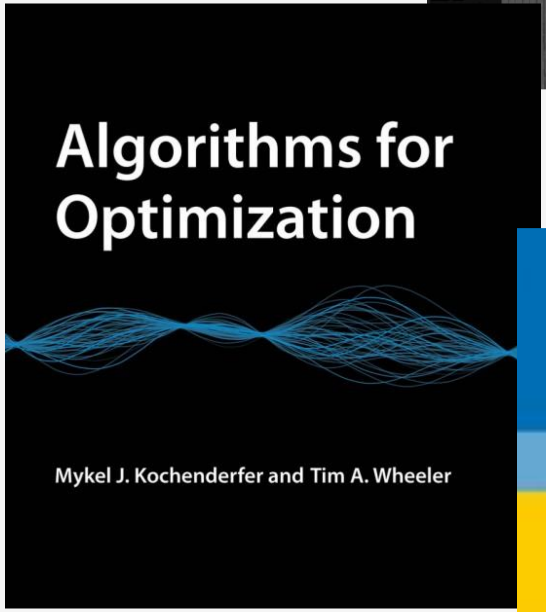
O... ...tion

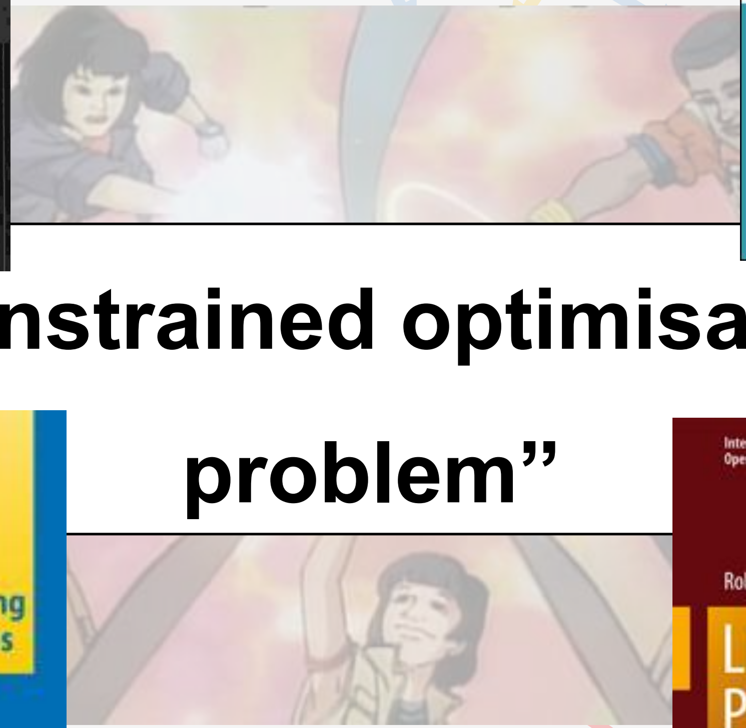
(th... ...ximise or minimise)



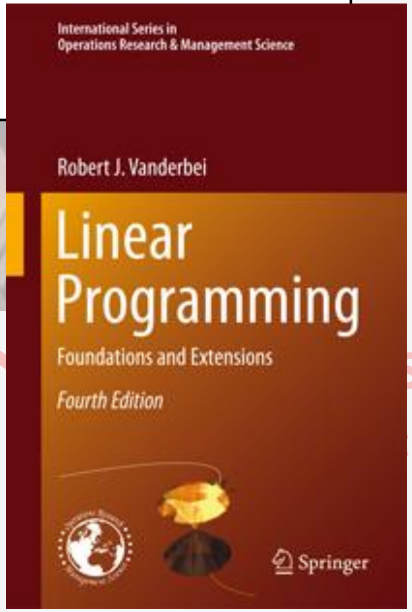



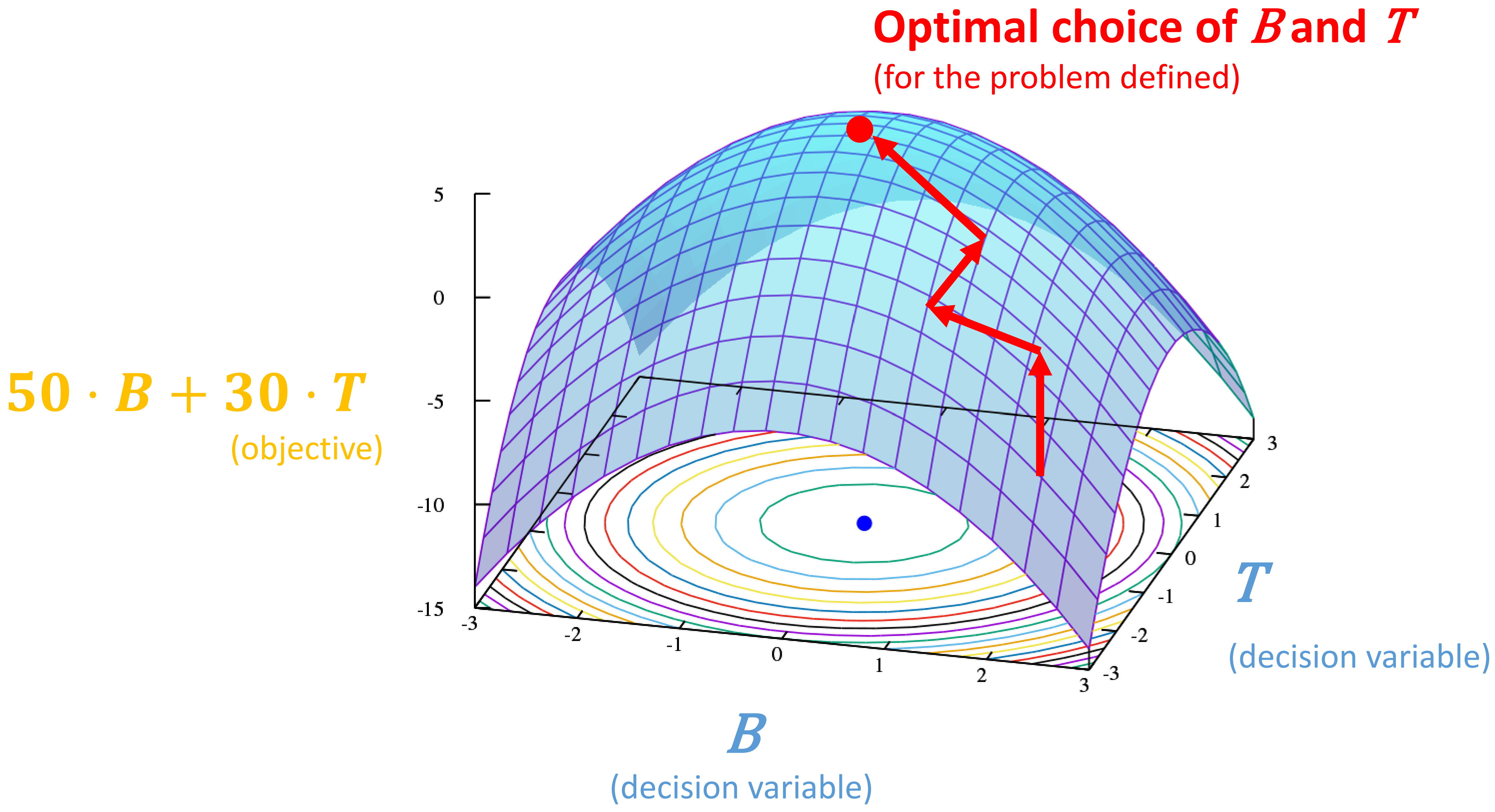



# "Constrained optimisation problem"


...s

...annot break)



Optimal choice of $B$ and $T$
(for the problem defined)
$50 \cdot B + 30 \cdot T$
(objective)
5
0
-5
-10
-15
-3
-2
-1
0
1
2
3
$B$
(decision variable)
$T$
(decision variable)

# So what did we do?

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- Can the task of planning and progressing training loads be formulated as an optimisation problem?

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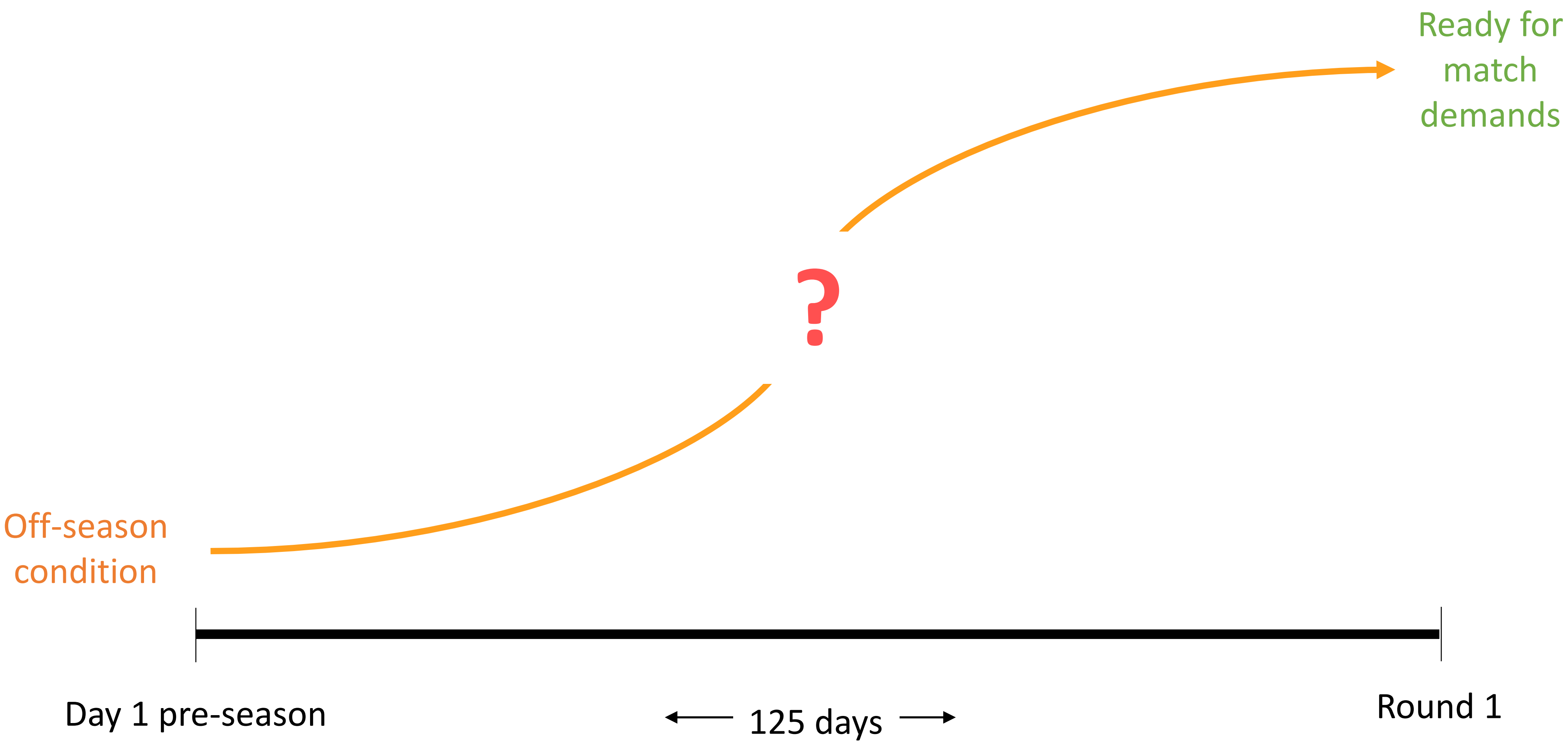
- Can the task of planning and progressing training loads be formulated as an optimisation problem?
  - **AFL pre-season** as a test case
  - Long period of time
    (lots of **decisions**)
  - Relatively **high freedom**
    (each club decides their pre-season – league sets the fixture)


Ready for match demands
?
Off-season condition
Day 1 pre-season
125 days
Round 1

# Decision variables

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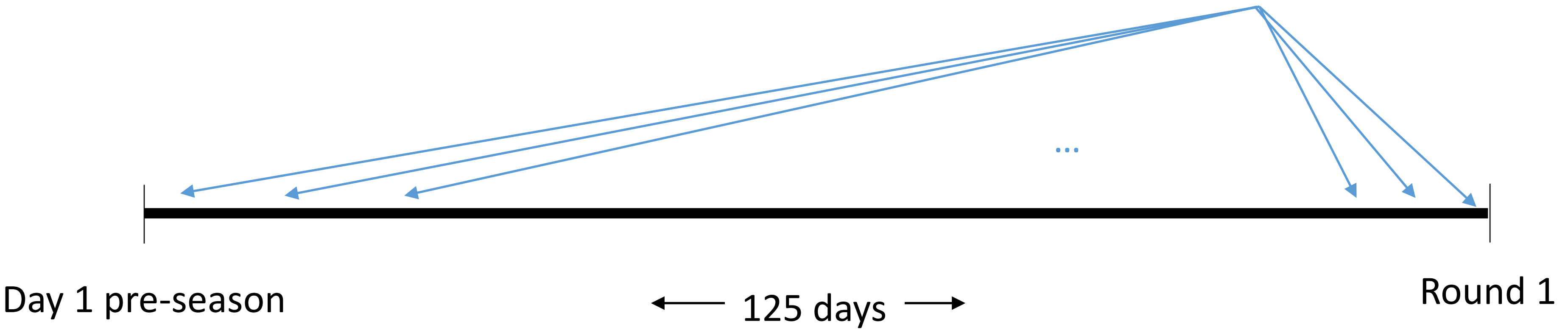
125 days of pre-season = 125 decision variables

$$w_i = \text{training load on day } i; \quad i \in \{1, 2, \ldots, 125\}$$



# Decision variables

Something that can be controlled.
We considered:

- Total session distance
- Total session high speed running

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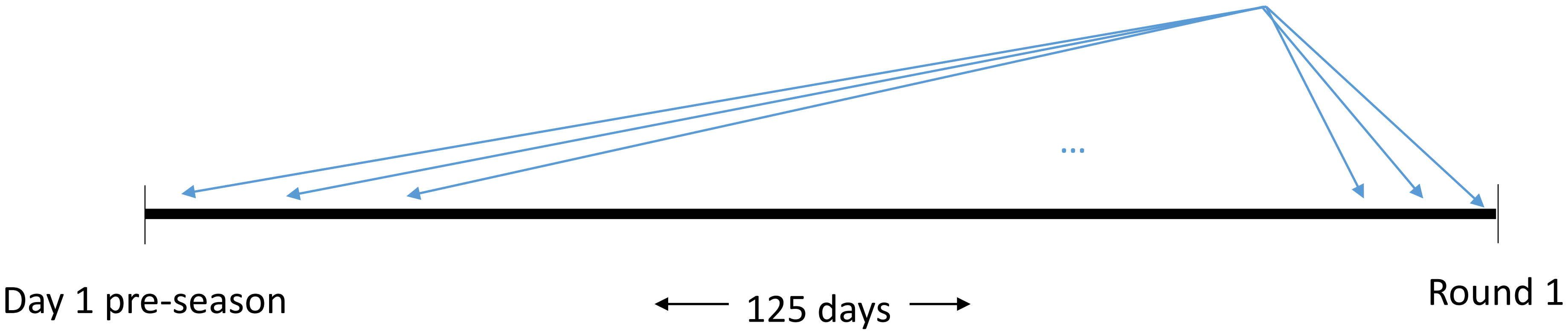

# Constraints

- Pre-season matches on days 98, 104, 112 ($w_{98,104,112} = 11{,}220\ \mathrm{m}$)
- AFL match on day 125 ($w_{125} = 13{,}200\ \mathrm{m}$)
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- Literature:
  - Acute:chronic workload ratio
  - Chronic training load

$$r_i = \sum_{j=i-6}^{i-1} \frac{w_j}{6} \Big/ \sum_{j=i-24}^{i-1} \frac{w_j}{24}$$

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  - Simple first attempt
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$$maximise: \quad f_A(\mathbf{w}) = \sum_{i=1}^{125} w_i$$

*"Just add up the load from each day"*

# Assumptions

- Off-season chronic training loads
  - Need to assume a baseline value
  - Interesting to see the effect of varying this parameter

    (i.e. what are the effects of players coming back in better/worse condition)

# Attempt 1

$w_i$ = training load on day $i$;

$$f_A(\mathbf{w}) = \sum_{i=1}^{125} w_i$$

[maximise total pre-season volume]

$0.6 < r_i < 1.3$ [keep the load progression reasonable]

$0 \leq w_i \leq 50{,}000$ [not allowed to do more than 50km in a day]

$w_{sundays} = 0$ [Sundays off]

$\textit{Off-season chronic load} = 14\ km/wk$ [assume off-season maintenance of 14km/wk]

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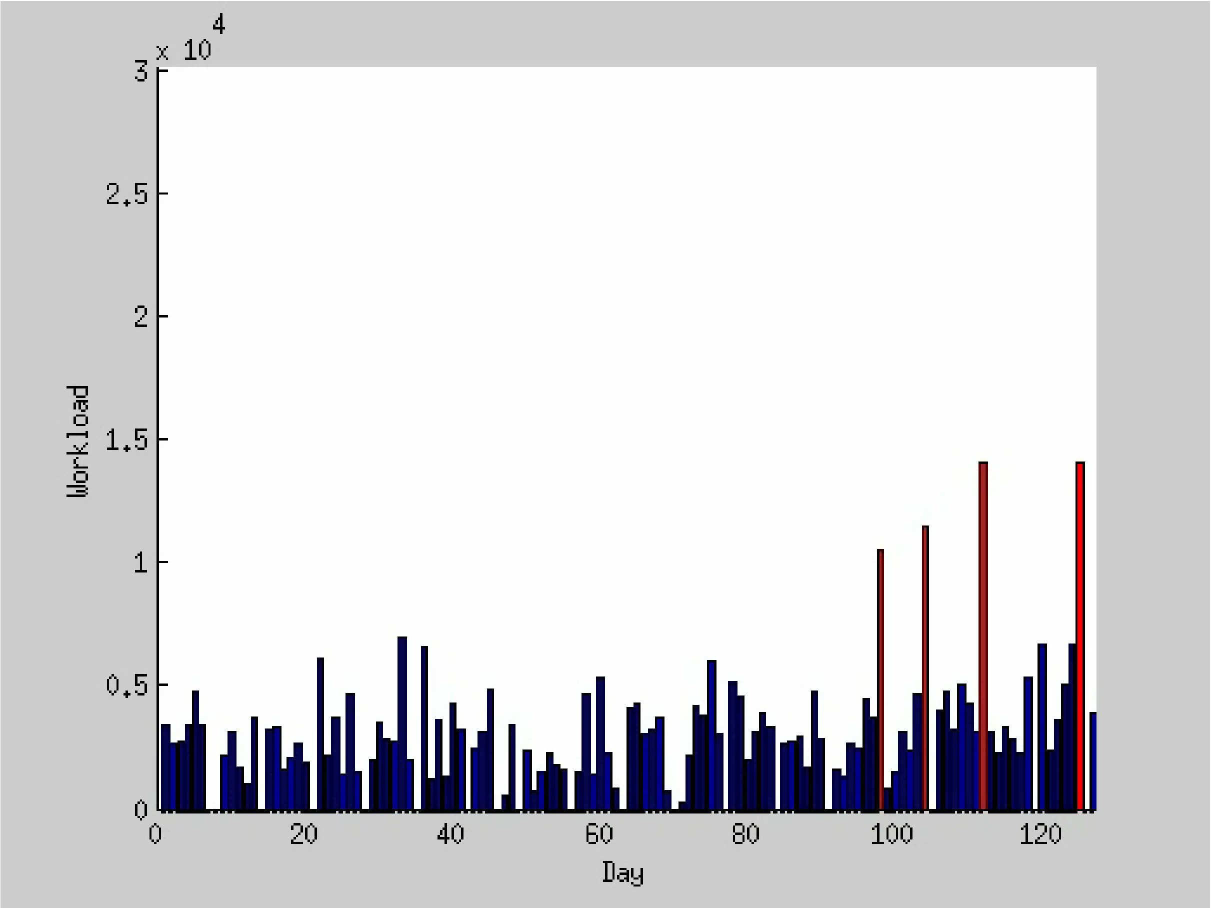

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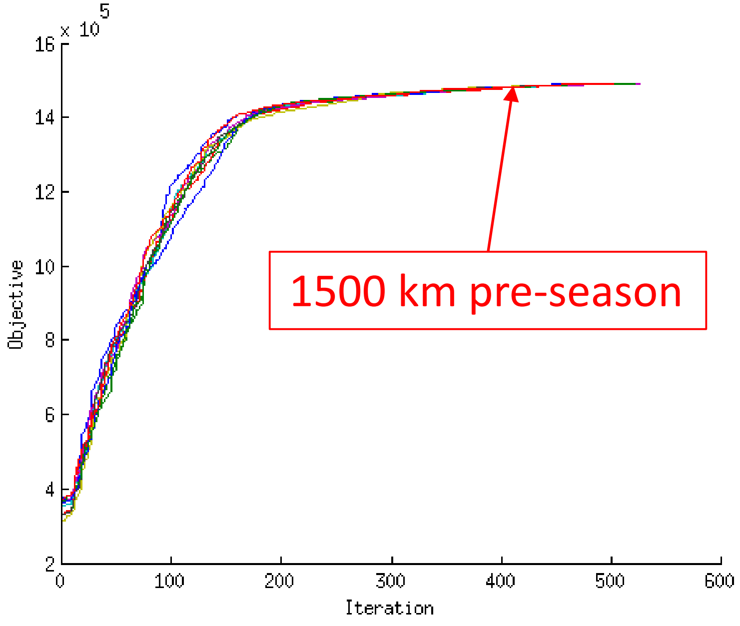


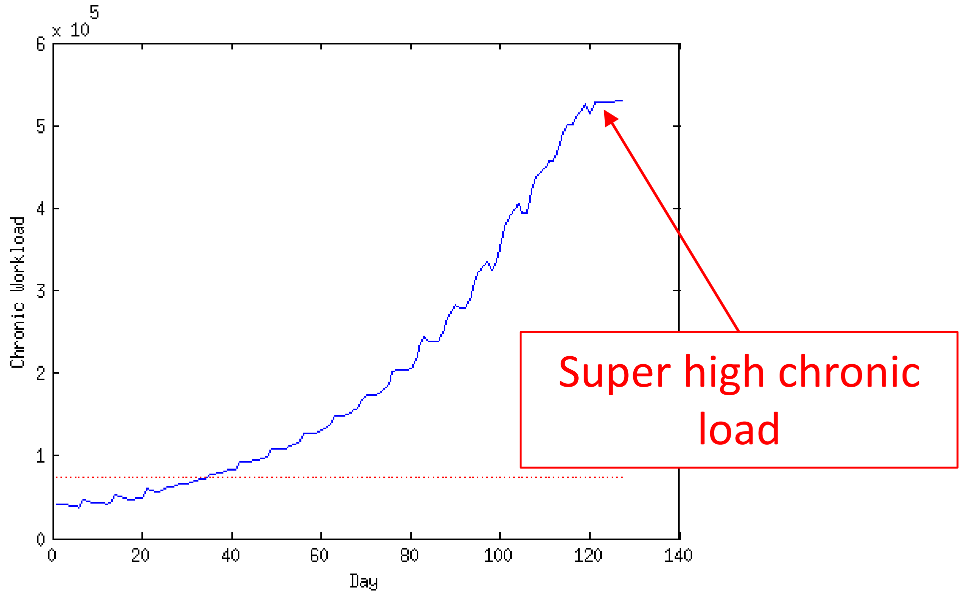

# Attempt 2

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$C_i < 73{,}721$ [upper limit on 3-week chronic load from *Colby et al. 2014*]

*Rest days (2 in each 7 day window) - manual* [known as a cardinality or $\boldsymbol{l_0 - norm}$ constraint. Very hard to get convergence]

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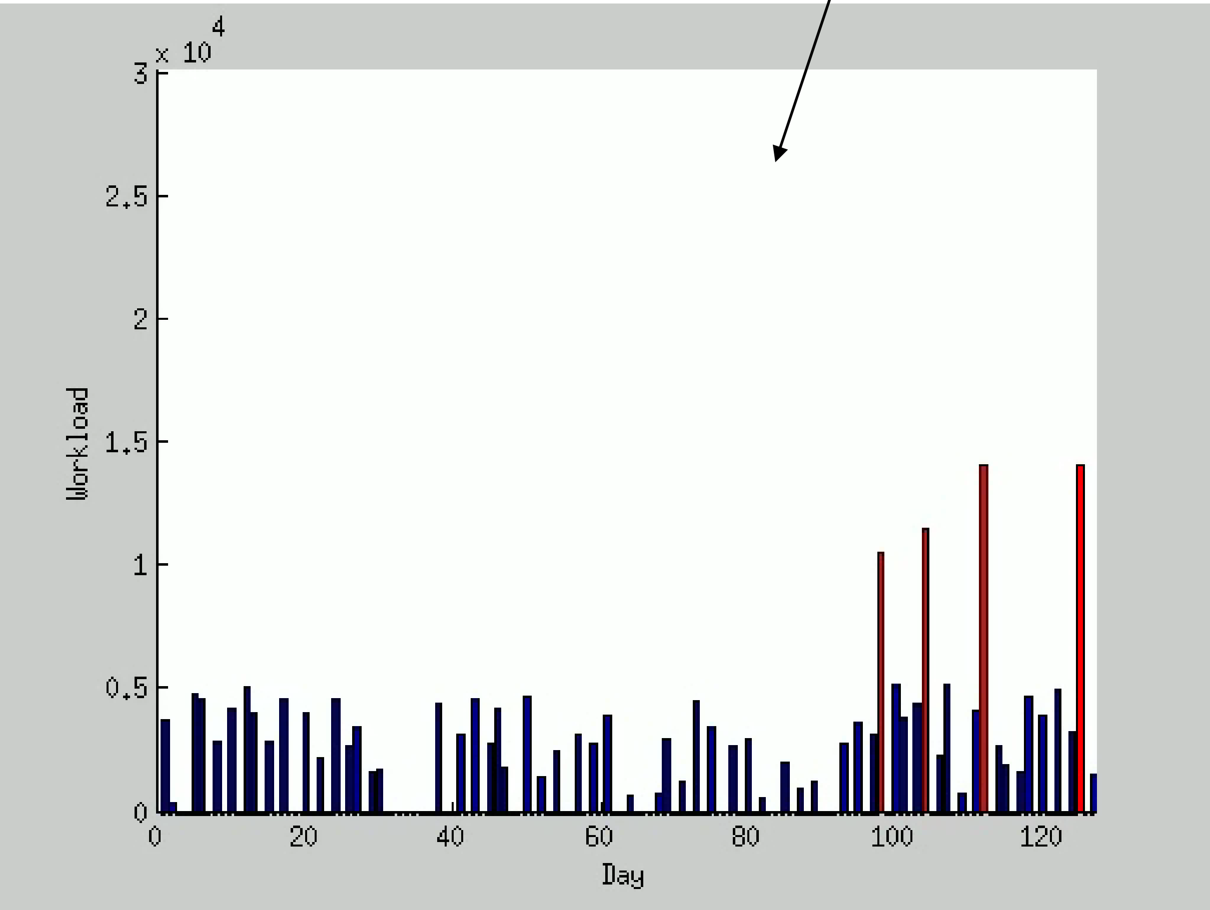
Starting to look feasible



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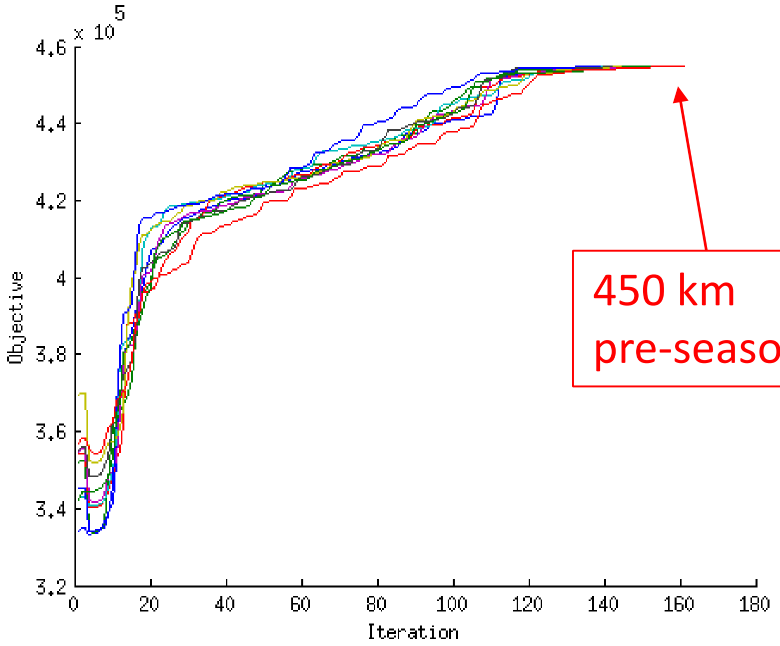
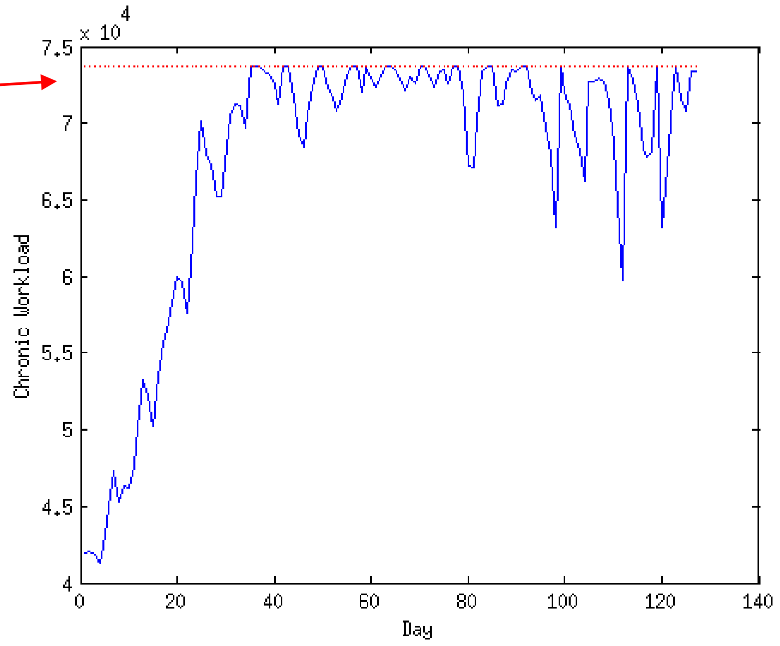



450 km pre-season

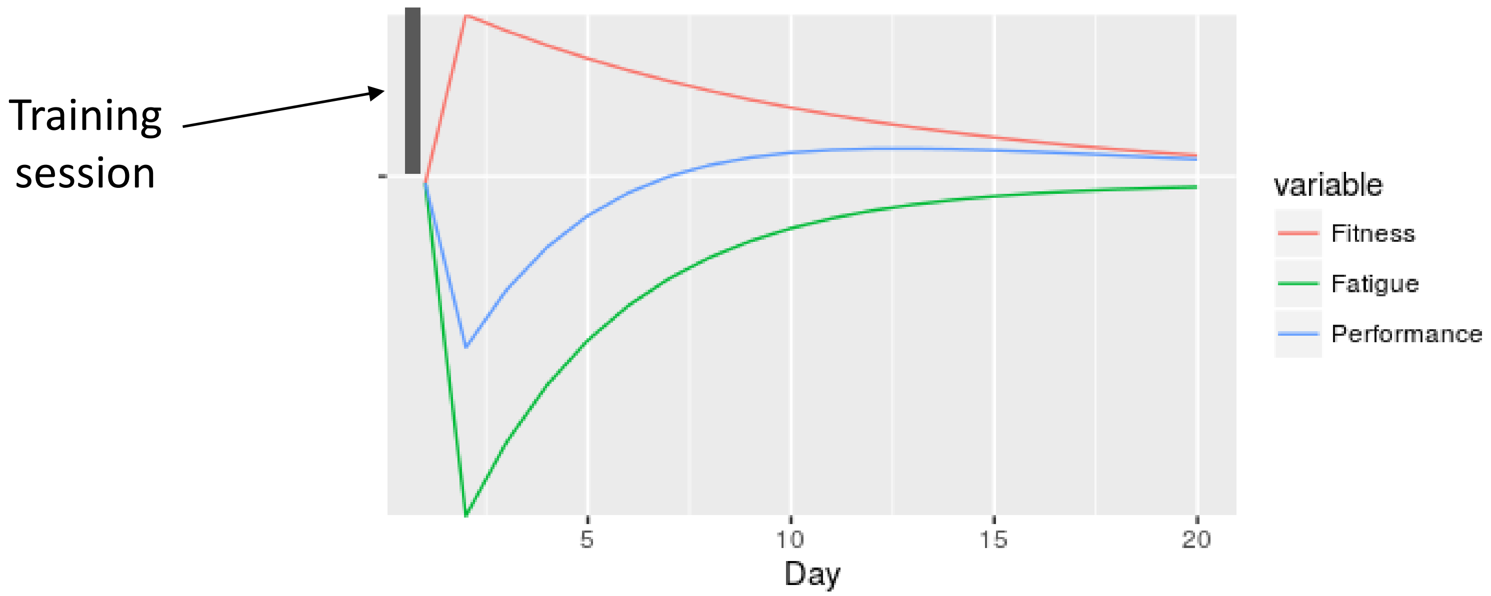
3-week load below limit



# Let's try changing the objective function

# Objective function

- Maximise Banister model projected performance @ Round 1
  - Includes consideration for the fatiguing effect of training
  - Being ready for Round 1 might be a more realistic goal
  - Still relatively simple



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$$p_i = p_0 + k_1 \sum_{j=1}^{i-1} w_j e^{\frac{-(i-j)}{\tau_1}} - k_2 \sum_{j=1}^{i-1} w_j e^{\frac{-(i-j)}{\tau_2}}$$

$$maximise: \quad f_B(w) = p_{125}$$

*"Projected performance level on day 125 (Rnd 1)"*

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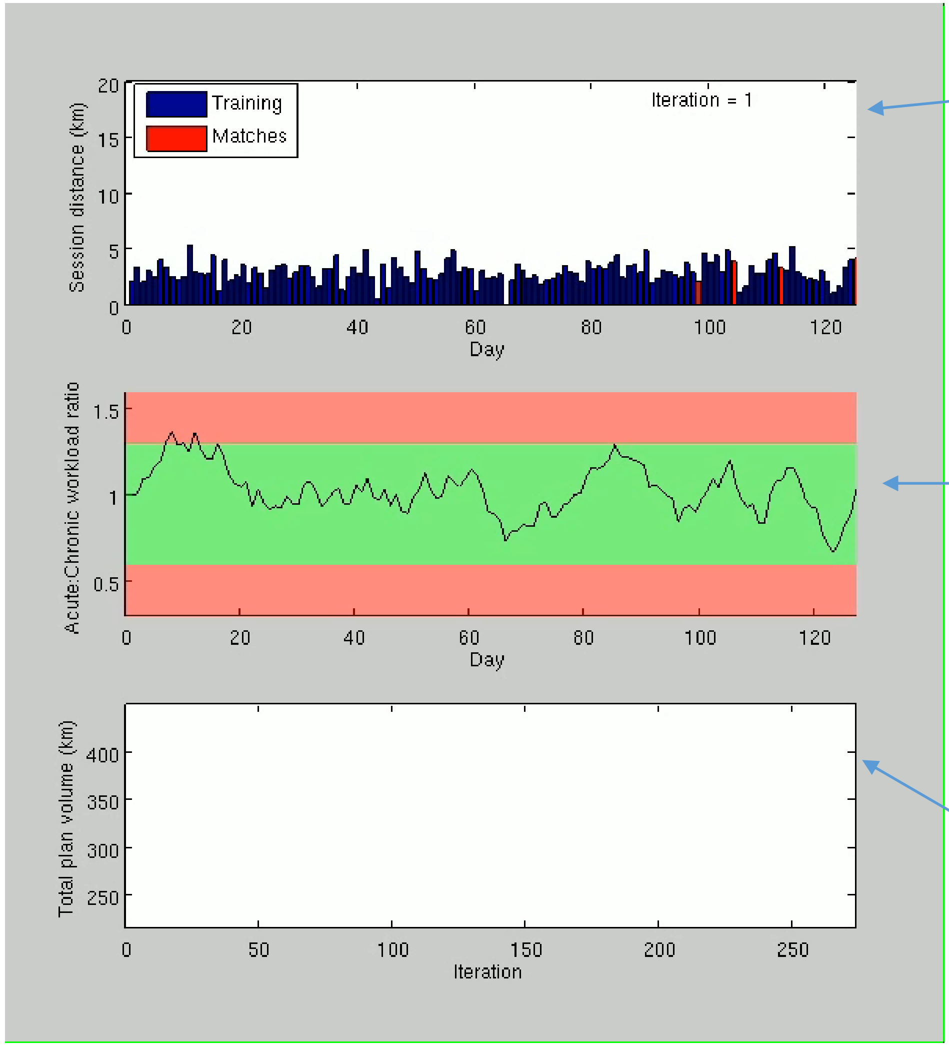


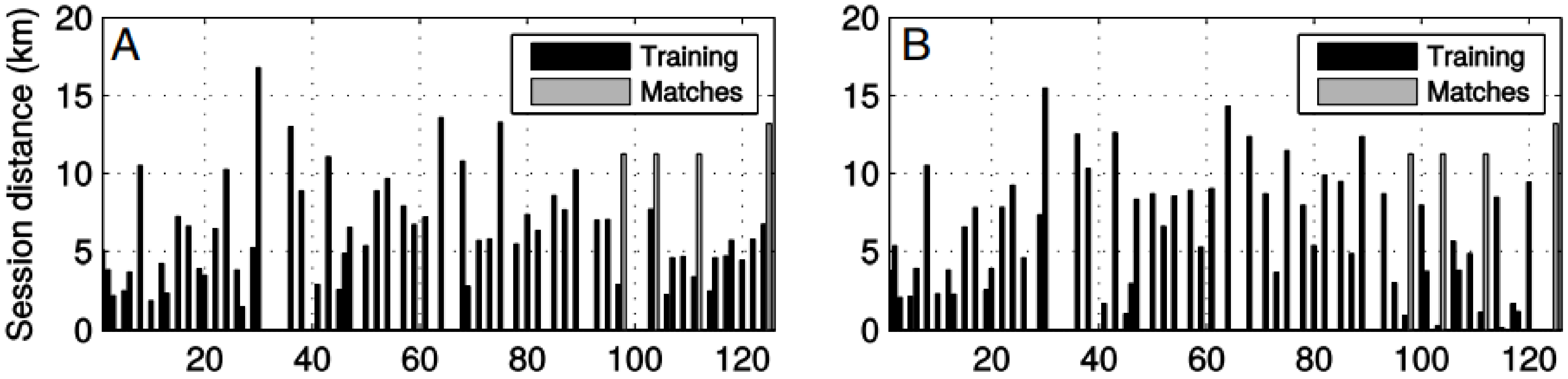

Optimisation solver is iteratively updating the training plan

ACWR each day is changing but stays within the defined constraints

Each iteration is improving the objective function

# So it works…

- Take a few simple rules about training progression
- Define a goal
- Press **go**
- Generates the optimal solution (***to the problem you specified***)

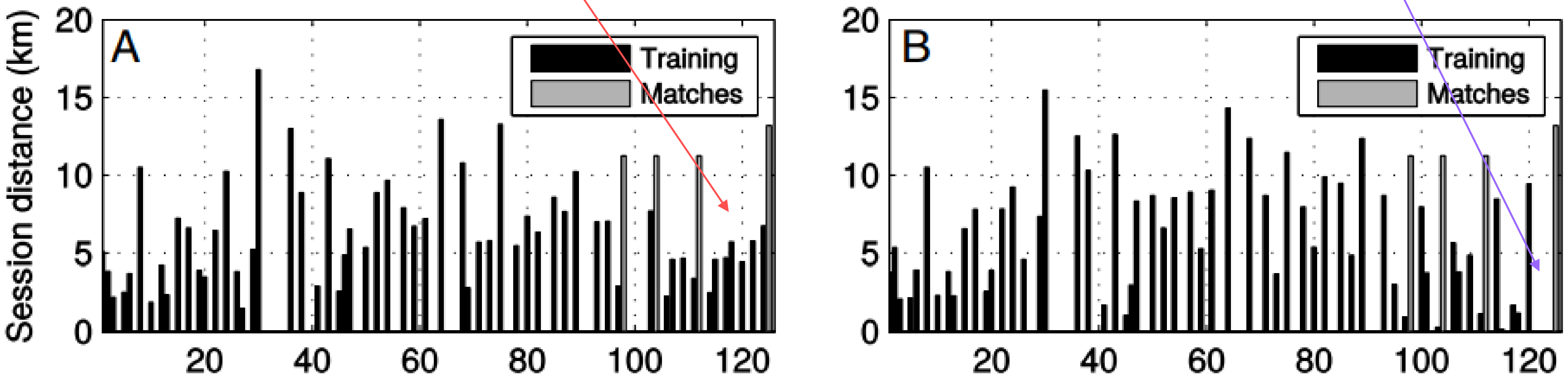



A: maximise total volume

B: maximise Banister projection

Frequent training leading up to round 1
(squeeze out as much volume as possible)

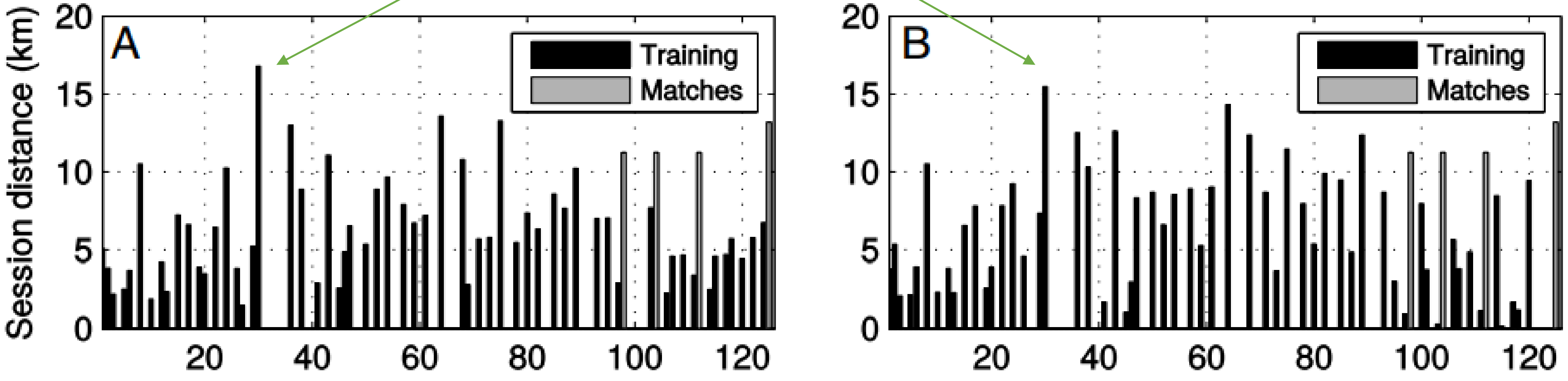
Cessation of training before round 1
(decay fatigue component of model – **peak**)




**A: maximise total volume**

**B: maximise Banister projection**

Both reach full match loads before Christmas

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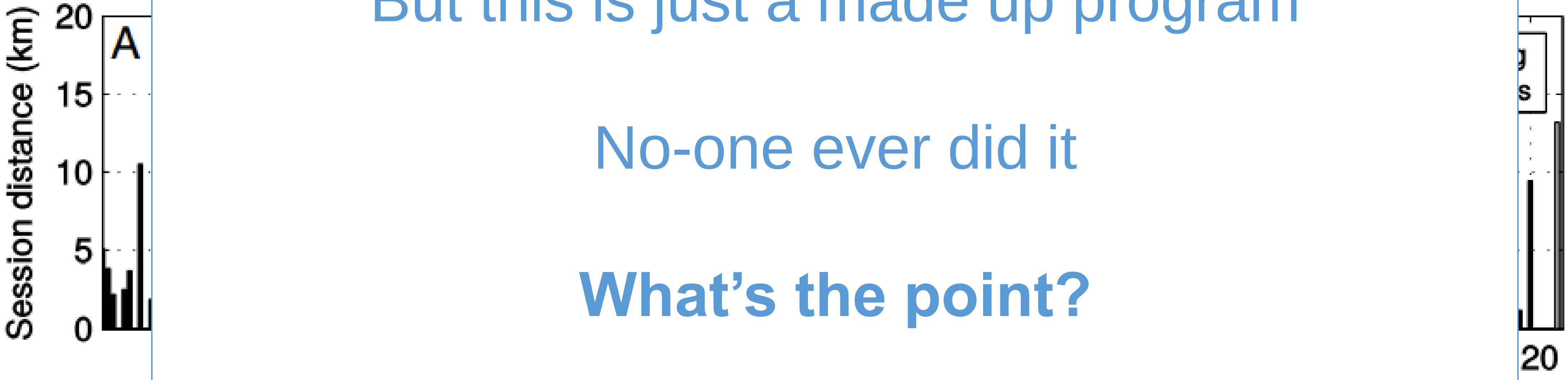



But this is just a made up program

No-one ever did it

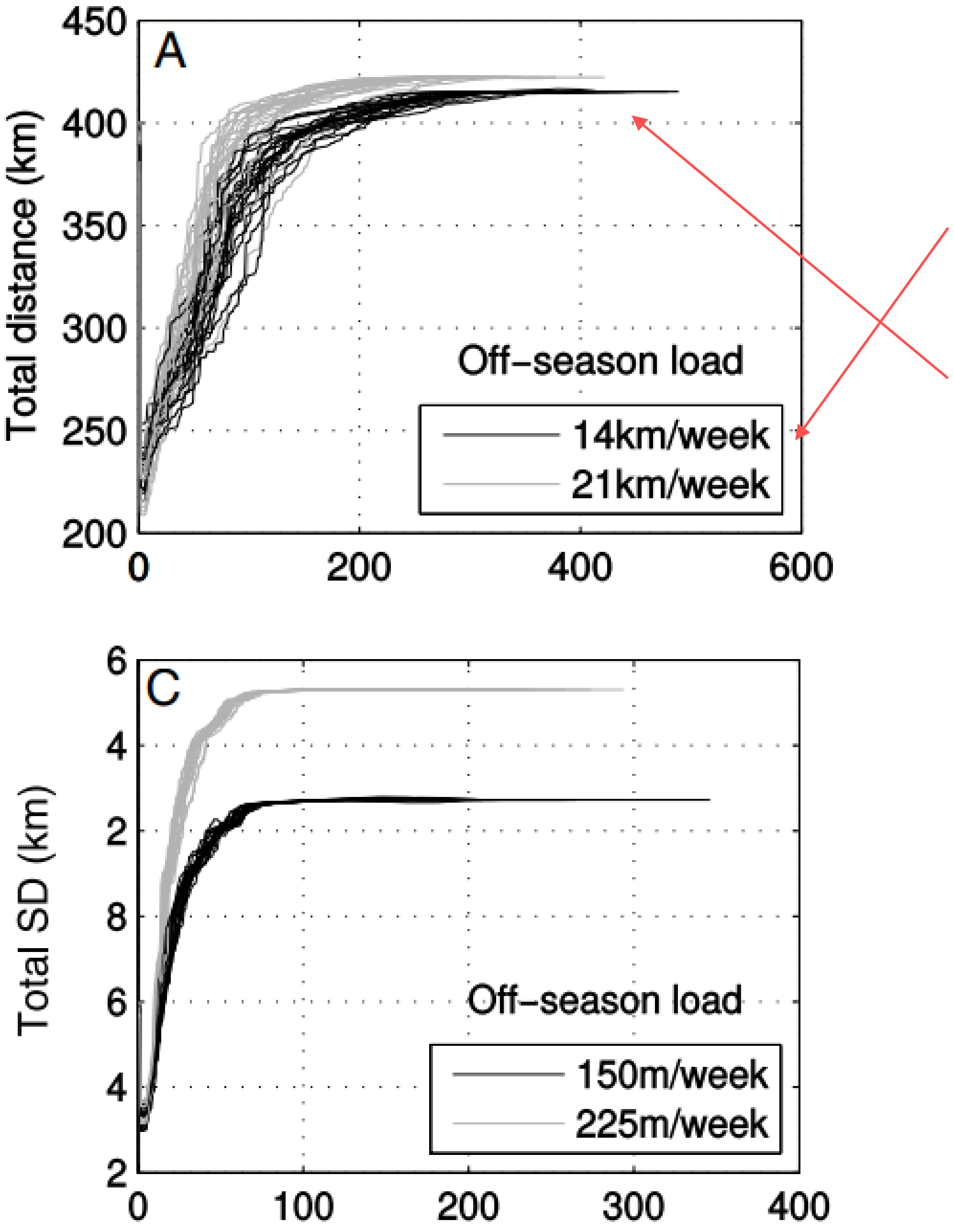
**What’s the point?**

A. maximise total volume

B. maximise Banister projection

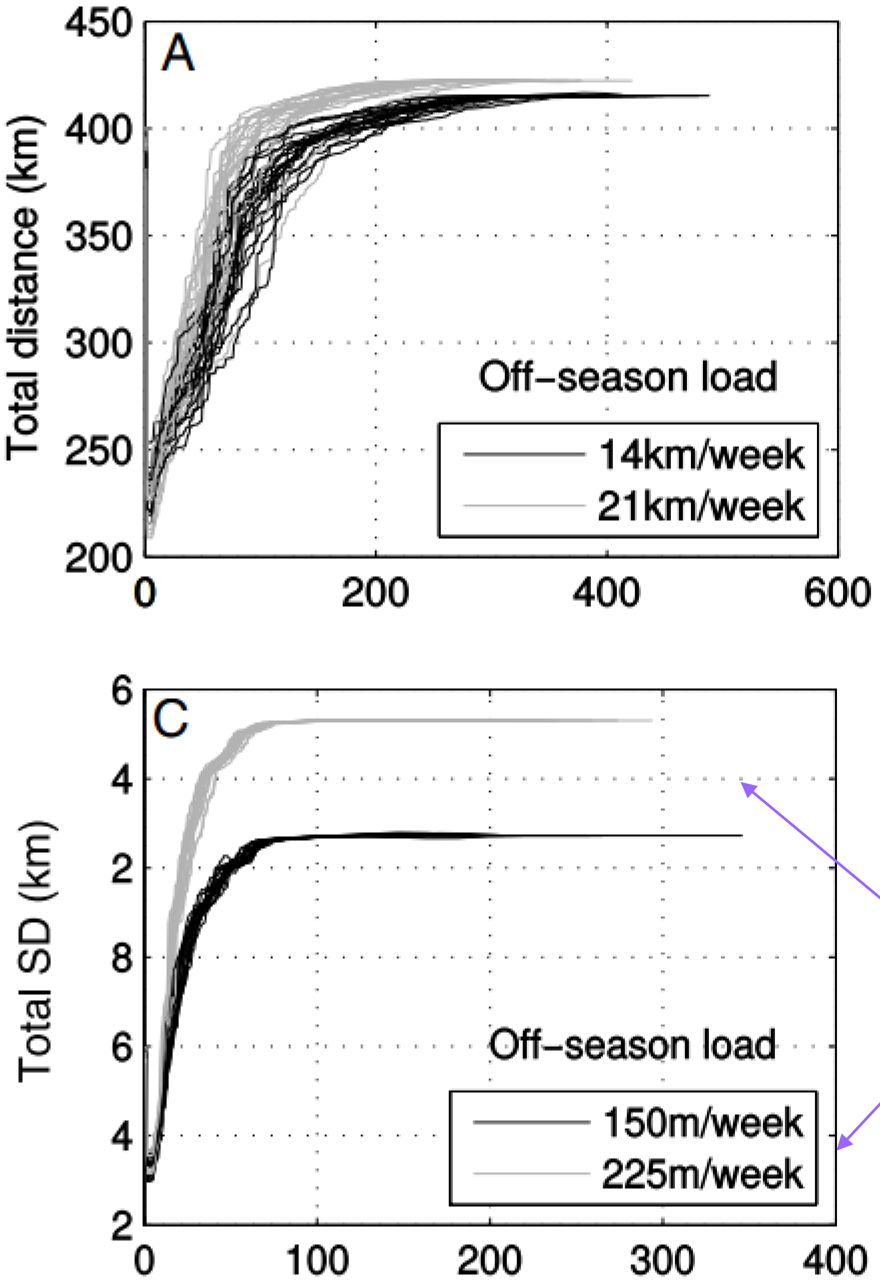
# Applications

- Rapid testing of ideas
  - Change a parameter/constraint/objective and see the effect in seconds
- **Cost-benefit simulations**
  - How much extra PS volume if off-season loads increased by 50%?
  - How much extra training can we do if increase the allowable risk?
- Approach is fully customisable
  - Program with a different load metric? – just plug it in
  - Want to use a different objective? – just plug it in
  - Want to use different injury risk constraints? – just change them
  - Different sport? Different timeline? – just change the numbers
- Totally objective – no risk of subjective bias creeping in




Increase off-season total distance by 7km/wk

Not much flow on effect to total pre-season volume




Increase off-season high speed running load by 75m

Large flow on effect to total pre-season HSR allowed by the model

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    - Change a parameter/constraint/objective and see the effect in seconds

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A new approach to predict changes in physical condition: A new extension of the classical Banister model

Marcos Matabuena, Rosana Rodríguez-López

*Departamento de Análise Matemática, Estatística e Optimización, Universidade de Santiago de Compostela, 15782, Santiago de Compostela, Spain*

**Modeling and Prediction of Competitive Performance in Swimming Upon Neural Networks**

*Jürgen Edelmann-Nusser, Andreas Hohmann, and Bernd Henneberg*

**Optimal vs. Robust: Applications to Planning Strategies Insights from a simulation study**

Mladen Jovanović[1] and Ivan Jukić[2]

BRIEF REPORT

**Use of Machine Learning to Model Volume Load Effects on Changes in Jump Performance**

**Authors:**
Kristof Kipp [1*], , John Krzyszkowski [1], , Daniel Kant-Hull [2]

# Interested?

- Paper in IJSPP

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*International Journal of Sports Physiology and Performance*, 2018, 13, 194-199
https://doi.org/10.1123/ijspp.2016-0695


Human Kinetics
ORIGINAL INVESTIGATION

## Optimizing Preseason Training Loads in Australian Football

**David L. Carey, Justin Crow, Kok-Leong Ong, Peter Blanch, Meg E. Morris, Ben J. Dascombe, and Kay M. Crossley**

***Purpose:*** To investigate whether preseason training plans for Australian football can be computer generated using current training-load guidelines to optimize injury-risk reduction and performance improvement. ***Methods:*** A constrained optimization problem was defined for daily total and sprint distance, using the preseason schedule of an elite Australian football team as a template. Maximizing total training volume and maximizing Banister-model-projected performance were both considered optimization objectives. Cumulative workload and acute:chronic workload-ratio constraints were placed on training programs to reflect current guidelines on relative and absolute training loads for injury-risk reduction. Optimization software was then used to generate preseason training plans. ***Results:*** The optimization framework was able to generate training plans that satisfied relative and absolute workload constraints. Increasing the off-season chronic training loads enabled the optimization algorithm to prescribe higher amounts of "safe" training and attain higher projected performance levels. Simulations showed that using a Banister-model objective led to plans that included a taper in training load prior to competition to minimize fatigue and maximize projected performance. In contrast, when the objective was to maximize total training volume, more frequent training was prescribed to accumulate as much load as possible. ***Conclusions:*** Feasible training plans that maximize projected performance and satisfy injury-risk constraints can be automatically generated by an optimization problem for Australian football. The optimization methods allow for individualized training-plan design and the ability to adapt to changing training objectives and different training-load metrics.

***Keywords:*** AFL, injury, performance, workload ratio

Training-load prescription in team-sport athletes is a balance between performance improvement[1,2] and injury-risk reduction.[3–6] The manipulation of training intensity, duration, and frequency to induce improvements in athletic performance is a fundamental objective of training-plan prescription.[7] To inform this process, mathematical models of the relationship between training loads and performance have been proposed for multiple athletic populations.[1,7,8] Banister et al[1] modeled the response to a

Currently, physical-preparation staff are tasked with balancing the training guidelines associated with injury-risk reduction and performance improvement when prescribing training loads. Mathematical optimization is a method that may help in this process, particularly as more data on training-load monitoring become available.[5,6,10–12] Optimization is the task of finding a set of values (decision variables) that maximize an objective function (goal) and satisfy a set of constraints. Optimizing training loads has been

# Thank you


- Wisbey, Ben, et al. "Quantifying movement demands of AFL football using GPS tracking." Journal of science and Medicine in Sport 13.5 (2010): 531-536.
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