# Experimental validation of a method for virtual testing of bike settings

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**Plan de relance – mesure de préservation de l'emploi de R&D**

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# Context

- **Optimizing cyclist position**
  - Aerodynamics
  - Biomechanics
  - Injury prevention

- **Aerodynamic drag = 80-90% of resistive forces**
- **Biomechanics optimization and injury prevention**

  ➔ **Keeping dynamic joint angles within limits**

- **Optimization strategy = optimizing aerodynamics under angular ranges constraints**

# Context

- **Optimization strategy**
  - Measuring joint angles
  - Measuring aerodynamics

  ➔ **Time-consuming and/or costly**

   **Iterative optimization difficult to implement**

- **Proposed framework**
  - Virtually change the bike settings
  - Predict the joint angles
  - Predict frontal area

# Motion capture system

- **Cyclist digitalization**

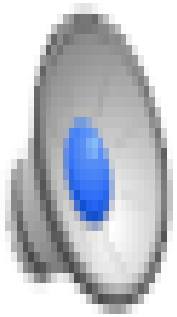
- **Set-up :  4 RGB-D Sensors**

# Virtual modification of bike settings

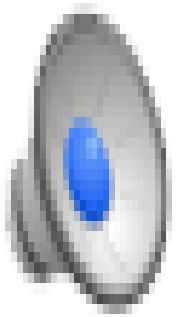
- **Measured reference sequence + Modified bike settings**
  **➔ Virtual 3D sequence**
- **3D body model = body parameters + pose parameters**
- **Body parameters are left unchanged**
- **Some pose parameters are calculated**
  - Forcing contact with the pedals, the handlebars and the saddle
- **Some pose parameters are imported from reference**
  - Elbow and ankle angles for example

# Virtual modification of bike settings

**Reference**



**Virtually modified**
**(handlebars height -2cm)**

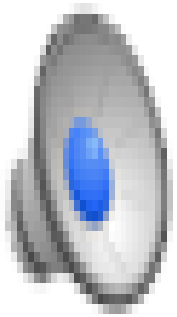


- **Simulation of a complete pedalling cycle**

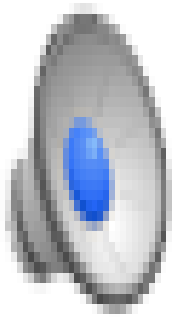
➔ **Joint angles and frontal area measurements**

# Virtual modification of bike settings

**Reference**



**Virtually modified**
**(drops position)**



- **Simulation of a complete pedalling cycle**

➔ **Joint angles and frontal area measurements**

# Experimental validation

- **11 subjects**
  - 18-20 years old
  - Cycling at least once a week
- **Tested bike settings**
  - Preferred bike setting
  - Saddle height +2, +1, -1, -2, -3 centimeters
  - Handlebars height -2, -3 centimeters
  - Handlebars reach +2, +3 centimeters
- **Pedalling cycle for every position**
  - Grabbed by the motion capture system
  - Simulated with virtual modification

# Experimental validation

- **3D models processed to calculate**
  - Maximum knee flexion

    maximum flexion of the knee joint at any point in the pedal stroke defined by the hip-knee line and the knee-ankle line
  - Maximum knee extension

    maximum extension of the knee joint
  - Hip angle closed

    the most closed angle of the hip joint defined by the knee, hip and shoulder
  - Hip angle open

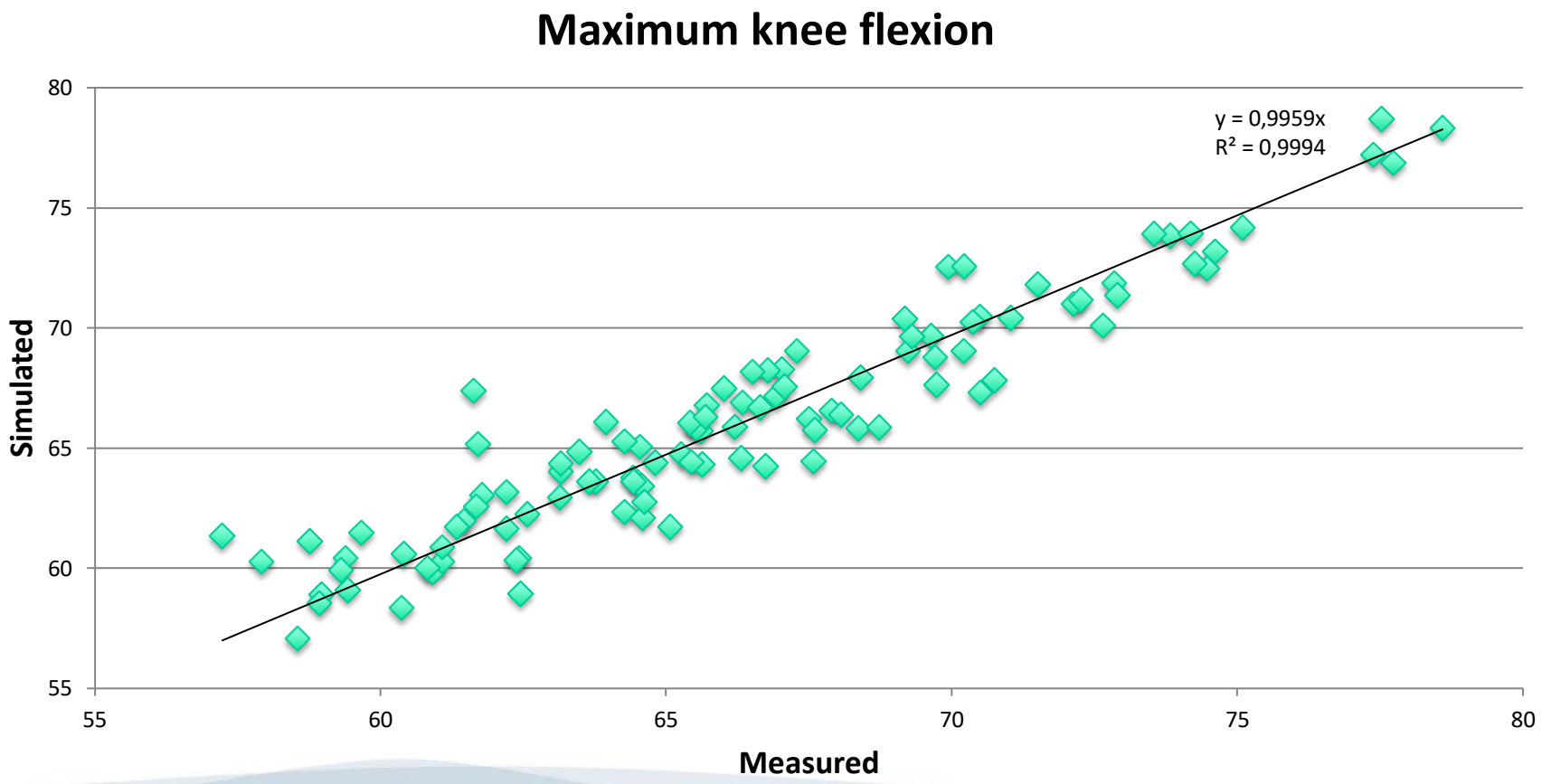
    the most open-angle of the hip joint

  ➔ For both legs

  - Frontal area

# Experimental validation

- **Direct measurement VS simulation**



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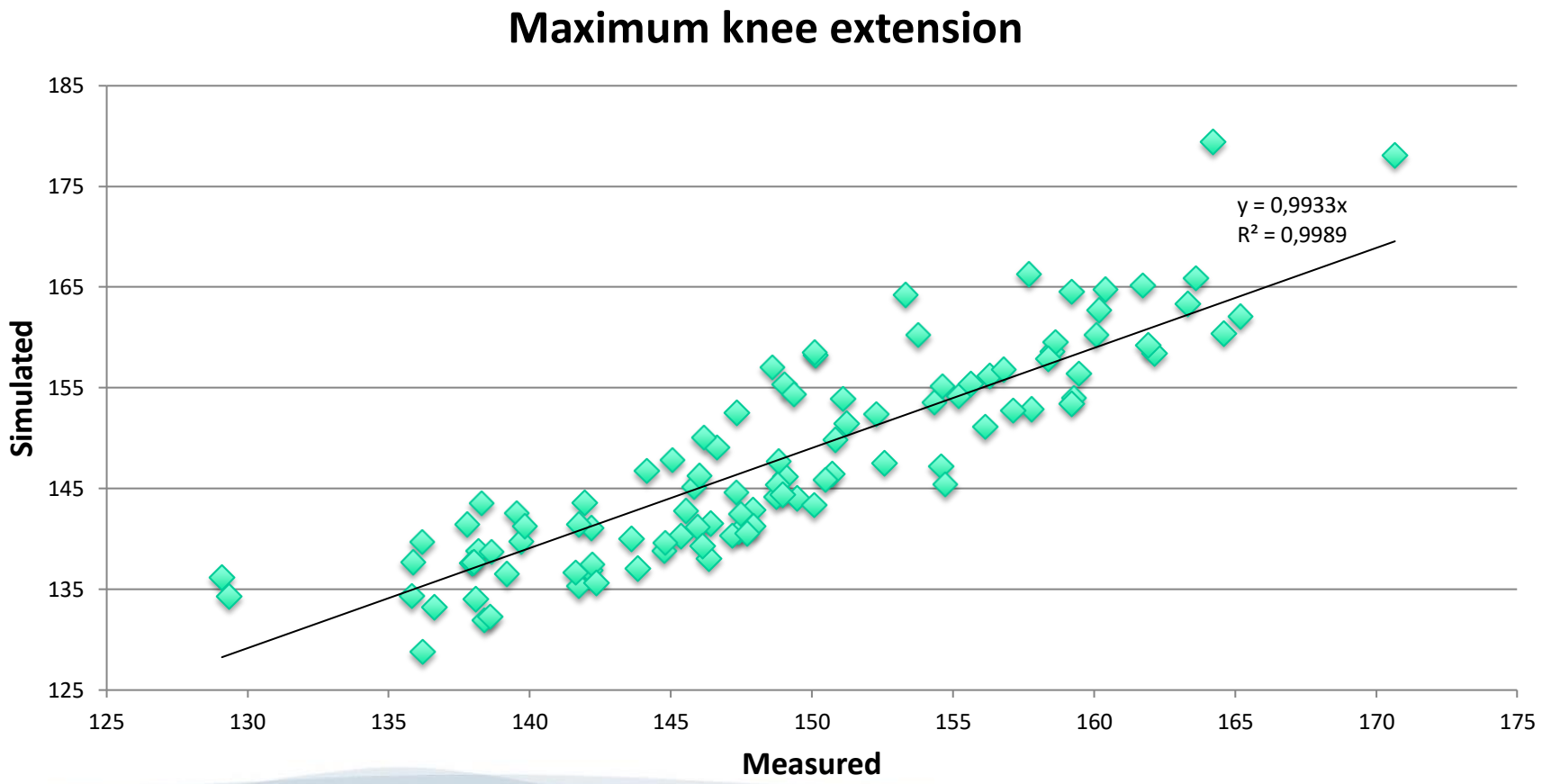

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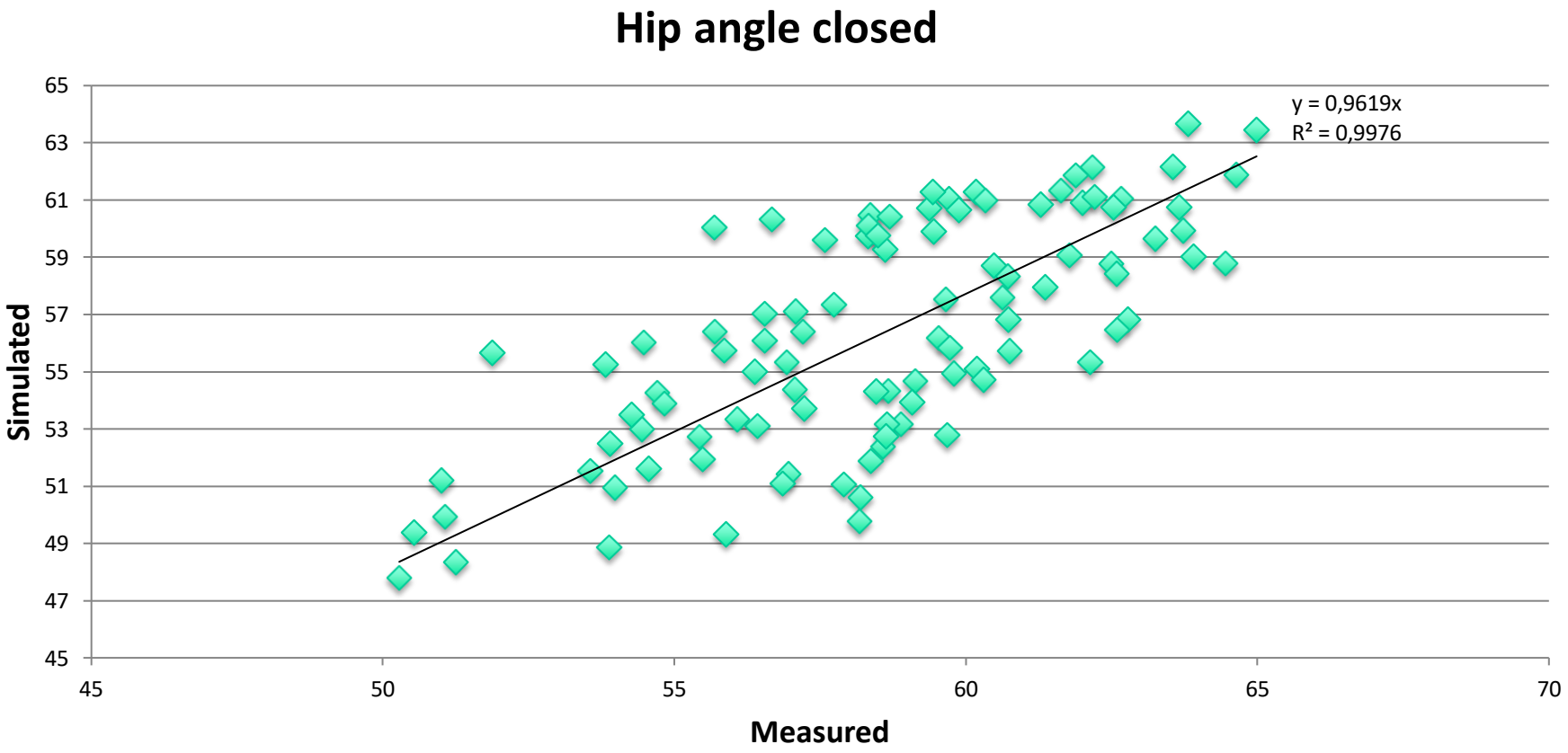

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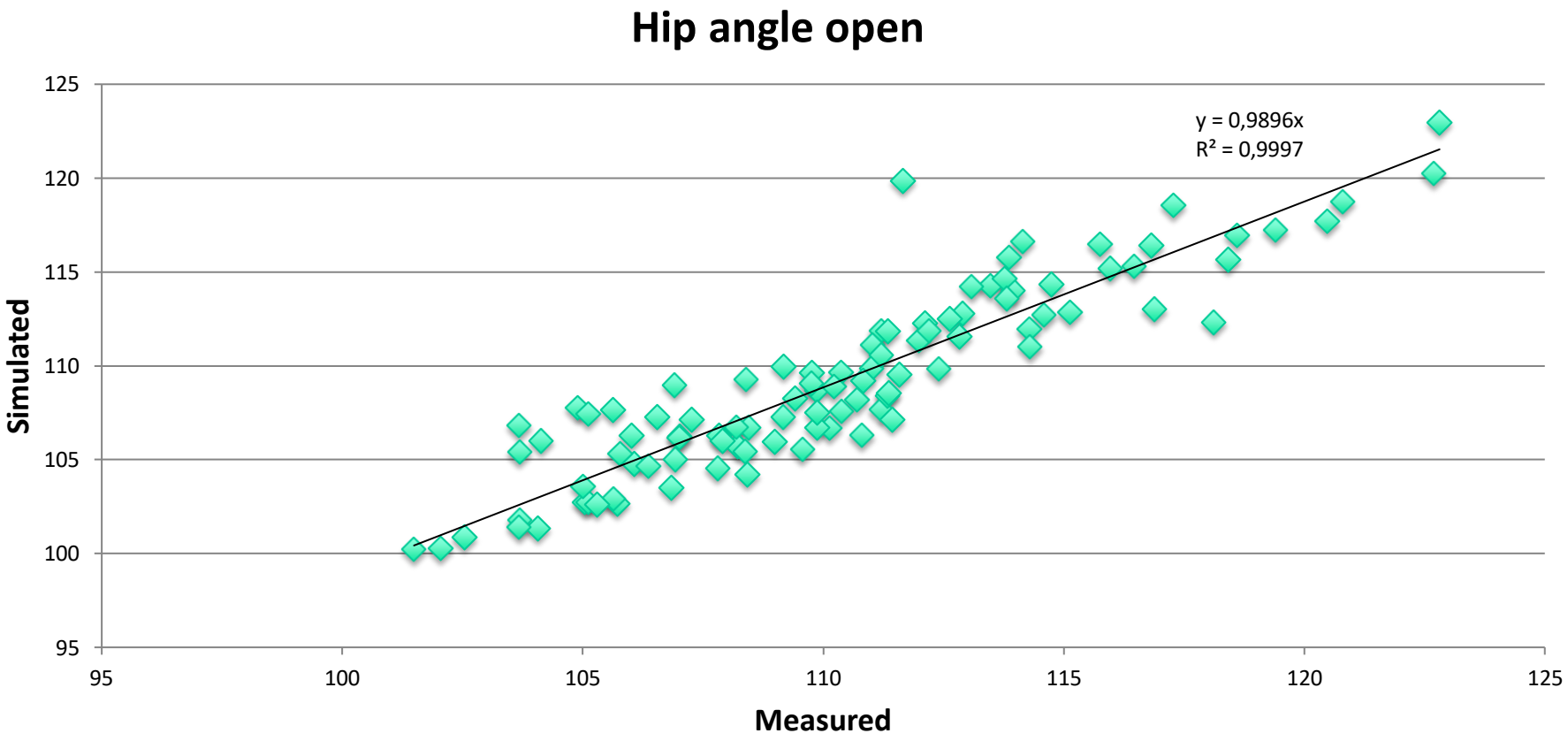

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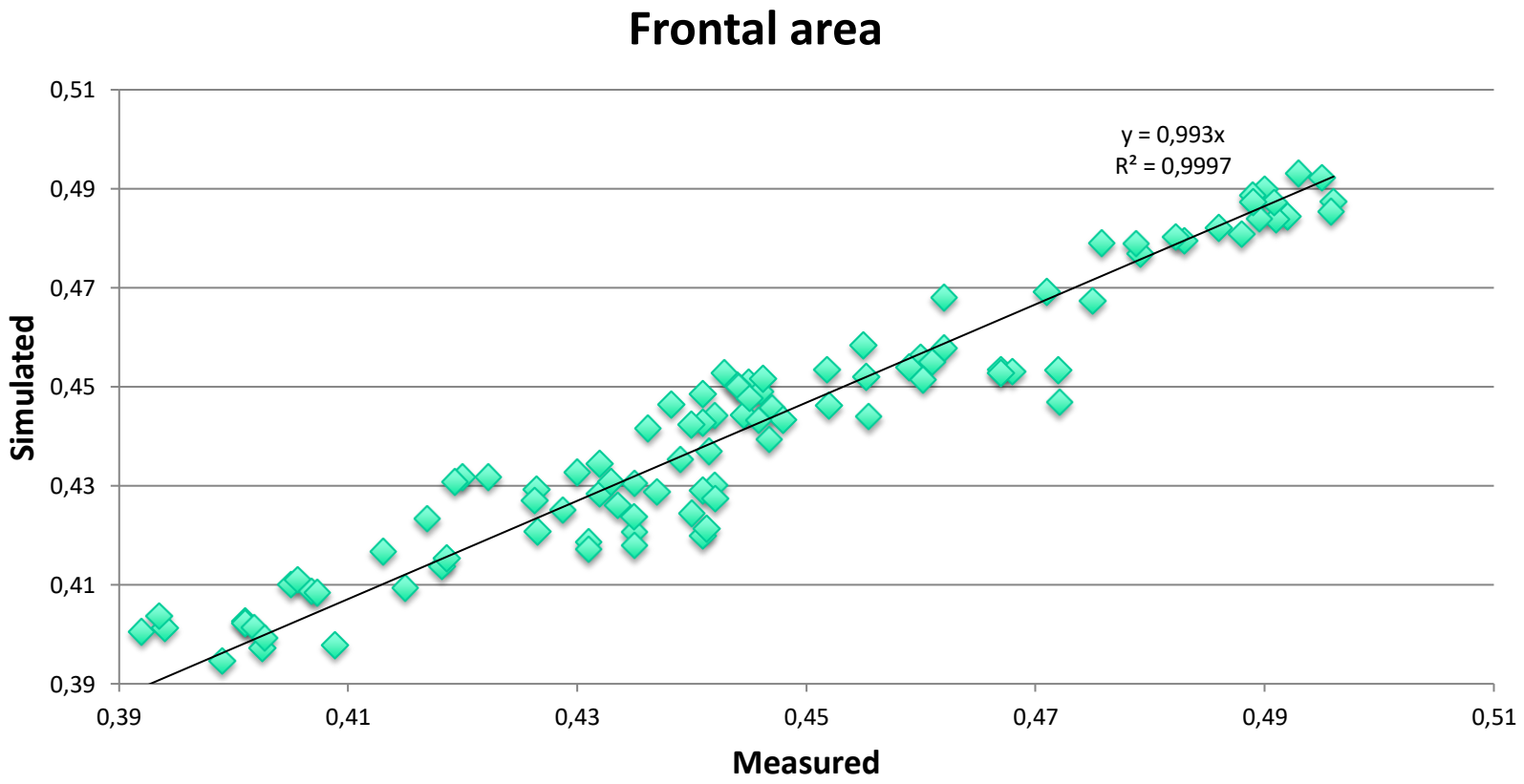

# Discussion

## -Good approximation of knee angles variation

- Proportionality = 0,993 – 0,996
- $R^2$ = 0,78 – 0,89

## -Correct approximation of hip angles variation

- Proportionality = 0,962 – 0,99
- $R^2$ = 0,50 – 0,83

## -Very good approximation of frontal area

- Proportionality = 0,993
- $R^2$ = 0,92

# Conclusion

- **Virtual measurement of knee/hip angles variation (recommended joint angular ranges are quite wide)**
- **Virtual measurement of aerodynamics**

 **Replace real testing**

 **Explore the bike setting space**

- quickly
- inexpensively

➔ **Limit the number of set-ups to be tested**

# Questions ?