The webcast will begin shortly…

ANYBODYRUN

A web application for running biomechanics

February 9th , 2021

Outline

- General introduction to the AnyBody Modeling System
- Presentation by John Rasmussen
  - *AnyBodyRun - A web application for running biomechanics*
- Question and answer session

Presenter:
Professor John Rasmussen,

Head of the biomechanics research group,
Department of Mechanical and Manufacturing Engineering,
Aalborg University, Denmark.

Host(s):
Bjørn Keller Engelund and Kristoffer Iversen
R&D Engineer
AnyBody Technology

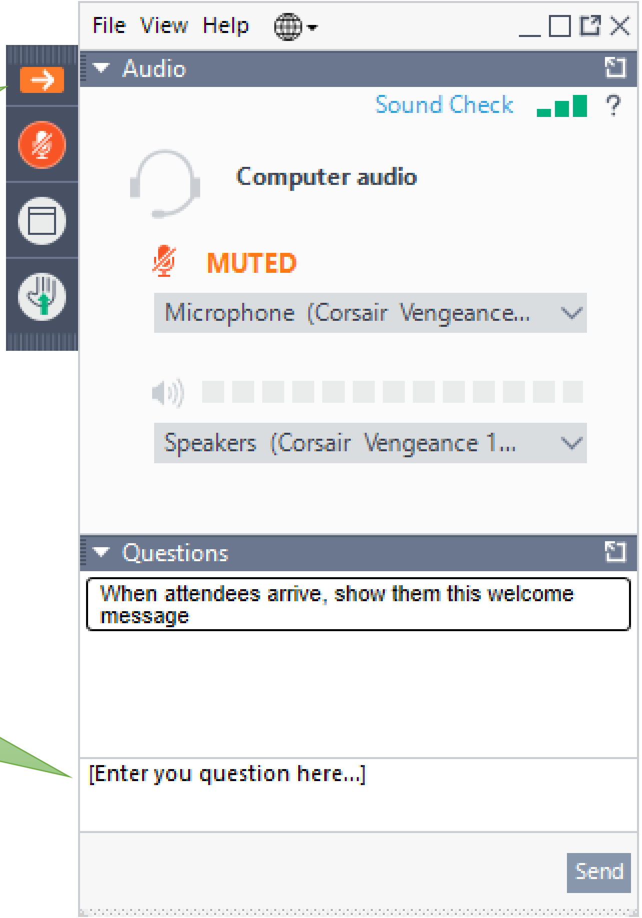
Control Panel

The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

> *Questions will be addressed at the end of the presentation. If your question is not addressed, we will do so by email.*

Expand/Collapse the Control Panel



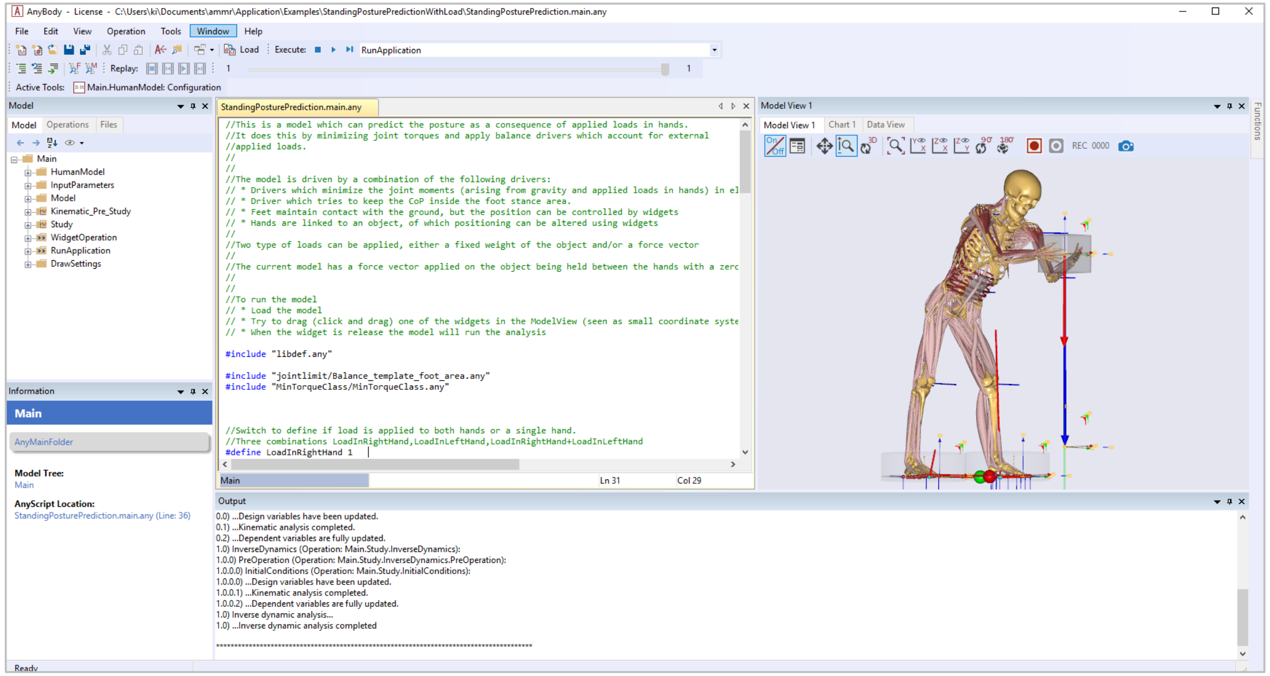
Ask a question during the presentation

Musculoskeletal Simulation

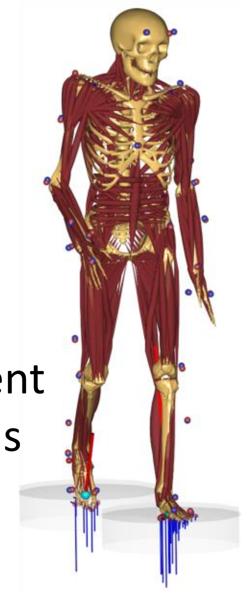
Motion Data
Kinematics and Forces

ANYBODY
Modeling System

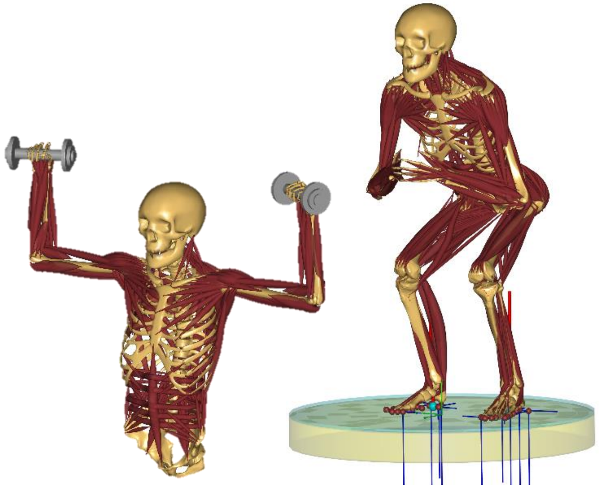
Body Loads
- Joint moments
- Muscle forces
- Joint reaction forces



Product optimization design



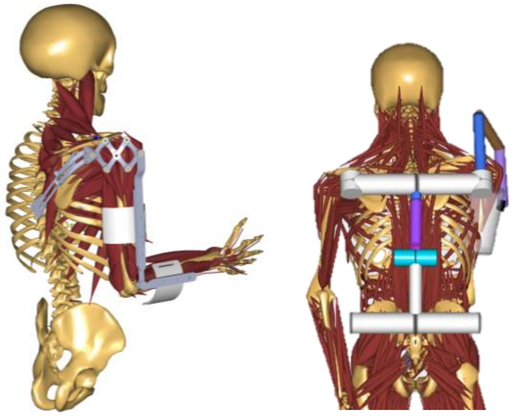
Movement Analysis



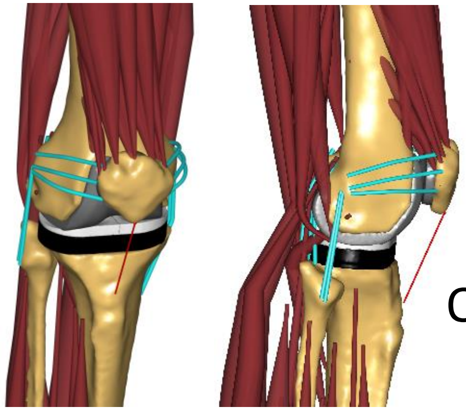
Sports

AnyBody

Modeling System



Assistive Devices



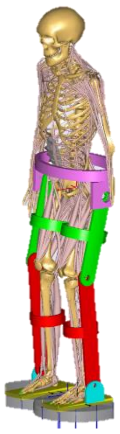
Orthopedics and rehab

AnyBody Modelling System

Motion and Forces

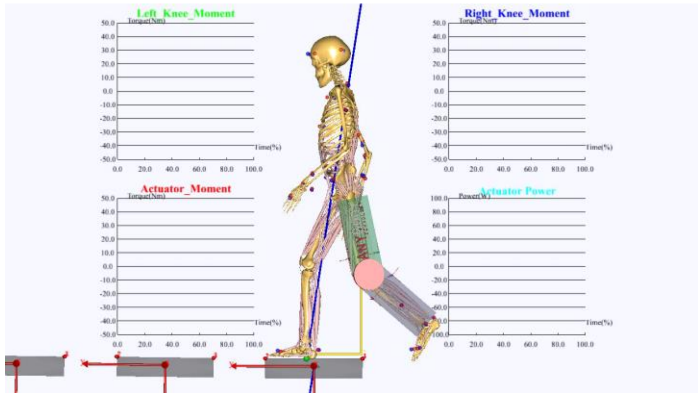
Body model

Environment model



Inverse dynamics
Muscle recruitment

Simulation



Internal body loads
- Muscle forces
- Joint moments

Design Optimization

Post Processing (e.g. Finite element tools)

ANYBODYRUN

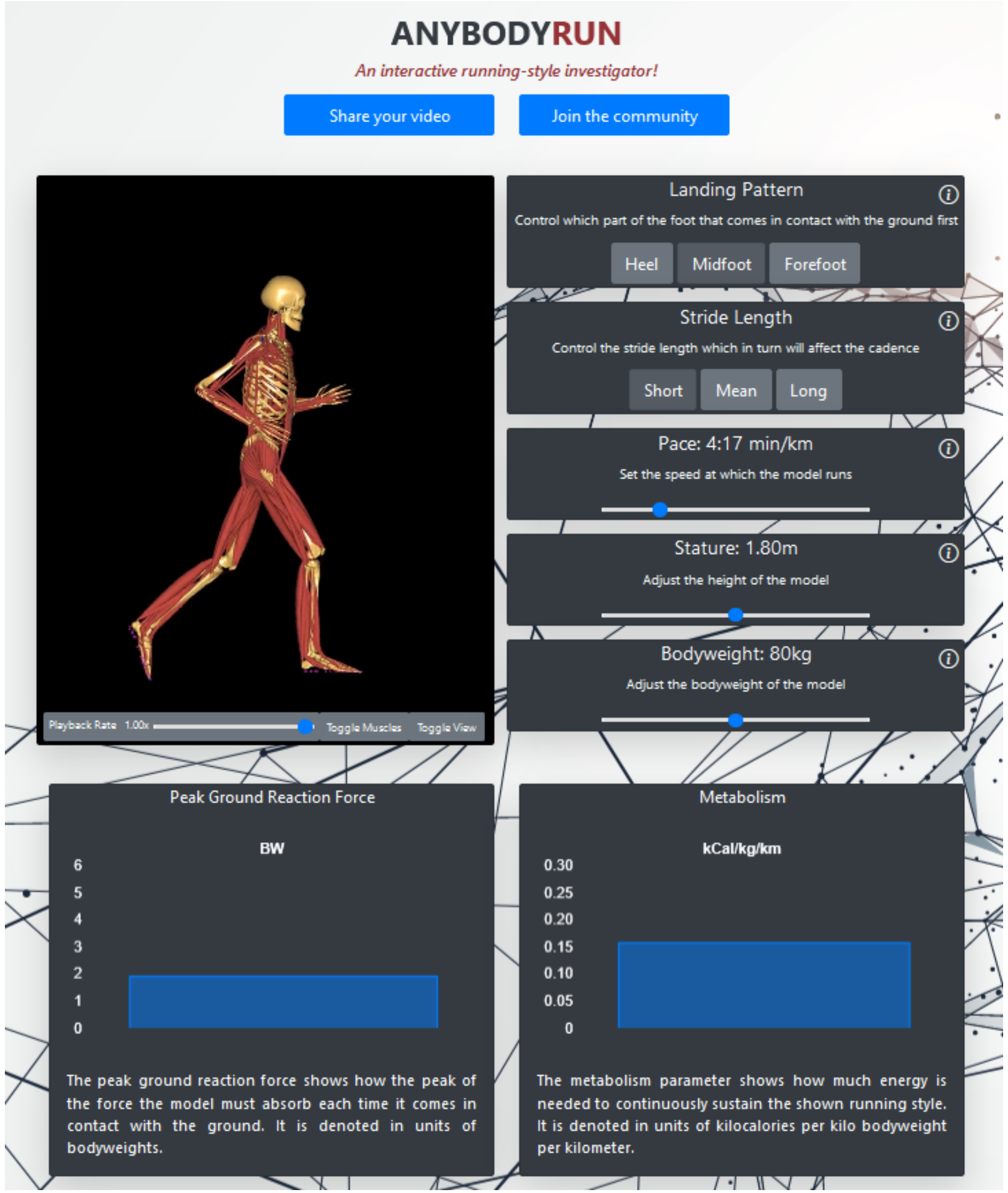
A web application for running biomechanics

Presented Professor John Rasmussen

AnyBodyRun.com

- a web application for running biomechanics

1. Introduction
2. Idea and technology
3. Outlook

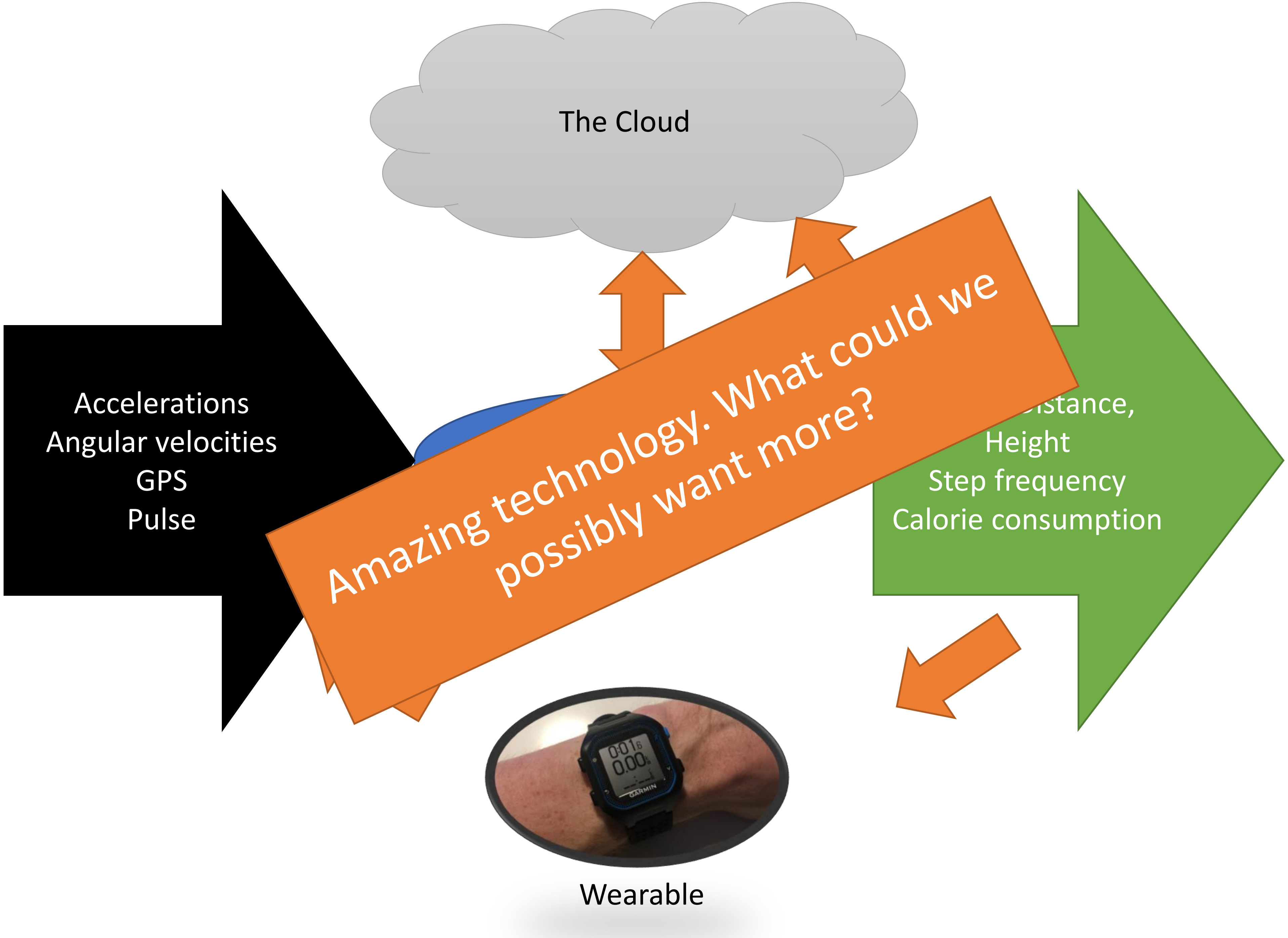


1. Introduction

Lots of new technology for running

- Garmin
- Polar
- Suunto
- Runcoach
- Fitbit
- Runkeeper
- Strava
- Runtastic

- Running watches
- Mobile
- Wearables
- Gadgets
- Social networks
- Big data
- Cloud
- IMUs
- Pulse
- Apps


The Cloud
Accelerations
Angular velocities
GPS
Pulse
istance,
Height
Step frequency
Calorie consumption
Amazing technology. What could we possibly want more?
Wearable

2. Idea and technology

Biomechanical model

Muscle forces

Joint reactions

Muscle mechanical work

Muscle metabolism

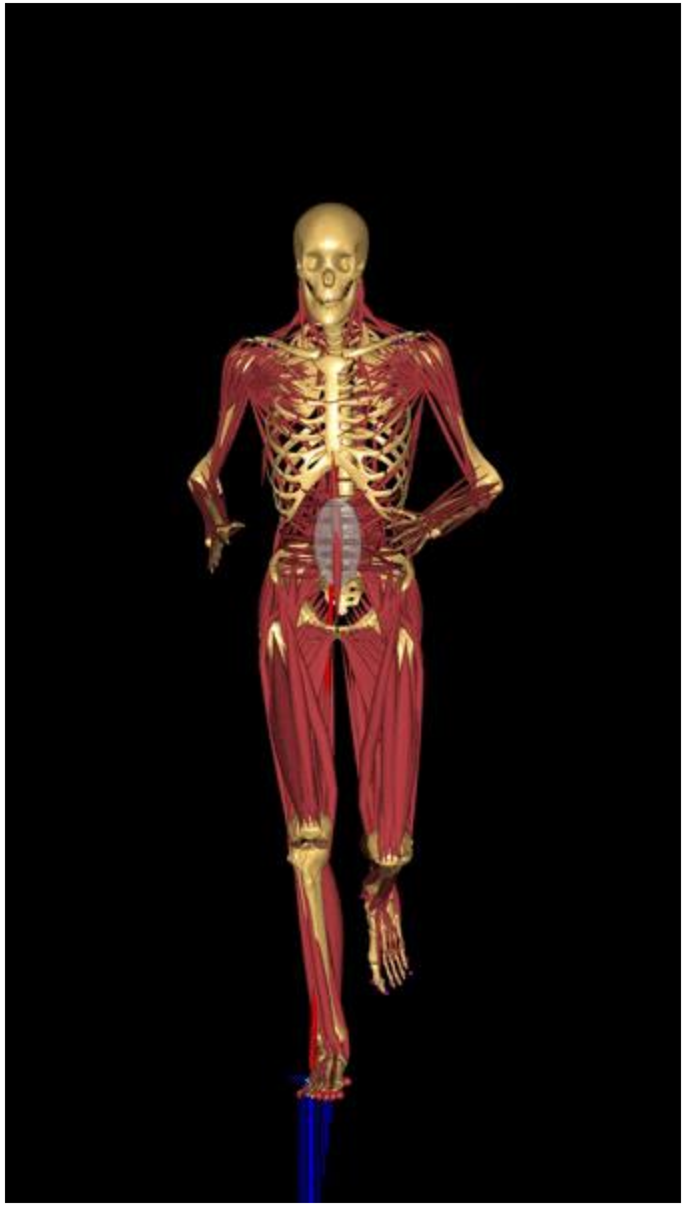
Ground reactions

Tendon forces

Ligament forces

Efficiency

We need a lot of information to compute this validly for a given person running in a given way



Input

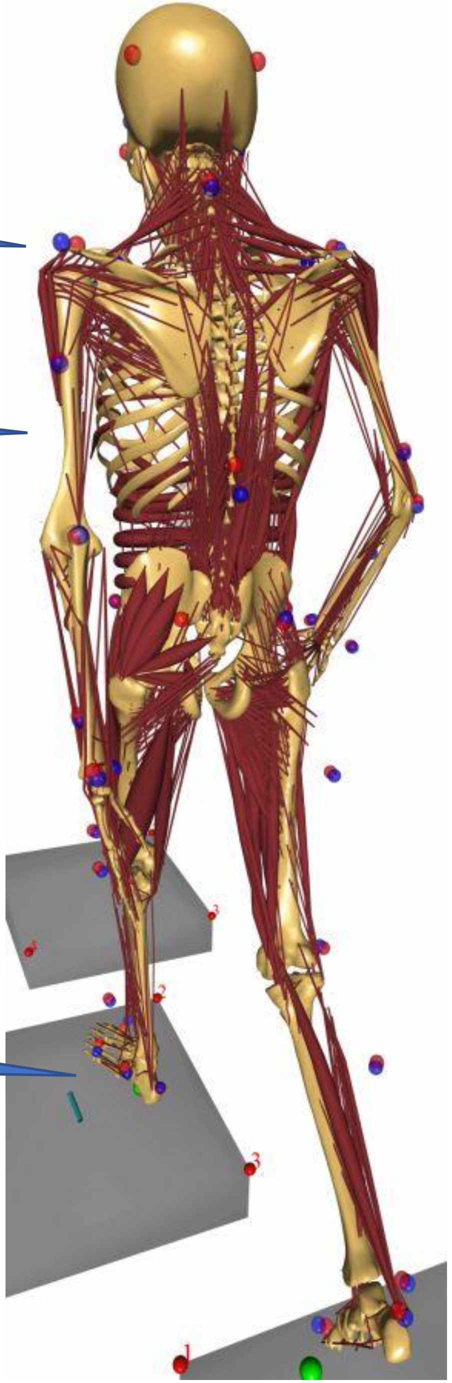
Derived from correlations in statistical data

Motion capture input

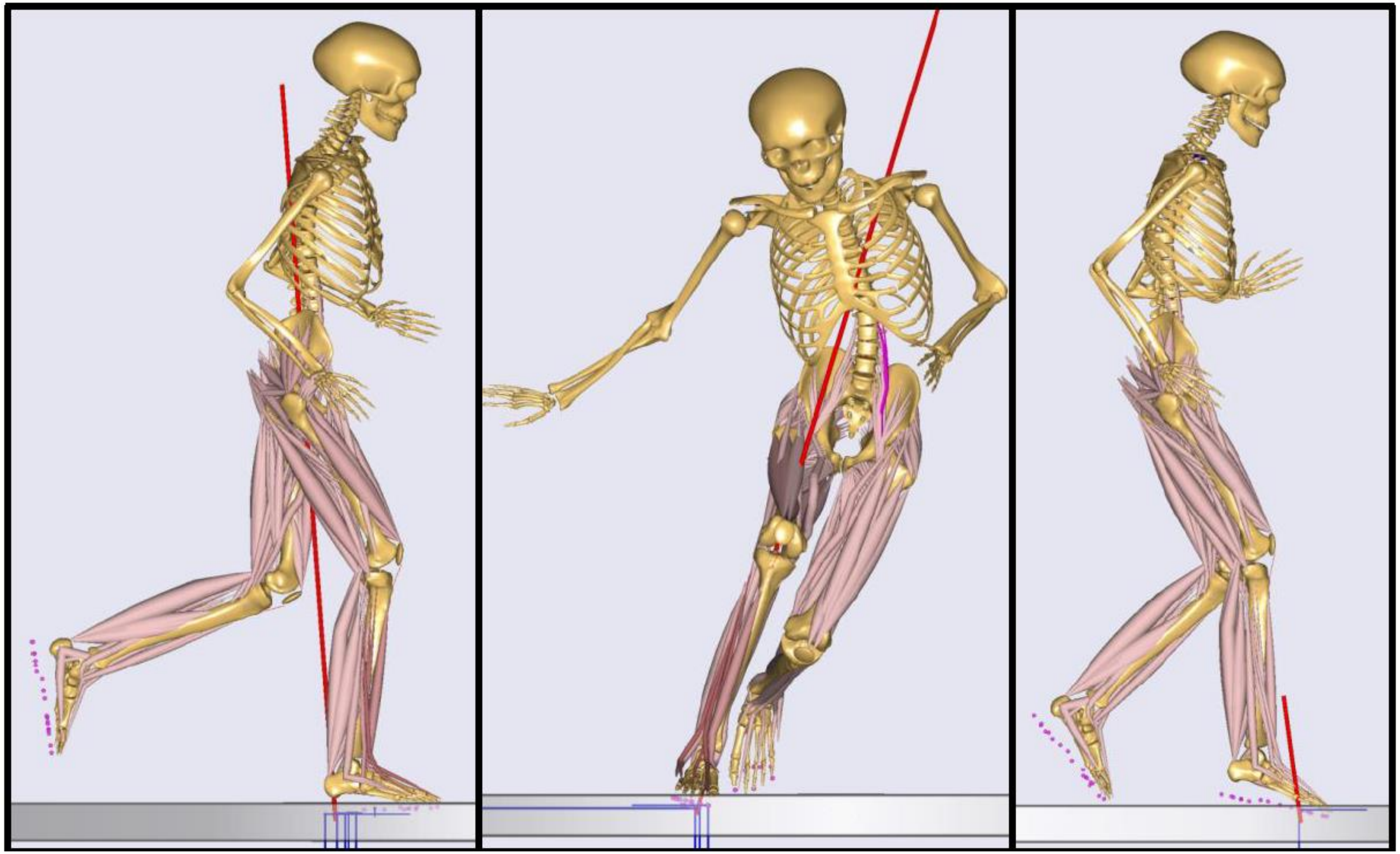
Anthropometry input

Can be simulated accurately

Force platform input



We can simulate GRF quite well



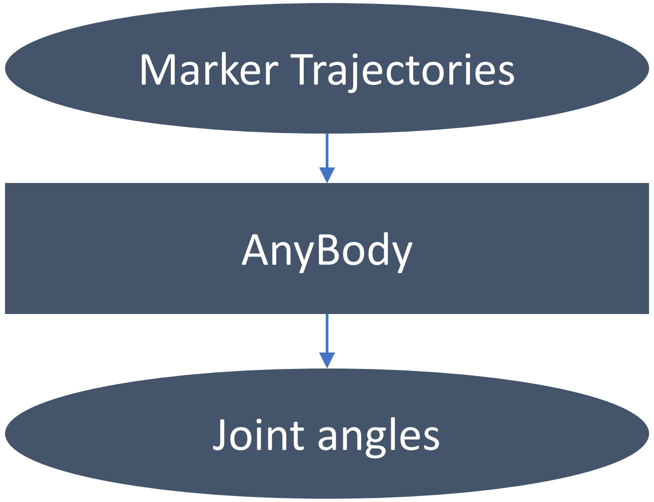
Skals et al.,
Multibody System Dynamics, 39(3)

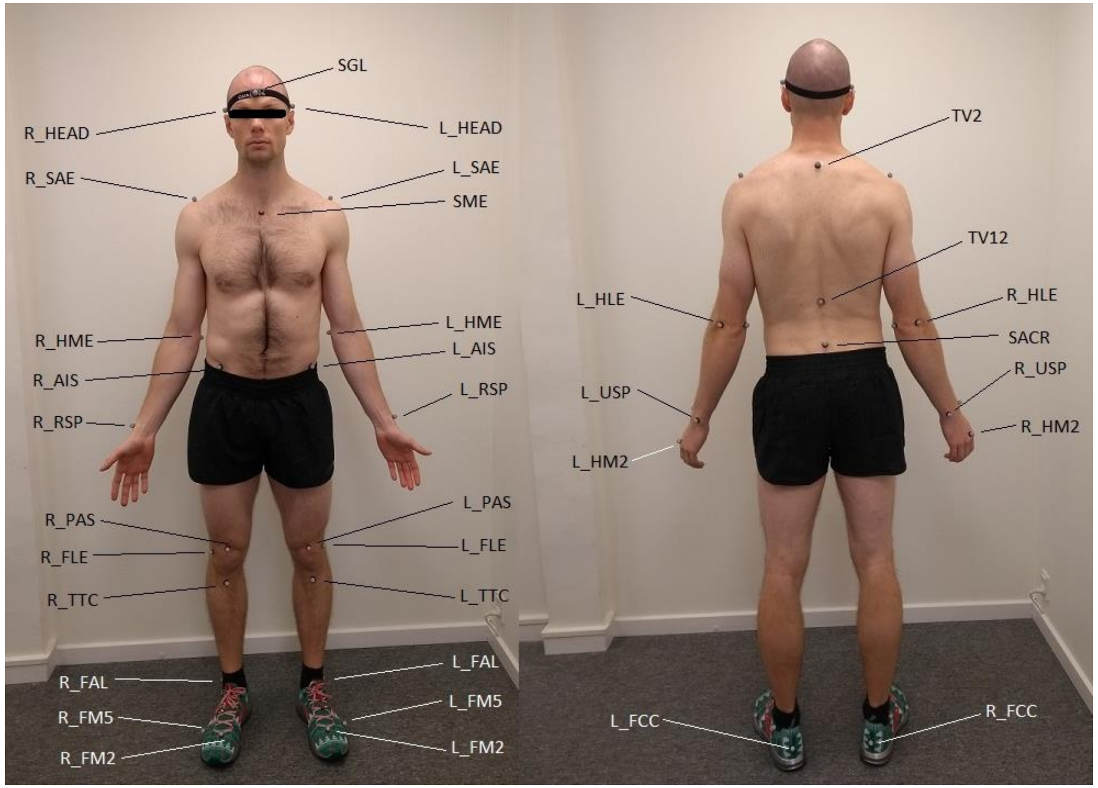
Statistical data

- Both of these statements are probably true:
  - People run differently
  - People run similarly
- So, running parameters will be statistically correlated.
- We need
  - Data
  - Running parameters

Data

- Pipeline of motion-captured running trials from a running shop.
- 285 successfully processed trials so far.

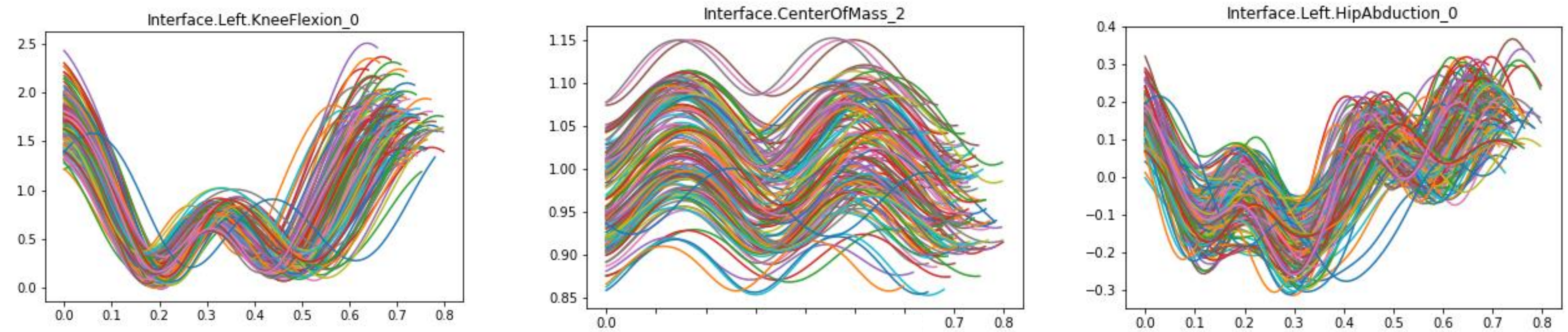




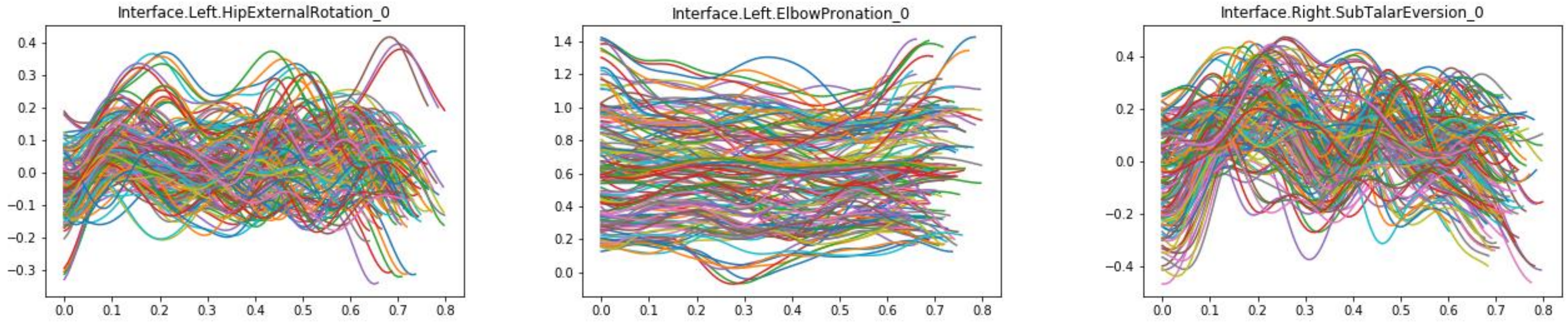
Kaiser Sport & Orthopaedics A/S

Joint angles: Different and similar

Some motions have much similarity between trials…



…and some less.



Fourier series

- Convergent, infinite series approximation
- Useful for approximation of periodic functions

Number of coefs

$$s_N(x) = \overbrace{a_0}^{A_0}/2 + \sum_{n=1}^{N} \left(\overbrace{a_n}^{A_n \sin(\phi_n)} \cos\left(\tfrac{2\pi n x}{P}\right) + \overbrace{b_n}^{A_n \cos(\phi_n)} \sin\left(\tfrac{2\pi n x}{P}\right) \right)$$

Offset

Amplitudes

Amplitudes

Wikipedia.org

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Running in circles: Describing running kinematics using Fourier series

Sebastian Deisting Skejø [a,*], Morten Enemark Lund [b], Martin Stensvig [c], Nickolaj Mads Kaae [c], John Rasmussen [e]

[a] *Department of Public Health, Aarhus University, Aarhus, Denmark*
[b] *AnyBody Technology A/S, Aalborg, Denmark*
[c] *Kaiser Sport & Ortopædi, Copenhagen, Denmark*
[d] *Department of Materials and Production, Aalborg University, Aalborg East, Denmark*

A R T I C L E I N F O

Article history:
Accepted 11 December 2020

A B S T R A C T

We explore the use of Fourier series to describe the kinematics of human running. From a database of 285 trials of treadmill running, we drive a musculoskeletal model with 104 anatomical joint angles to obtain kinematics. Using FFT analysis, we determine a fundamental frequency for all independent joint angles and compute average step kinematics. Finally, we represent the average step kinematics using Fourier

Big data!

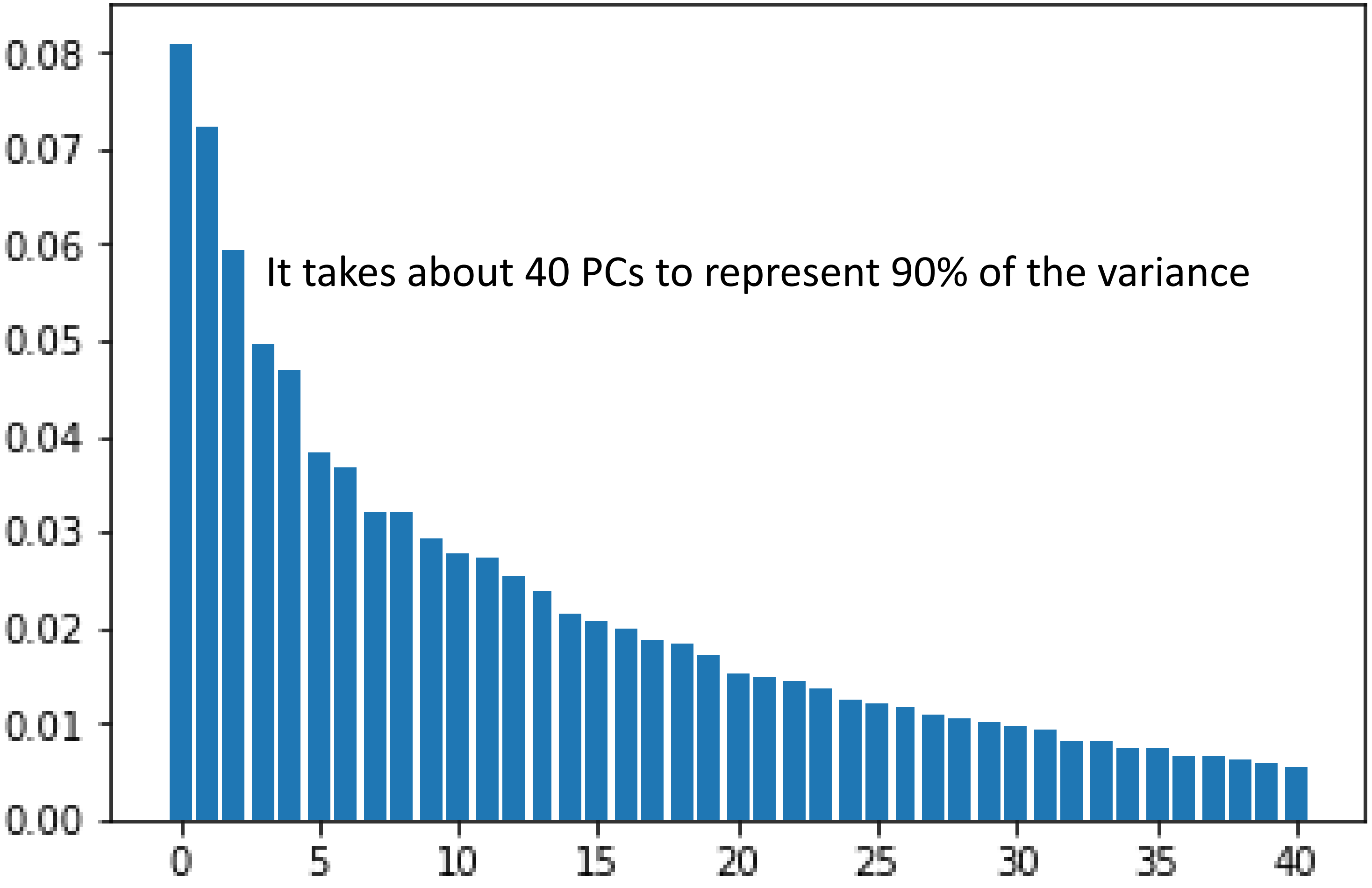
285 runners x 104 DoF = 29640 functions to approximate

285 Trials

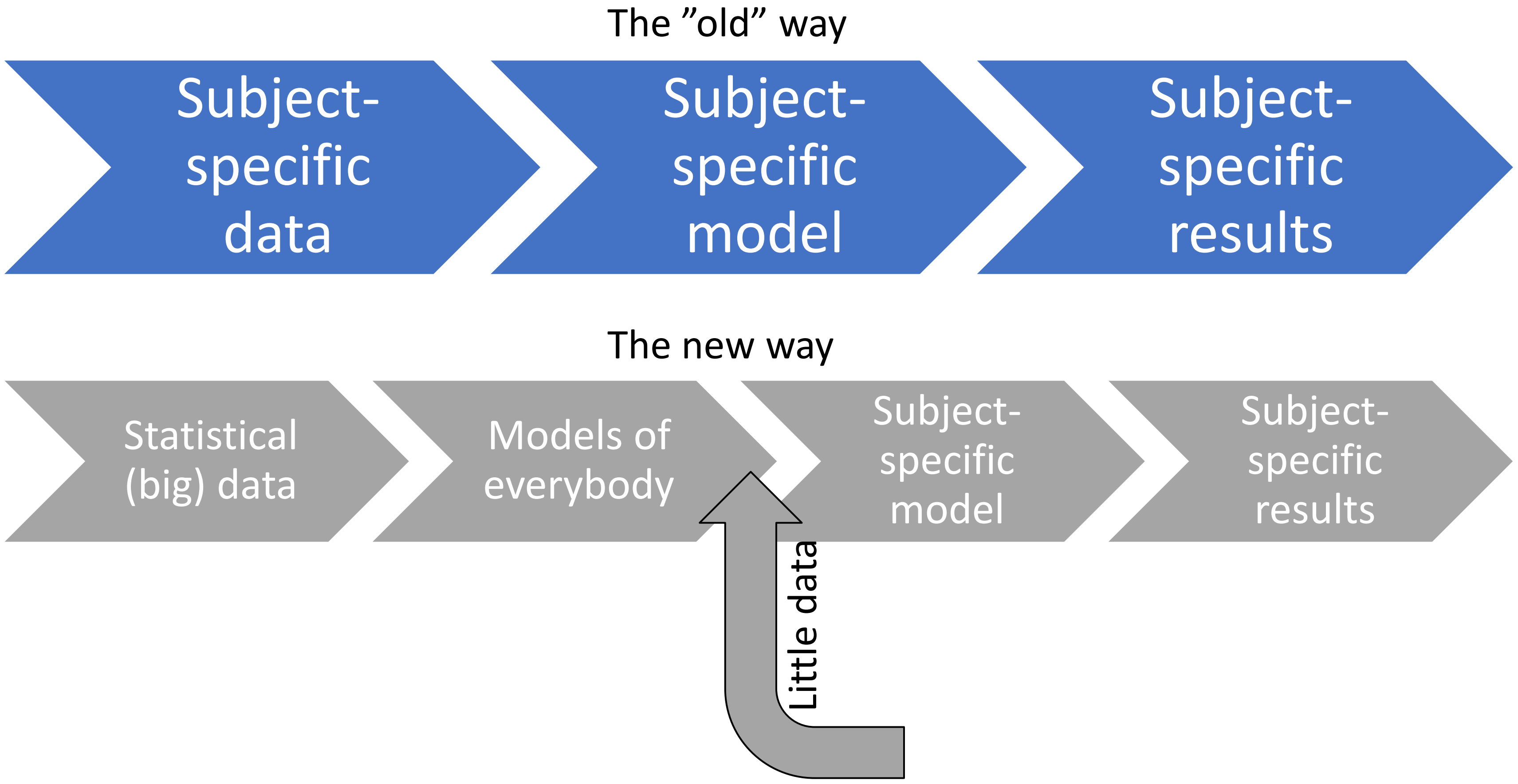
																			T	U	V	W	
	Omega																	a3	osY_0_b3	osY_0_a4	osY_0_b4	osY_0_a5	osY_
J_Running_Running trial 1	8.448199	0.035708	0.003839	-0.00449	-0.01942	-0.00113	0.001042	0.00097	-0.00014	0.002504	-1.6E-05	0.000168	-0.00333	0.000148	-0.00256	0.0002	0.000334	-0.00205	0.001808	0.000253	0.000424	0.000623	-0.0
J_Running_Running trial 2	8.643846	0.036227	0.003497	-0.00456	-0.019	-0.00074	0.001499	0.000812	-8.6E-05	0.002556	-4.9E-05	3.75E-05	-0.00391	0.000466	-0.00392	0.000387	-0.00018	-0.00212	0.001833	0.00039	0.000155	0.000631	-0.0
J_Running_Running trial 3	8.792152	0.036937	0.003338	-0.00407	-0.02052	5.14E-05	0.001604	0.001032	-0.00027	0.002924	-5.8E-05	-0.00017	-0.0033	0.001962	-0.00497	0.00044	-0.00013	-0.00218	0.001847	0.000241	0.00012	0.000598	-0.0
J_Running_Running trial 4	9.050938	0.037616	0.004135	-0.00284	-0.02108	0.002025	0.001423	0.000534	-0.00024	0.003291	-0.00022	-9.1E-05	-0.00332	0.003427	-0.00637	0.000404	-0.00015	-0.00228	0.001639	0.000235	8.16E-05	0.000575	-0.0
J_Running_Running trial 5	9.457112	0.038822	0.003729	-0.00354	-0.02023	0.002058	0.001271	0.000774	-6.7E-05	0.003924	9.96E-05	-9.4E-05	-0.00244	0.005897	-0.0077	0.000126	0.000197	-0.00239	0.002041	0.000311	4.36E-05	0.000861	-0.0
AJ_Running_Running trial 1	8.366281	0.044031	-0.00162	-0.00128	-0.01075	-0.00656	0.000327	-0.00017	-0.00057	0.000423	6.92E-05	-0.0001	0.001172	-0.0034	-0.00282	-0.00091	0.00036	-0.00098	0.001003	0.000247	-0.00037	0.000323	-0.0
AJ_Running_Running trial 2	8.562924	0.04171	0.000753	-0.00171	-0.01395	-0.00856	0.00067	-0.00021	-0.00096	0.001043	2.21E-05	5.47E-05	0.001589	-0.00139	-0.00198	-0.00103	0.000552	-0.0023	0.001131	0.000367	-0.00024	0.00122	-0.0
AJ_Running_Running trial 3	9.097102	0.040824	0.000694	-0.00219	-0.01435	-0.00763	0.001098	6.17E-06	-0.00072	0.001673	-5.7E-05	-7.2E-05	9.46E-05	0.000617	-0.00707	-0.00057	0.000534	-0.0025	0.001694	3.89E-06	-0.00023	0.000761	-0
_Running_2_Running trial 1	8.723054	0.06111	-0.00028	0.003566	-0.01559	-0.00495	-0.00017	0.00078	-0.00087	0.001513	4.52E-05	-9.4E-05	-0.00059	-0.00627	0.003204	0.000998	-0.00064	-0.00143	0.00349	-0.00042	-0.00036	0.000995	-0.0
_Running_2_Running trial 2	8.903434	0.060729	-0.00075	0.00211	-0.01615	-0.00809	-0.00046	0.000443	-0.00153	0.001361	6.65E-05	-6.1E-05	-0.00015	-0.00681	0.002963	0.000495	-0.00056	-0.00248	0.003348	-0.00039	-0.00039	0.001212	-1.
_Running_2_Running trial 3	9.108696	0.060444	-0.00101	0.00269	-0.01889	-0.00675	-0.00028	0.000452	-0.00152	0.001647	-0.00016	-0.00032	-0.00071	-0.00659	0.003664	0.000976	-0.00083	-0.00249	0.003283	-0.00033	-0.00059	0.000903	-0.0
RP_Running_Running trial 1	8.833096	0.061634	0.001719	0.004021	-0.01635	-0.0077	-0.00029	0.000346	-0.00135	0.000738	8.14E-05	-0.00016	-0.00337	-0.00479	0.007552	0.000235	-0.00028	-0.00305	0.002234	-0.00036	-0.00073	0.000883	-0.0
RP_Running_Running trial 2	8.940215	0.062187	0.001084	0.006304	-0.01795	-0.0063	-0.00025	0.000645	-0.00132	0.000999	1.89E-05	-0.00026	-0.00332	-0.0058	0.007305	0.000543	-0.00048	-0.00276	0.003053	-0.00065	-0.00078	0.000788	-0.0
RP_Running_Running trial 3	9.10182	0.061991	0.001899	0.005601	-0.01869	-0.00764	-4E-05	0.000869	-0.00151	0.000817	8.58E-05	-0.00041	-0.00268	-0.00536	0.005148	0.000136	-0.00031	-0.00305	0.002869	-0.00034	-0.00094	0.000695	-0.0
RP_Running_Running trial 4	9.241903	0.061222	0.000698	0.004958	-0.01962	-0.00713	0.000519	0.000758	-0.00162	0.0011	-0.0002	-0.00048	-0.00285	-0.00489	0.006752	0.001123	0.000146	-0.00335	0.002558	-0.0003	-0.00085	0.000585	-0.0
AEK_Running_Running trial 1	8.872725	0.039892	-0.00203	-0.00342	-0.01624	-0.00499	0.000532	0.000233	-0.00077	-1.1E-05	2.9E-05	7.05E-05	-0.00285	-0.00552	0.002947	0.001405	0.001483	-0.00158	0.002178	-2.2E-05	-0.00024	0.000581	-0.0
AEK_Running_Running trial 2	9.363269	0.036795	-0.00107	-0.0035	-0.01535	-0.00865	0.000686	0.000529	-0.00064	2.9E-05	-2E-05	0.000228	-0.00248	-0.00364	0.000562	0.00093	0.001821	-0.00319	0.001734	7.83E-05	-0.00035	0.000568	-0.0
AEK_Running_Running trial 3	9.608649	0.038657	-0.00207	-0.00414	-0.01781	-0.00587	0.000561	0.00037	-0.00082	0.000373	0.000127	0.000191	-0.00217	-0.00218	-0.00099	0.001782	0.001561	-0.00322	0.002474	-0.00016	-0.00051	-6.7E-05	-0.0
Running_Running trial 1	8.466483	0.031246	0.001656	0.002641	-0.0187	-0.00547	-3.8E-05	0.000269	-0.00086	0.000256	0.00013	-6.7E-05	0.002147	-0.01108	0.006387	0.000771	0.001081	-0.00298	0.002085	-0.00031	-0.00031	0.000908	0.00
Running_Running trial 2	8.682999	0.03877	0.002219	0.002114	-0.01762	-0.0032	0.000341	0.000366	-0.00096	0.000569	0.000452	-0.00012	0.004028	-0.00956	0.007078	0.000359	2.32E-05	-0.00193	0.001212	-5.8E-05	-0.00026	0.000488	0.0
Running_Running trial 3	8.956291	0.037124	0.003254	0.003766	-0.01812	-0.00453	0.000184	0.000573	-0.00121	-0.00011	7.29E-05	0.000207	0.002423	-0.0087	0.006519	0.000369	0.000355	-0.00338	0.001288	-0.00016	0.000165	0.000462	0.00
AVN_Running_Running trial 1	9.116281	0.049125	0.001844	0.001553	-0.01638	-0.00013	5.36E-05	5.96E-05	-0.00124	0.002055	-0.00016	-5.8E-05	-0.00037	0.004642	0.002594	-0.00186	0.000722	-0.00193	0.003988	-0.00016	-1.9E-05	0.001196	8.1
AVN_Running_Running trial 2	9.471887	0.048584	0.003061	0.001337	-0.0157	-0.00039	0.000402	0.000225	-0.00146	0.002618	-0.00041	-6.7E-05	-0.00177	0.005447	0.001398	-0.00135	0.000668	-0.00296	0.004047	-0.00018	5.65E-06	0.001176	0.0
AVN_Running_Running trial 3	9.727813	0.048876	0.002513	0.000804	-0.01407	0.001183	0.000453	0.000364	-0.00133	0.003432	-0.00021	6.64E-05	-0.00146	0.005836	0.001112	-0.00118	0.001005	-0.00297	0.004115	3.93E-05	0.000274	0.00141	0.00
01_Running_Running trial 2	7.905042	0.040567	0.001089	-0.00194	-0.01612	-0.00956	0.000539	0.000814	-0.00047	0.000465	2.81E-06	-0.00015	-0.0005	-0.00598	0.005793	-0.00036	0.000307	-0.00011	0.00309	-0.00023	0.0004	0.002107	0.00
01_Running_Running trial 3	7.967521	0.039481	-0.00064	-0.00082	-0.01784	-0.00703	0.000563	-4.6E-05	-0.00046	0.000643	-6.8E-05	-0.00019	-0.00078	-0.00259	0.002653	-9.3E-05	0.00043	0.000349	0.003148	-0.00016	0.000287	0.001082	3.7
01_Running_Running trial 4	8.041502	0.036389	0.000122	-0.00067	-0.0205	-0.00896	0.00047	0.000229	-0.00015	0.00078	-7E-05	-0.0002	0.000414	-0.00194	0.003048	0.000262	0.000573	-5.3E-05	0.004895	-0.00054	0.000413	0.002418	-0.0
Running_Running trial 1	8.764394	0.049296	0.001141	0.002768	-0.02139	-0.00999	-0.00073	0.00085	-0.00188	0.002197	0.000292	-0.00039	-0.00091	-9.6E-05	0.003254	0.000502	-0.00134	-0.00127	0.002112	-0.00033	-0.00032	0.000957	-
Running_Running trial 2	9.108774	0.048135	0.001827	0.002496	-0.02134	-0.00985	-0.00091	-8.9E-06	-0.00162	0.001901	0.000334	1.33E-05	-0.00071	-0.00068	0.003513	0.000573	-0.00134	-0.00149	0.001526	-0.00029	-0.0002	0.000763	-8.
Running_Running trial 3	9.12394	0.049218	0.001511	0.002308	-0.02582	-0.00235	-0.00042	0.000315	-0.0002	0.003144	0.000171	-0.00024	-0.00068	0.000216	0.001205	0.000324	-0.00166	-0.0008	0.001904	-0.00021	-0.00023	0.000478	-0.0
A_Running_Running trial 1	9.006426	0.04312	0.001339	5.8E-05	-0.01516	-0.00183	0.000655	0.000154	0.000311	0.000732	-8.3E-05	0.000103	0.001095	-0.0123	0.009553	-0.00055	-0.00074	-0.00111	0.003082	-9.4E-05	-0.00029	0.000823	0.00
A_Running_Running trial 2	9.263696	0.038164	0.002528	-0.0006	-0.01705	-0.00365	0.000816	0.000207	0.000524	0.001137	-0.00033	0.000174	0.001513	-0.01008	0.010884	-0.00046	-0.00038	-0.00236	0.003785	-0.00023	-0.00024	0.000933	5.2
A_Running_Running trial 3	9.598359	0.035495	0.001943	-0.00142	-0.01809	-0.00601	0.001105	0.000515	-5.7E-05	0.00124	-0.00037	3.52E-05	0.001457	-0.00798	0.010188	-0.00019	-0.00029	-0.00431	0.003313	-0.00015	-0.00026	0.000966	-9.
_Running_Running trial 2	8.183816	0.051982	0.002791	-0.00068	-0.01599	-0.00546	0.000626	-0.00047	-0.00254	0.000408	-3.8E-05	5.95E-05	0.000111	-0.00673	0.002439	-0.00248	-0.00063	-0.00173	0.004067	-0.00082	0.001406	-0.00044	-0.0
_Running_Running trial 3	8.474187	0.052947	0.003031	-0.00078	-0.01601	-0.00521	0.000535	-0.00035	-0.00249	0.000298	-0.00021	9.73E-05	-0.00055	-0.00516	0.004215	-0.00253	-0.00056	-0.00159	0.004629	-0.00091	0.001505	-0.00033	-0.0
_Running_Running trial 4	8.851719	0.051359	0.005027	0.000891	-0.01502	-0.01064	0.000191	-2.7E-05	-0.0026	-0.001	-0.00024	-0.00016	-0.00034	-0.00317	0.00484	-0.00252	-0.00081	-0.00412	0.00312	-0.00163	0.000347	1.96E-05	-0.0
5_Running_Running trial 1	9.369388	0.050967	-0.00109	0.000498	-0.0163	8.75E-05	0.000394	-6.5E-05	-0.00062	0.000465	3.68E-05	5.35E-05	0.002512	-0.00784	0.00714	0.000296	0.000159	-0.00411	0.00323	5.27E-05	-0.00026	0.000681	-0.0
5_Running_Running trial 2	9.469866	0.051916	-0.0014	-0.00051	-0.01632	0.002984	0.000266	-0.00021	-0.00021	0.000671	-8.4E-07	-5.6E-05	0.002793	-0.00694	0.009044	0.000466	-2.6E-05	-0.00383	0.004406	4.94E-06	-0.00042	0.000488	-0.0

Fourier coefficients, anthropometry, running characteristics, etc. About 1400 columns

PCA: yes, parameters are dependent

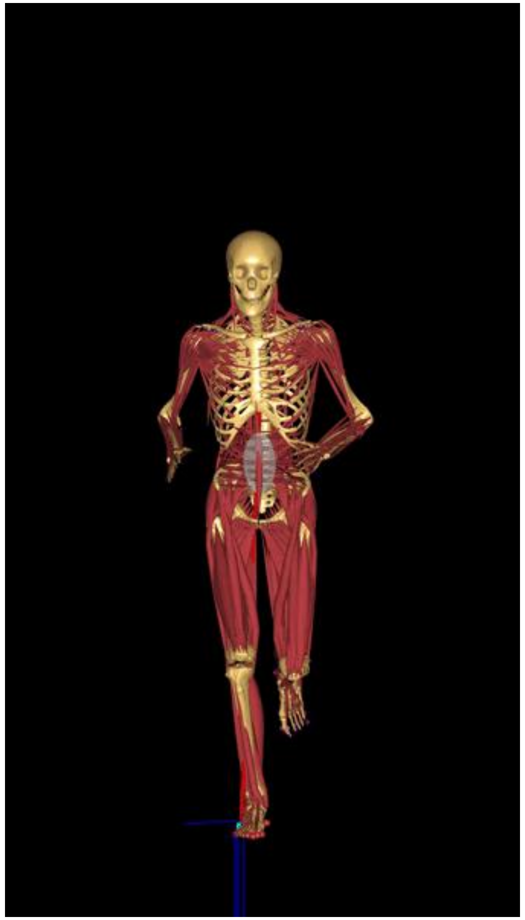


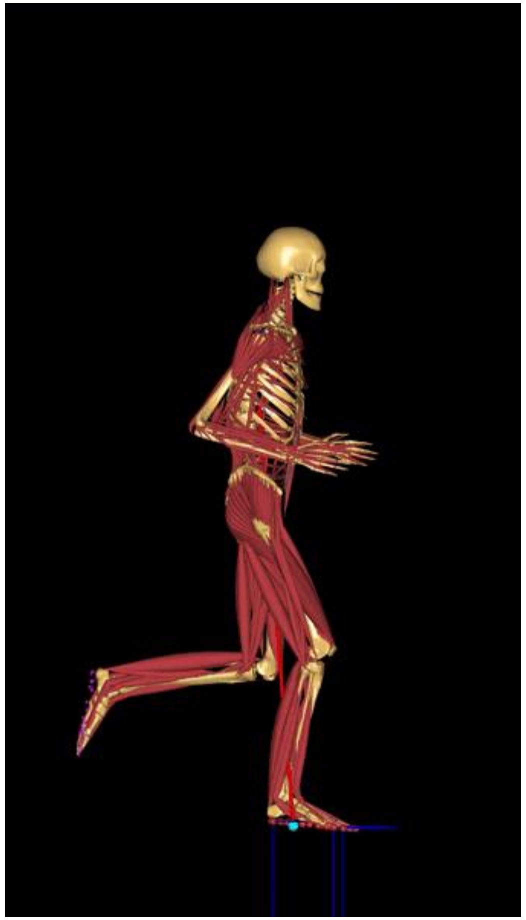
A new modelling paradigm



Average runner

- Completely virtual.
- Completely detailed.
- We can simulate its biomechanics and find any property.
  - Running economy
  - Ground reaction forces
  - Tissue loads
- Prospective/predictive:
  - If we make it run differently, then we can see the changes in loads, economy, etc.





DHM2020
L. Hanson et al. (Eds.)

doi:10.3233/ATDE200045

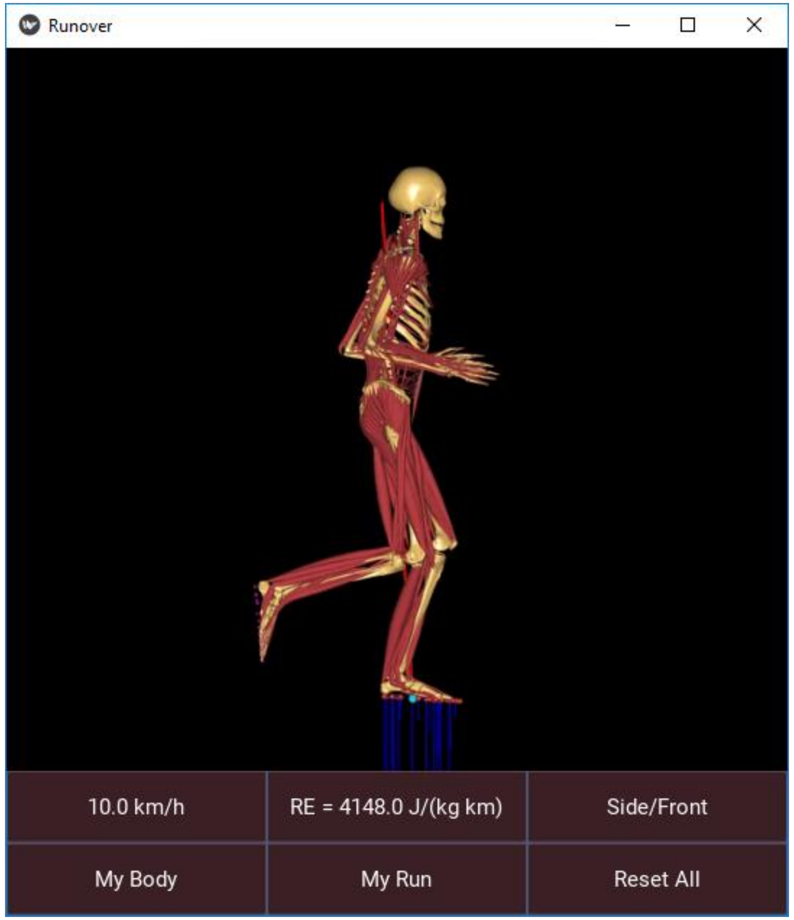
Data-Based Parametric Biomechanical Models for Cyclic Motions

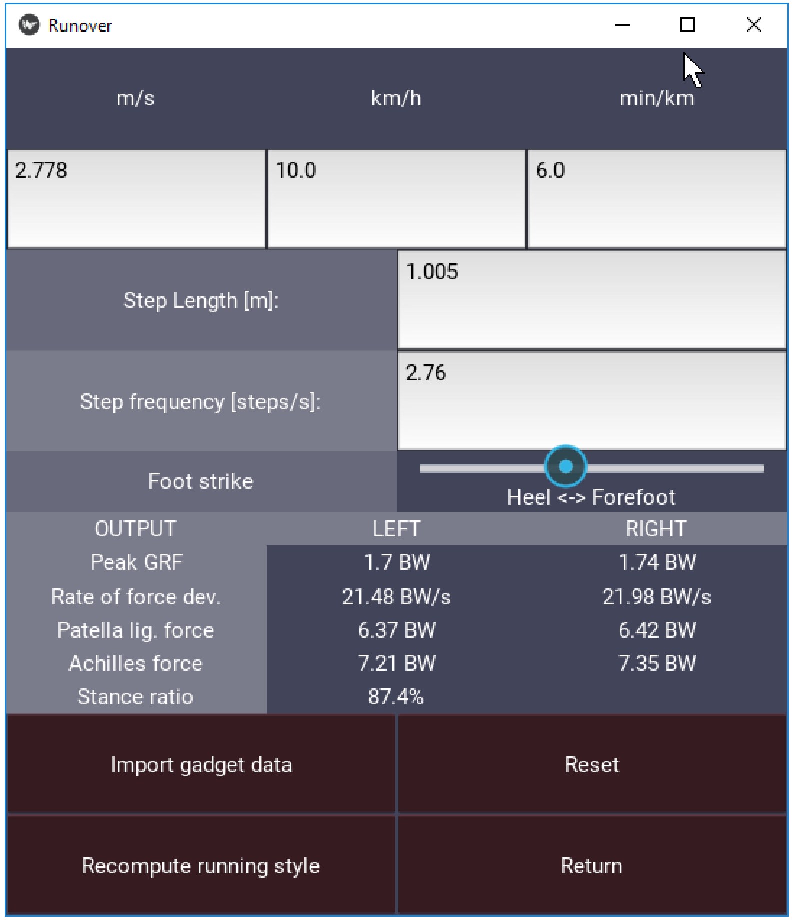
John RASMUSSEN [a,1], Morten Enemark LUND [b]
and Rasmus Plenge WAAGEPETERSEN [c]
[a] *Aalborg University, Department of Materials and Production, Fibigerstræde 16, 9220 Aalborg Ø, Denmark*
[b] *AnyBody Technology, Niels Jernes Vej 10, 9220 Aalborg Ø, Denmark*
[c] *Aalborg University, Department of Mathematical Sciences, Skjernvej 4A, 9220 Aalborg Ø, Denmark*

Abstract. We present a method to convert motion capture data and anthropometric statistics into parametric biomechanical models of cyclic motions, such as walking,

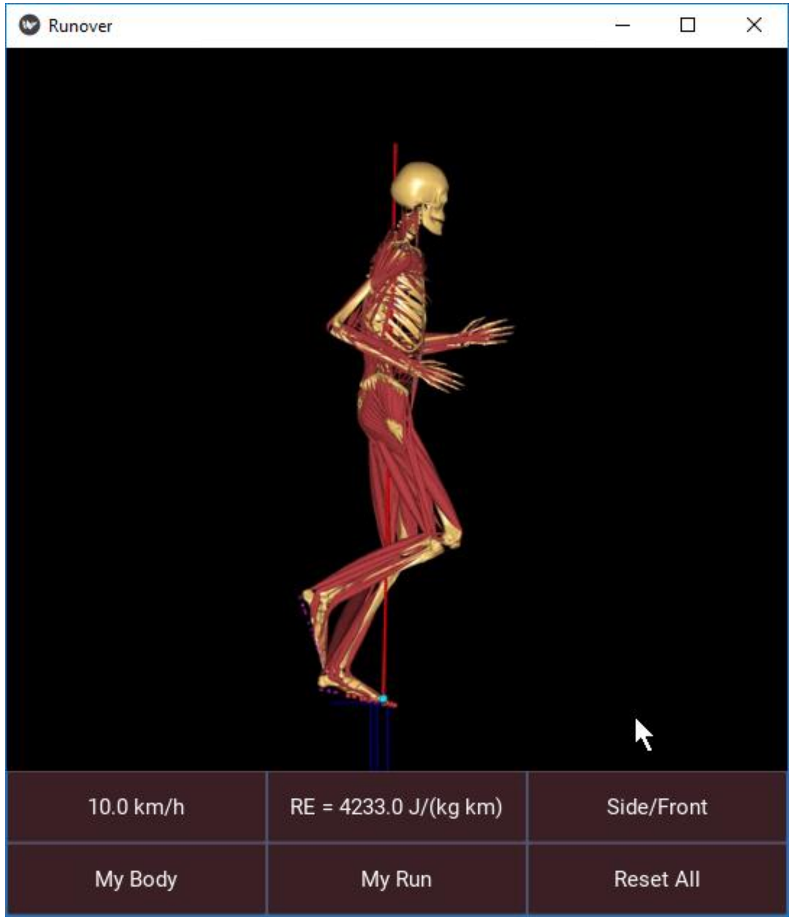
Open access: http://ebooks.iospress.nl/publication/55322

Desktop Implementation: The Runover App

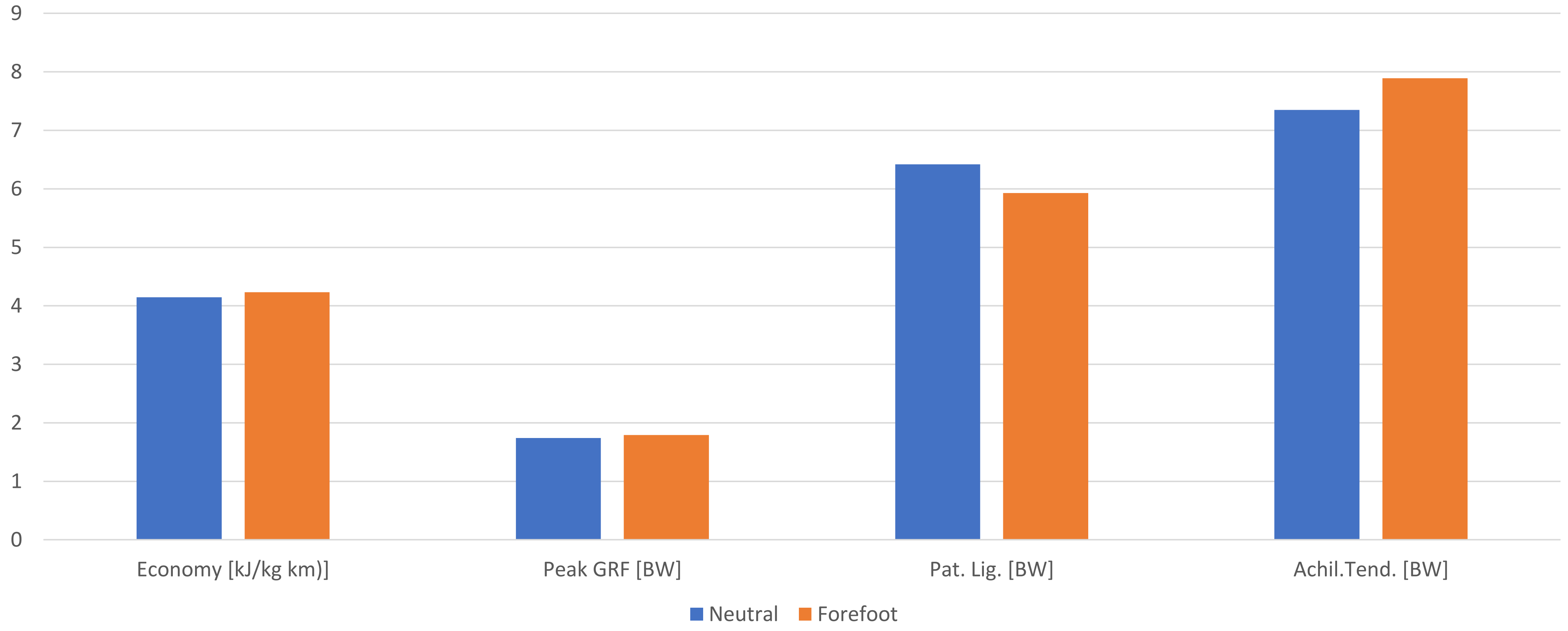




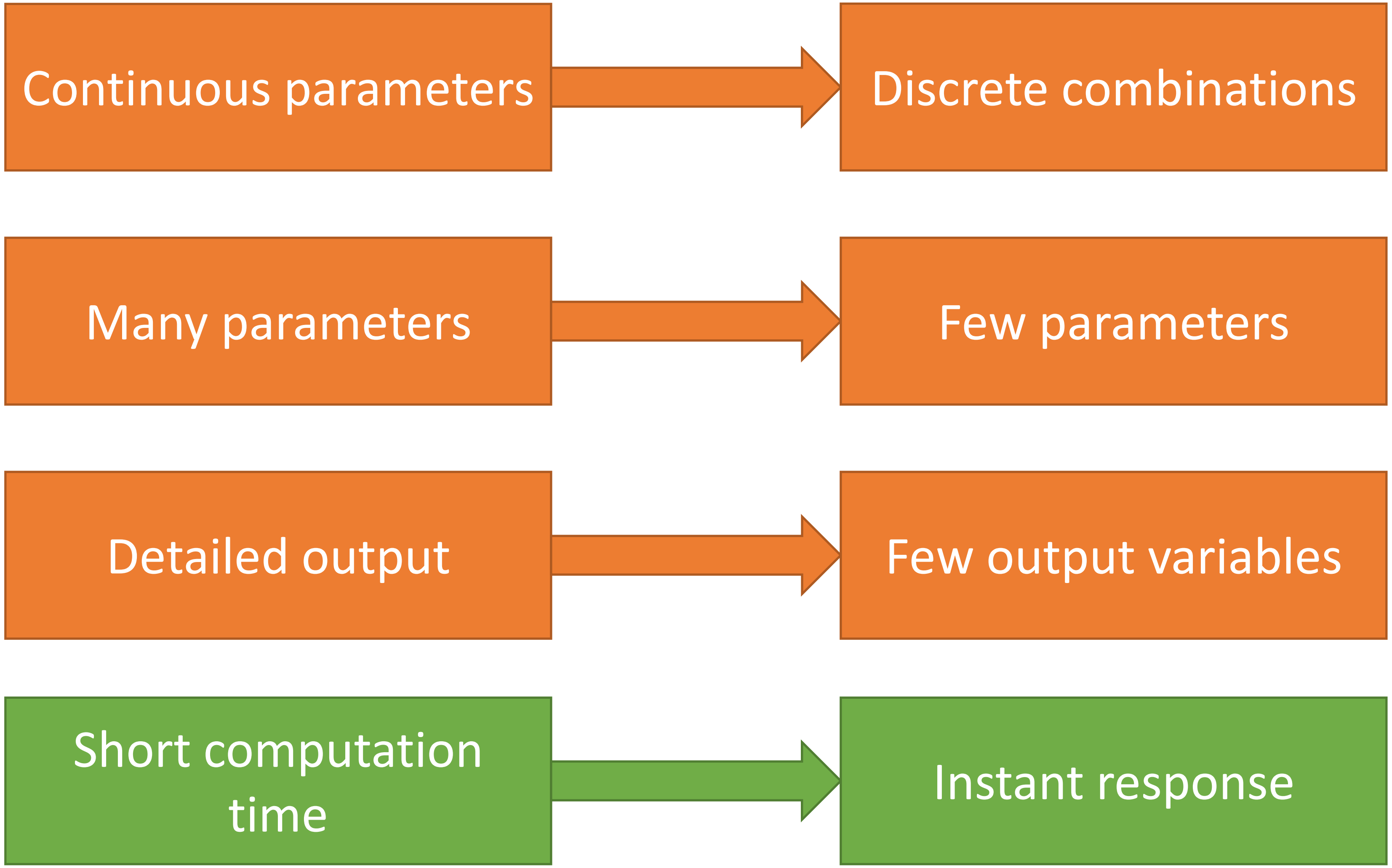
Forefoot landing



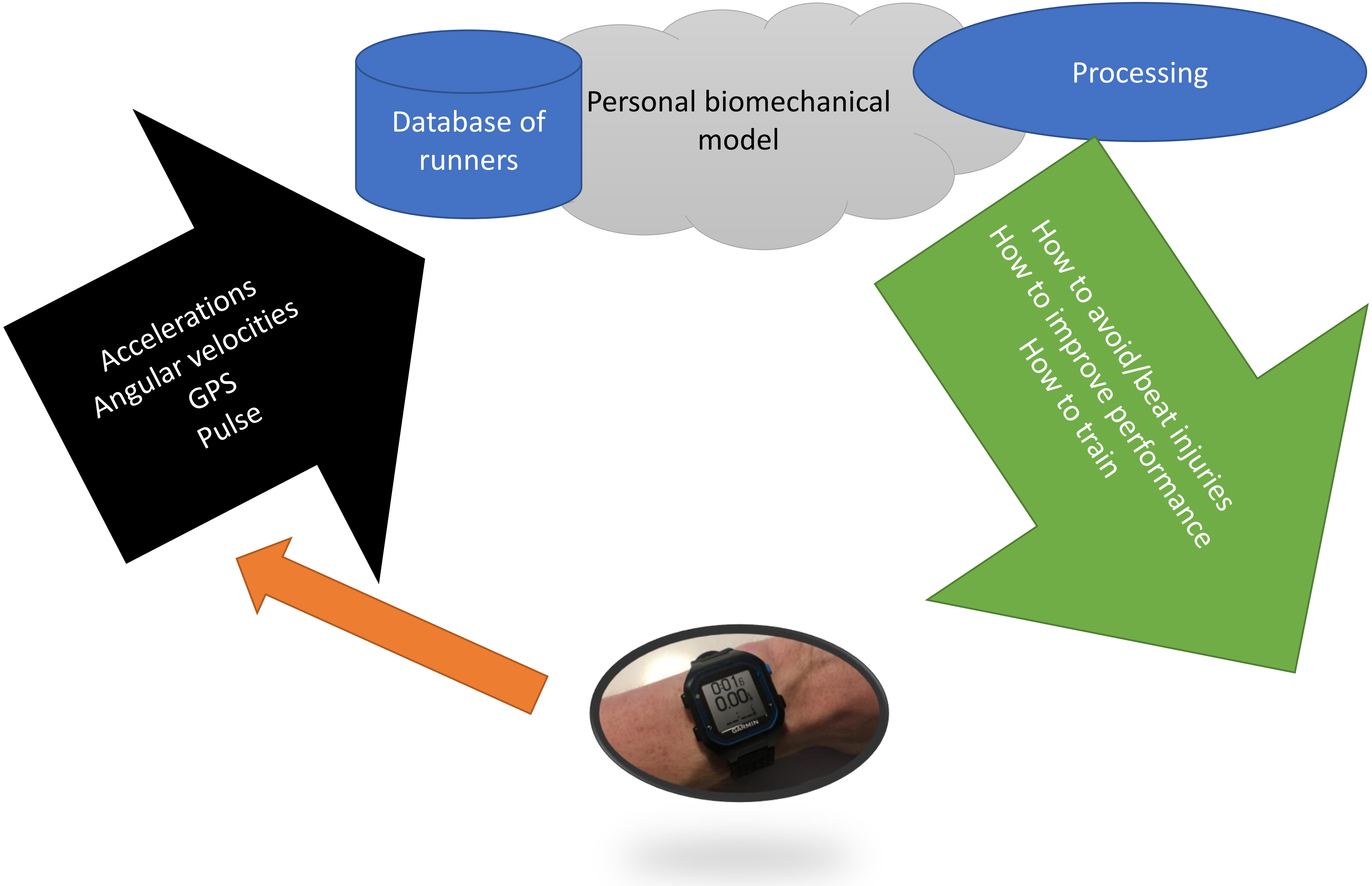
Neutral and forefoot running for John
(might be different for another person)



Putting it on the web: AnyBodyRun.com



3. Outlook


Database of runners
Personal biomechanical model
Processing
Accelerations
Angular velocities
GPS
Pulse
How to avoid/beat injuries
How to improve performance
How to train
0:01
0.00
GARMIN

Acknowledgements

The Biomechanics Research Group at
Aalborg University

AnyBody Technology

Kaiser Sport & Orthopaedics

Supported by Innovation Fund Denmark

www.anybodytech.com

- Events, Dates, Publication list, ...

www.anyscript.org

- Wiki, Blog, Repositories, Forum

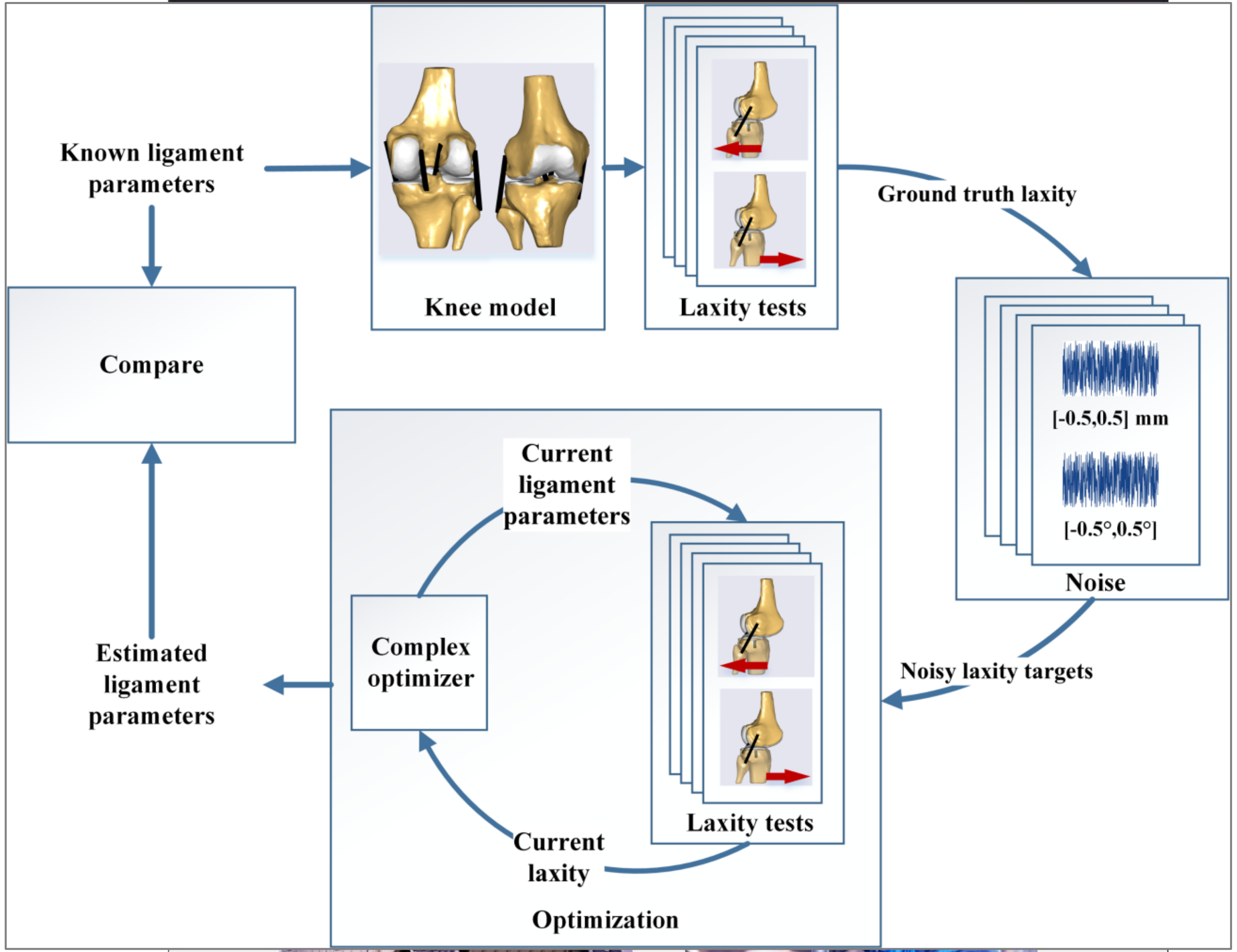
Events

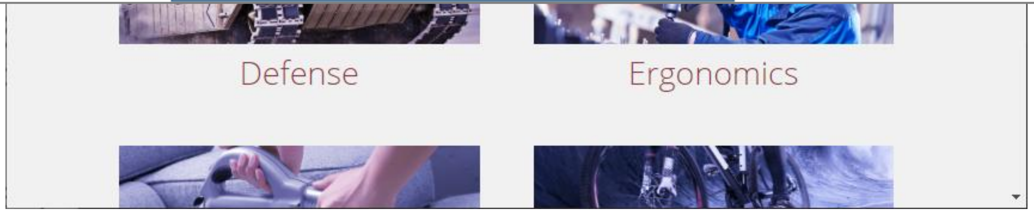
- March 23 – webcast: A methodology to evaluate the effects of kinematic measurement uncertainties on knee ligament properties estimated from laxity measurements
- Aalborg University in Denmark is planning a new Advanced Musculoskeletal Modelling PhD course to be held 3-7 May 2021. ONLINE

Meet us? Send email to sales@anybodytech.com

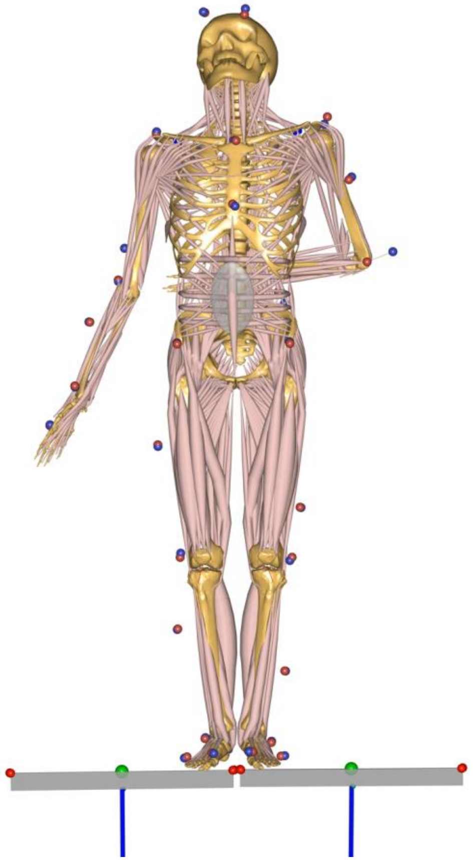
Want to present? Send email to ki@anybodytech.com

Find us:





Time for questions



Like the FaceBook group: AnyBodyRun

Visit https://anybodyrun.com/