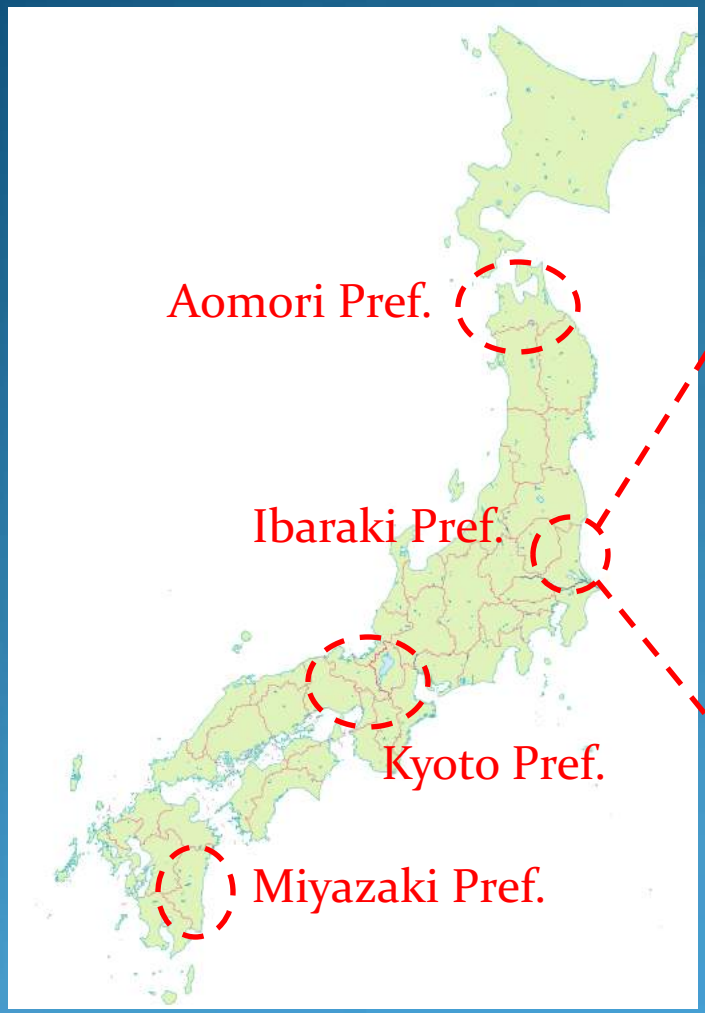
A biomechanical analysis in the mechanical energy flow between body segments on race walking technique

Koji HOGA, Ph.D
Information and Science staff, JOC and JAAF
Department of Physical Therapy,
Ibaraki prefectural University of Health Science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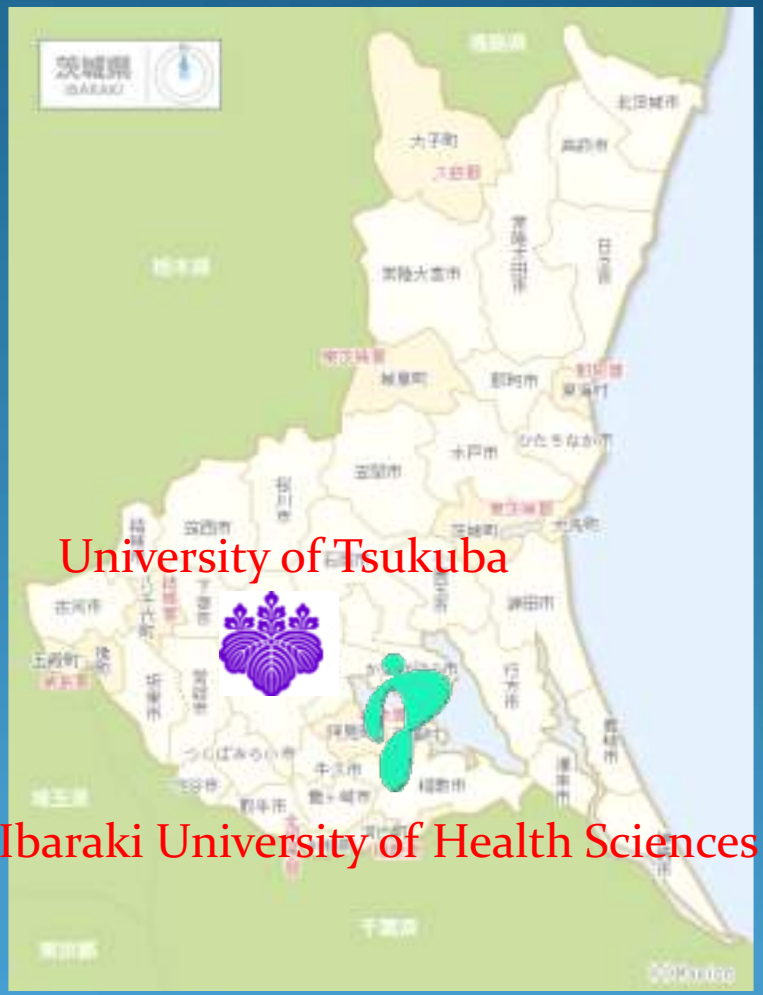

茨城県
University of Tsukuba
Ibaraki University of Health Sciences

Student (1989-92)

Ph.D. Student of Biomechanics (1998-2002)

Researcher in Aomori (2003-2007)

Race Walking :
Track and Road event in athletics

- Winner:
  who reached in the shortest time of all competitors

-Walking speed:
  one of the most important factors
  to achieve better result

Race walking event: endurance event

Indoor: over 3,000m

Outdoor (track): over 5,000m

Road: over 10km

Factors to achieve better result

- To obtain higher walking speed
- To maintenance high walking speed

➡ 'Economy', 'Efficiency',,,

Biomechanical analysis about Economy and Efficiency of race walking

- **Estimation from the mechanical energy of CG**

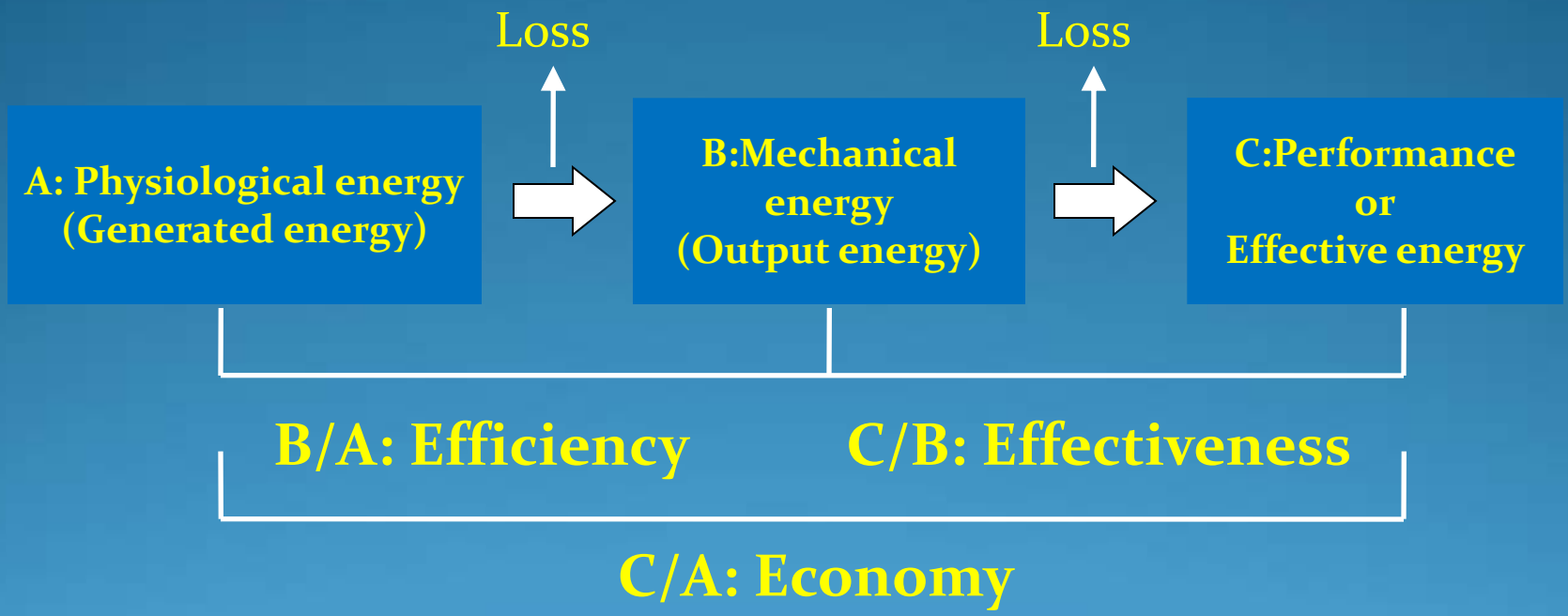
  Cavagna and Franzetti (1981)

  Marchetti et al. (1982)

- **Mechanical energy flow between body segment**

  Hoga et al. (2003, 2006)

'Three Es ' on human movement (Ae and Fujii, 1996)



Estimation of the mechanical work and transfer of the whole body (Pierrynowski et al., 1980)

Mechanical work of whole body: $W_W = \sum_{i=1}^{s} \sum_{j=1}^{n} |\Delta E_{i,j}|$

; assuming there was not mechanical energy flow between the body segments

Mechanical work of whole body: $W_{Wb} = \sum_{j=1}^{n} |\sum_{i=1}^{s} \Delta E_{i,j}|$

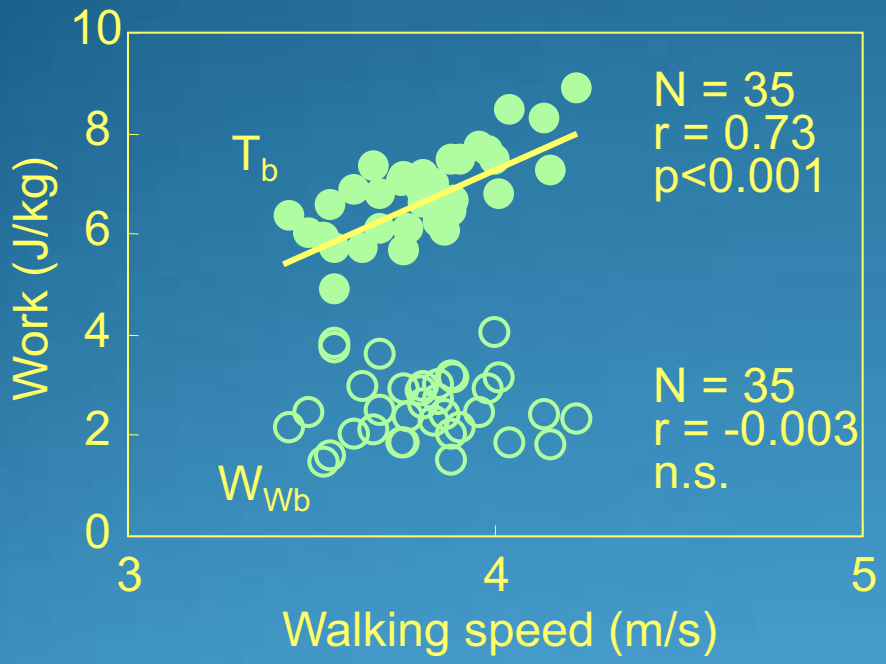
; assuming there was mechanical energy flow between the body segments

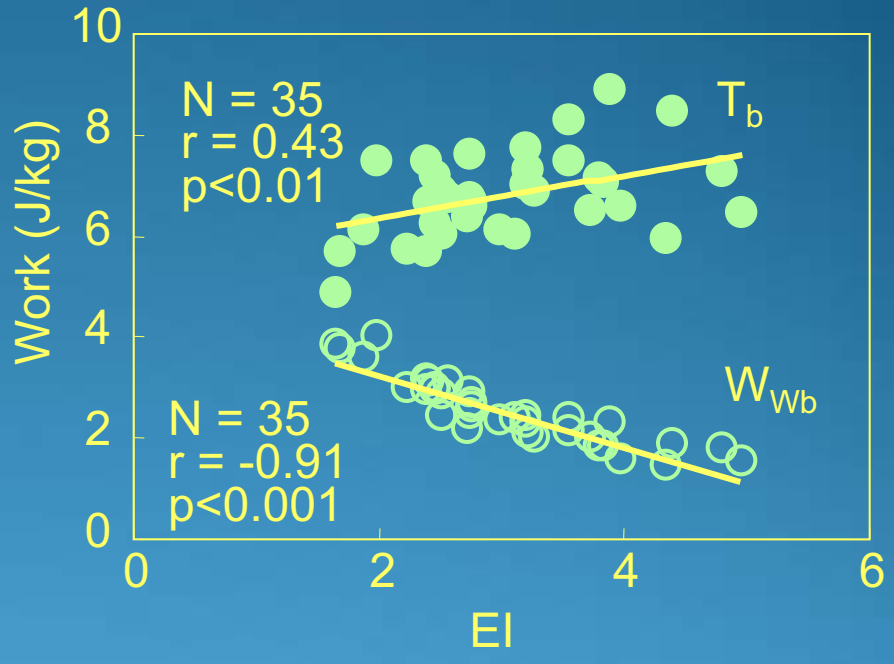
Mechanical energy transfer: $T_b = W_W - W_{Wb}$

Effectiveness Index: EI = $\dfrac{\frac{1}{2} M V_x^2}{W_{Wb}}$ (Ae and Fujii, 1996)

2-dimensional study on official race and experiment (1998-2001)

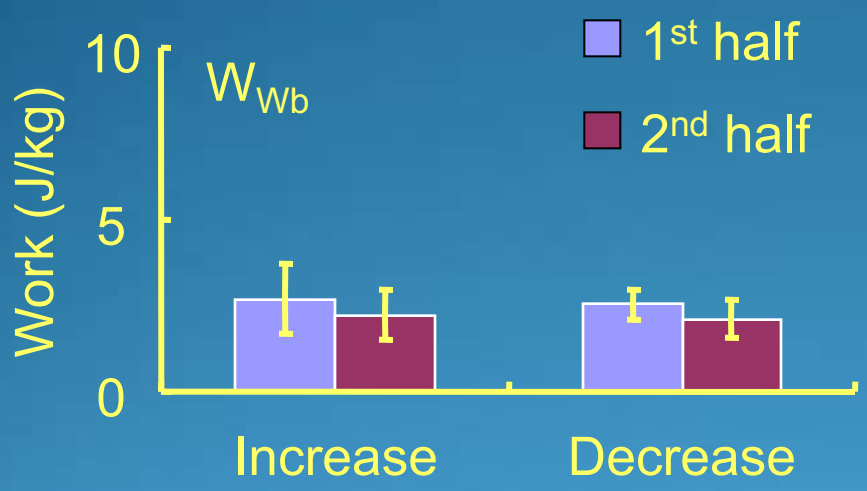
Mechanical work (W_{Wb}) and Mechanical transfer (T_b) versus Walking speed and *EI* in competition

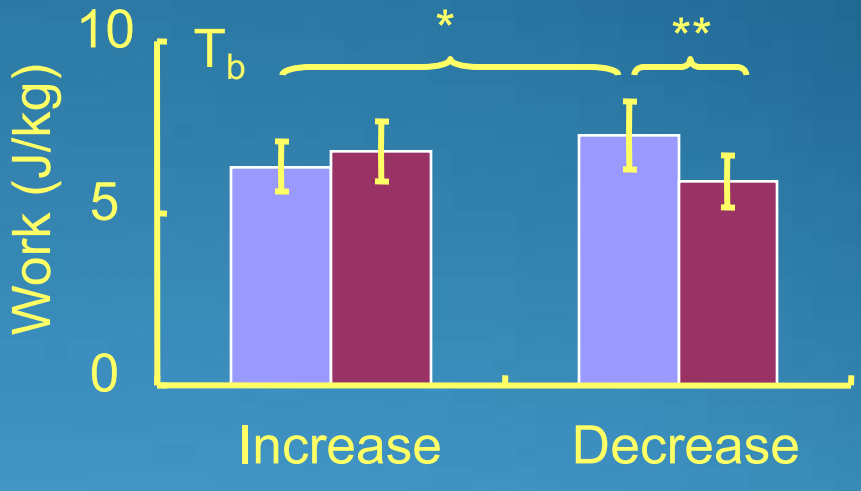




- **Data were collected at first half of the Men20km races in Japan**
- **Subject's race records expand from 1:19:50 to 1:34:59.**
- **Subject's personal best records expand from 1:18:27 to 1:34:59.**

Mechanical work of the whole body (W_{Wb}) and the mechanical energy transfer within the whole body (T_b) in the 1st and 2nd half of competition

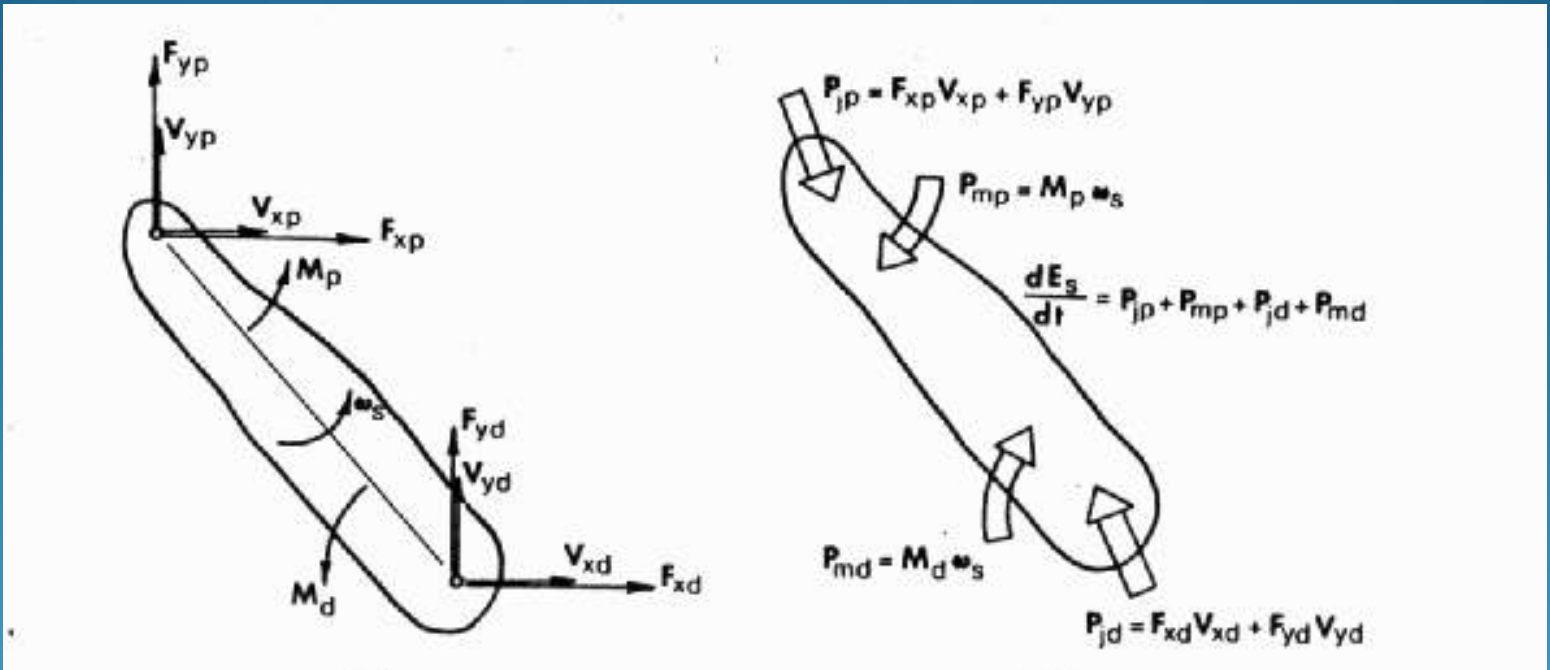




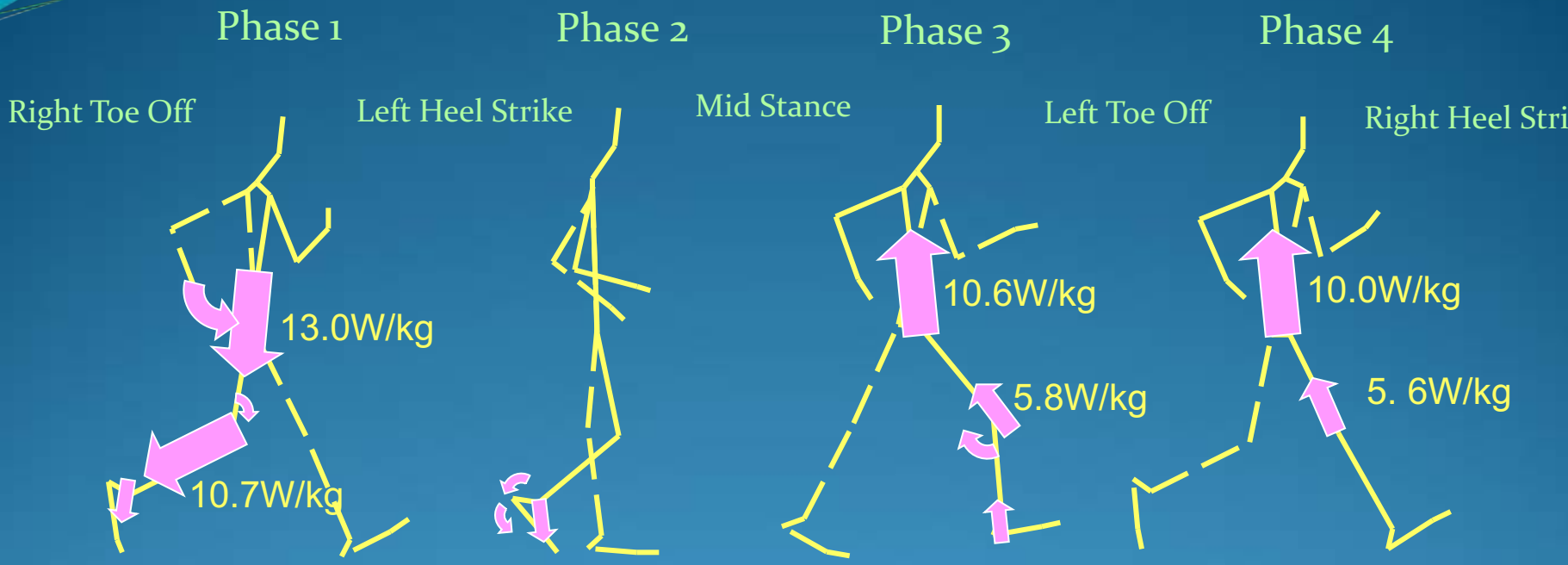
* p<0.05, ** p<0.01

Increase: group of speed increased in the 2nd half (N=11)
Decrease: group of speed decreased group in the 2nd half (N=11)

Detail of the mechanical energy transfer (flow) in each joint of the body



Mechanical power and power balance of the given segment of the body (Winter, 1980)



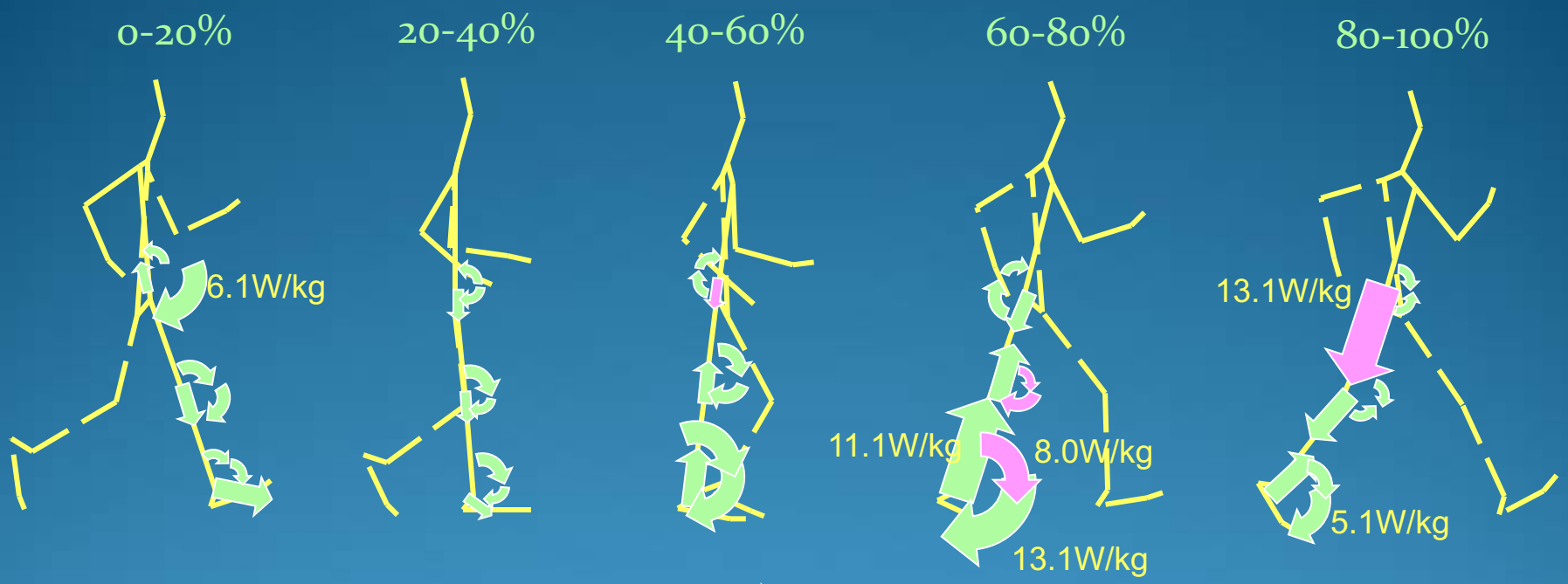
Mean Joint Force Power:

Mean Segment Torque Power:

- Direction of arrows: direction of mechanical energy flow
- Size of arrows: magnitude of mechanical energy flow

Mean power of each phase of right foot recovery phase which was significantly related to the walking speed ($p<0.05$)

Normalized right foot support phase (Right heel strike – Right toe off)



Mean Joint Force Power:

Mean Segment Torque Power:

There was not significant relationship to walking speed

Mean Joint Force Power:

Mean Segment Torque Power:

There was significant relationship to walking speed

Mean joint force power and segment torque power of the support leg during right foot support phase

Right foot recovery phase

Flight phase | Left foot support phase | Flight phase

Phase 1 | Phase 2 | Phase 3 | Phase 4

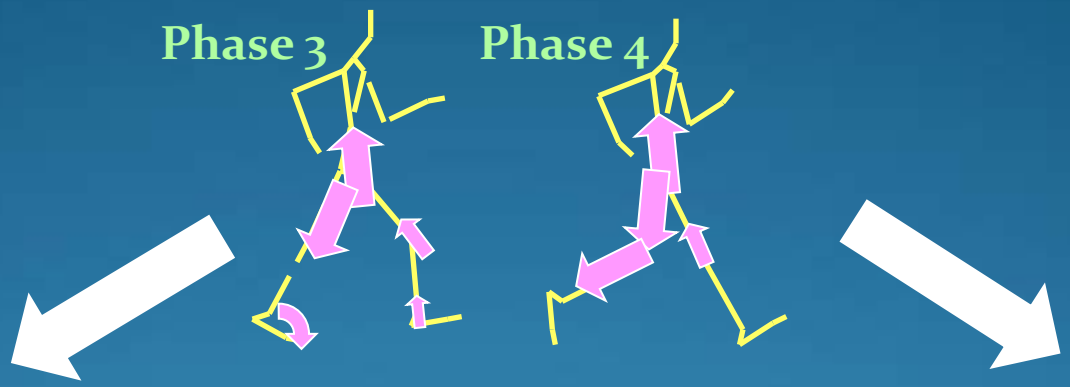
Right toe off | Left heel strike | Mid Stance | Left toe off | Right heel strike

Mechanical energy flow
Left leg ⇒ Right leg

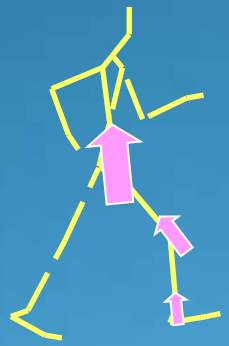
Mechanical energy flow
Right leg ⇒ Left leg

Contribute to maintain horizontal velocity ➡ Large step length
High step frequency

How these power can be enhanced?



Mechanical energy flow from recovery leg to torso (pelvis)



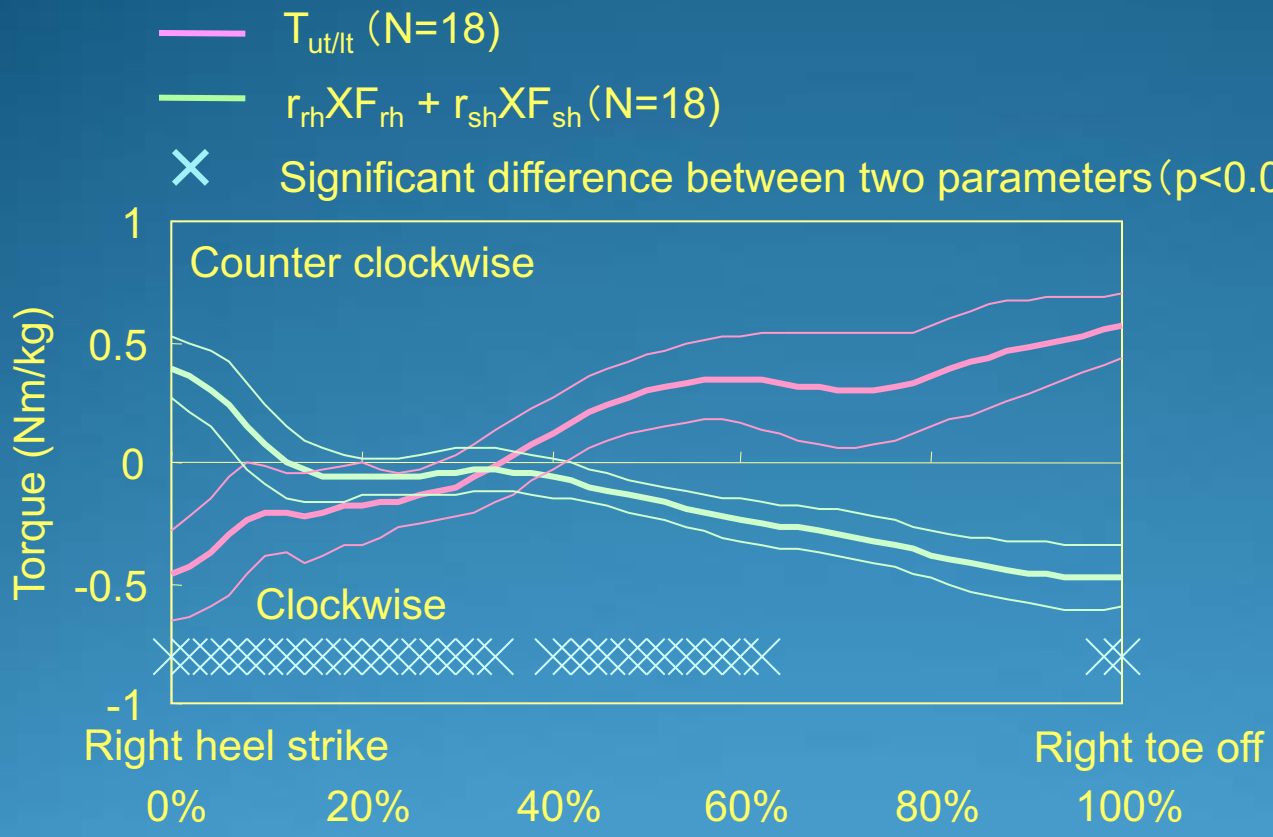
: Hip extensors' torque in phase 3 and 4

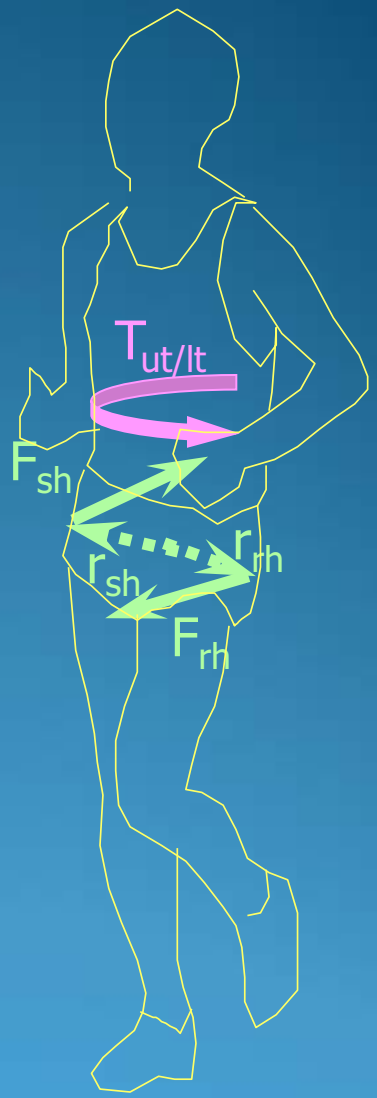
Mechanical energy flow from torso (pelvis) to support leg

: Torque about torso (next slide)

3-dimensional Experimental study (2002.5.25)

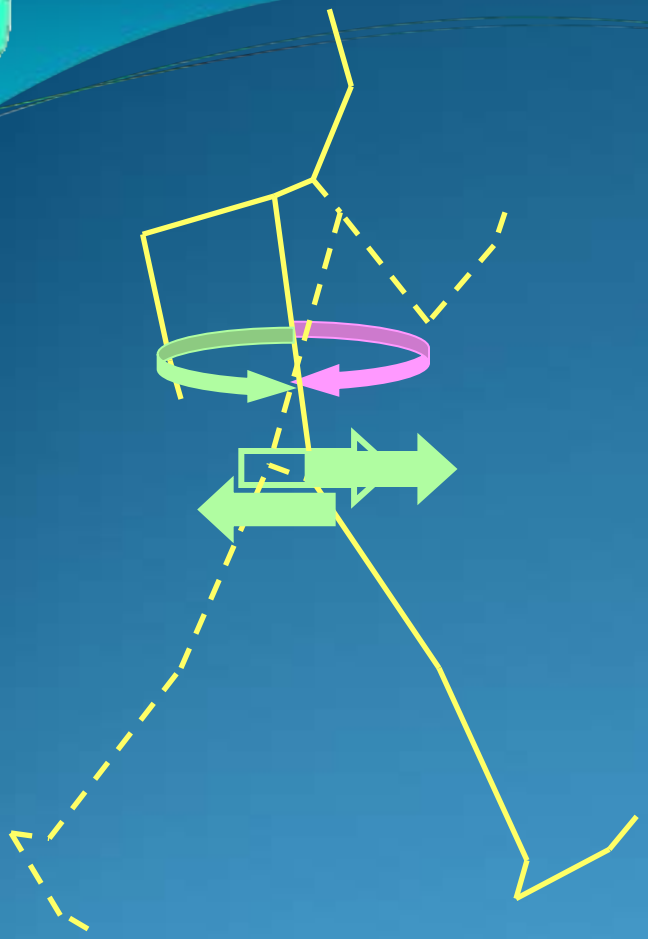
Relationships between torso muscle torque and hip joint force





*** Torso muscle torque contributes to fix torso against rotation and to enhance support hip joint force!**

Hip extensors' torque and hip joint force in the late recovery phase



Mechanical energy flow from recovery leg to pelvis

Joint force moment at recovery hip to rotate pelvis

Torso torque which conquer to the joint force moment

Joint force at the support hip

Mechanical energy flow to the support leg

Contribute to maintain horizontal velocity

Large step length
High step frequency

Cherry blossoms, National Flower of Japan in Japan National Training Centre

Daisy, National flower of Italy

Thank you for your attention