Running

Modeling of
Human Movement

MCEN 4228/5228

Fall 2021

Running

- Running Kinematics
- Running Kinetics
- Running Energetics

Running kinematics

- What defines gaits?
- Components of a stride
- Vertical displacement of the body
- Horizontal velocity of the body

What defines a walk vs. a run?

- Kinematic
- Kinetic

Walking and running speeds

Walking speeds: 0.5 - 2 m/s

Running speeds: 2.5 m/s - max

- Peak for elite male athletes = 12 m/s

Running kinematics

- What defines gaits?
- Components of a stride
- Vertical displacement of the body
- Horizontal velocity of the body

Kinematic terms for gait analysis

Stride: One complete cycle from an event (e.g., right foot touch-down) to the next time that event occurs.

Stance phase: Time when a limb is in contact with the ground.

Swing phase: Time when a limb is NOT in contact with the ground.

Kinematic terms for gait analysis

Double support: Time when 2 limbs are in contact with the ground.

Aerial phase: Time when no feet are on the ground.

Walk

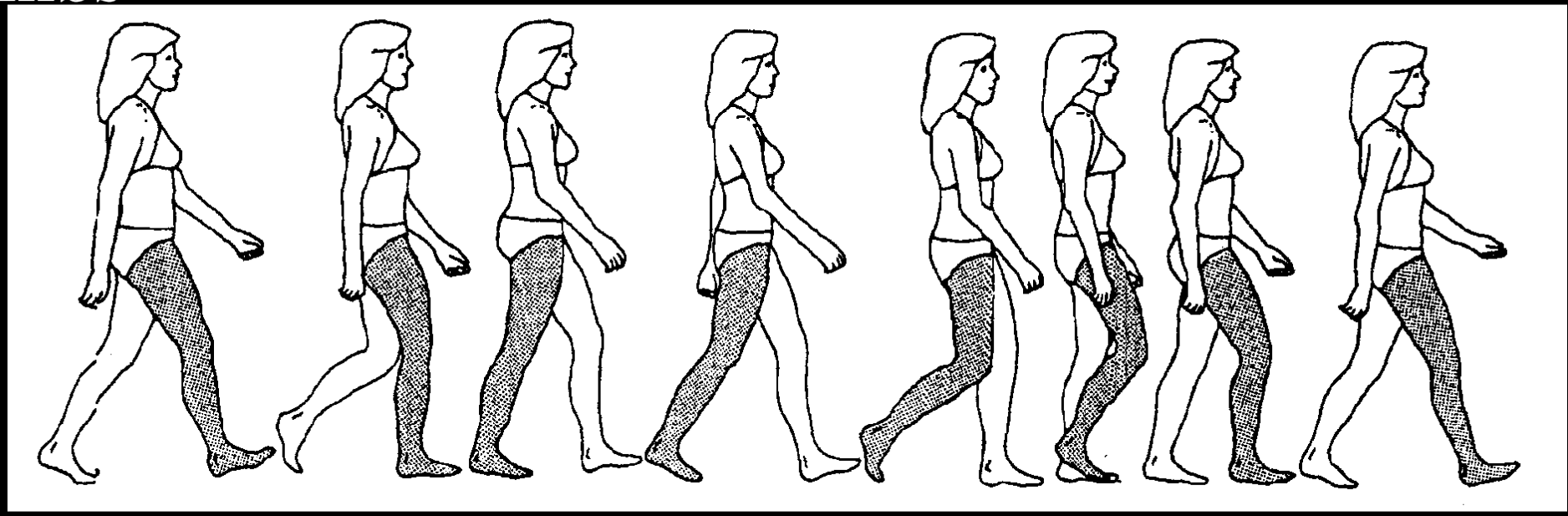
Both limbs

Double support

Single limb stance

Double support

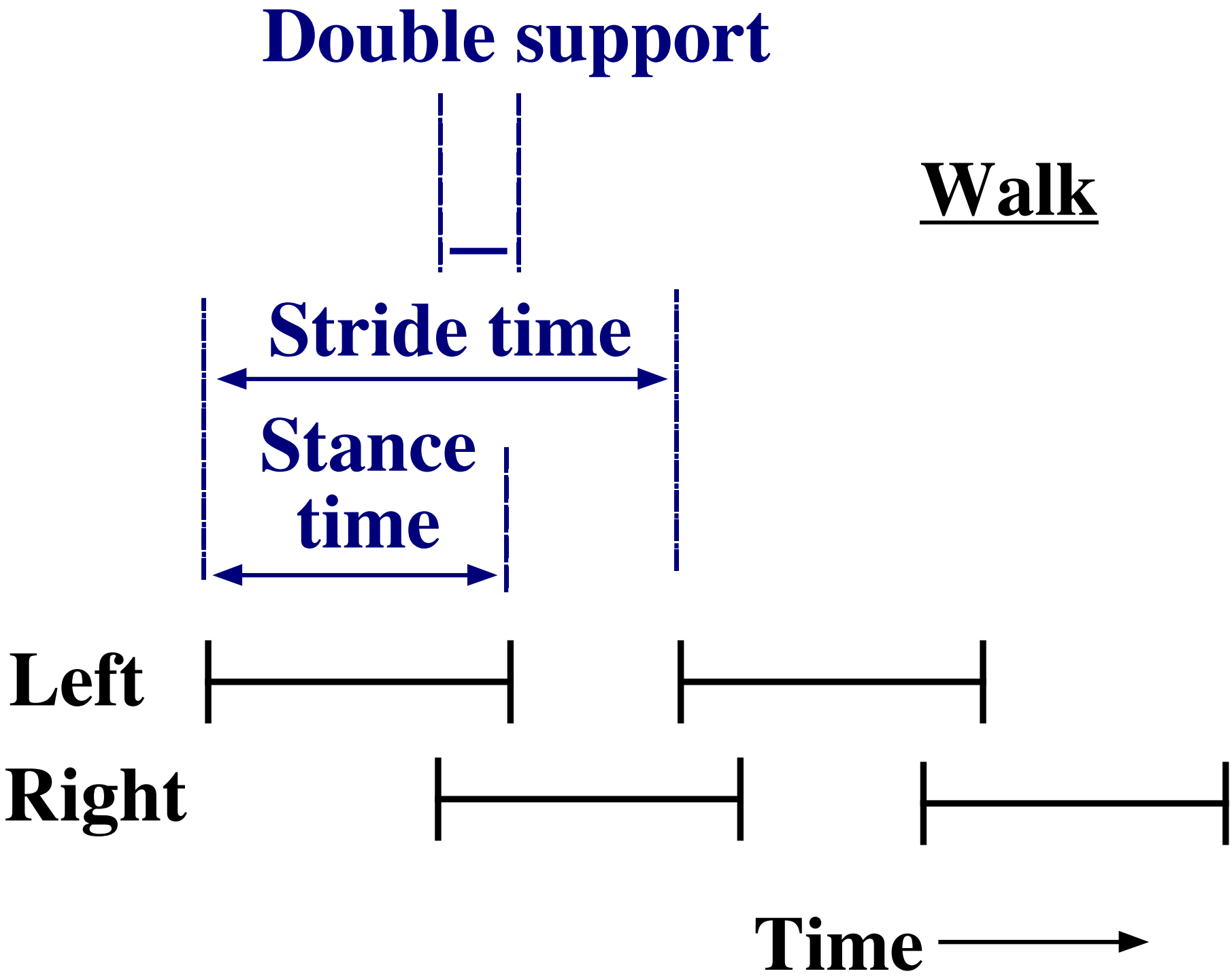
Single limb stance



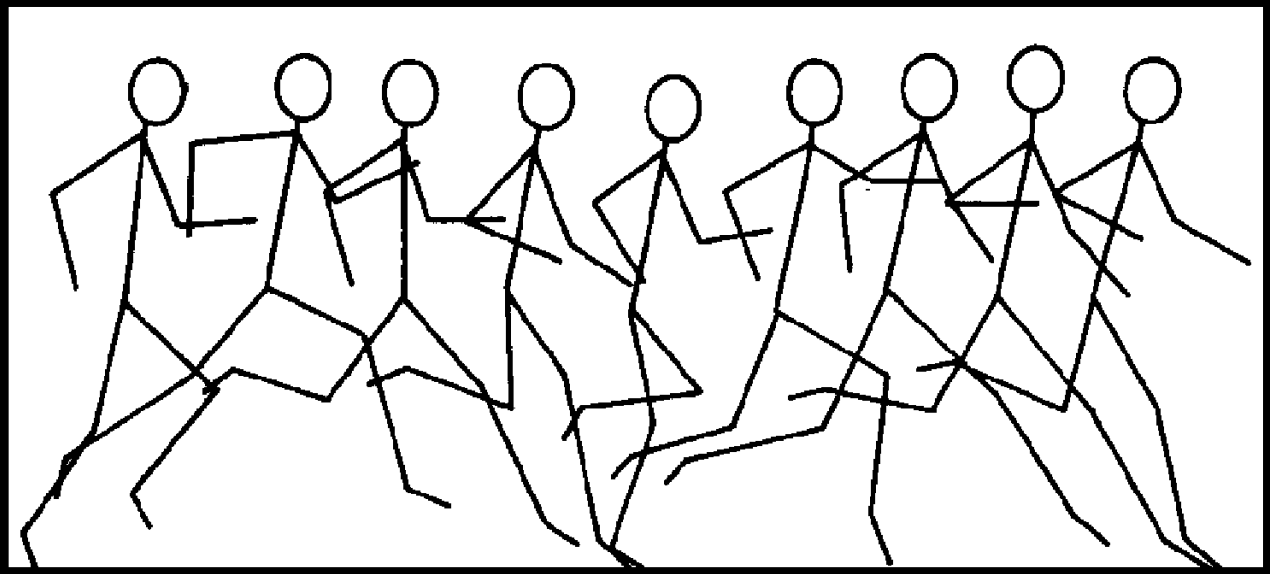
Right limb

Stance phase

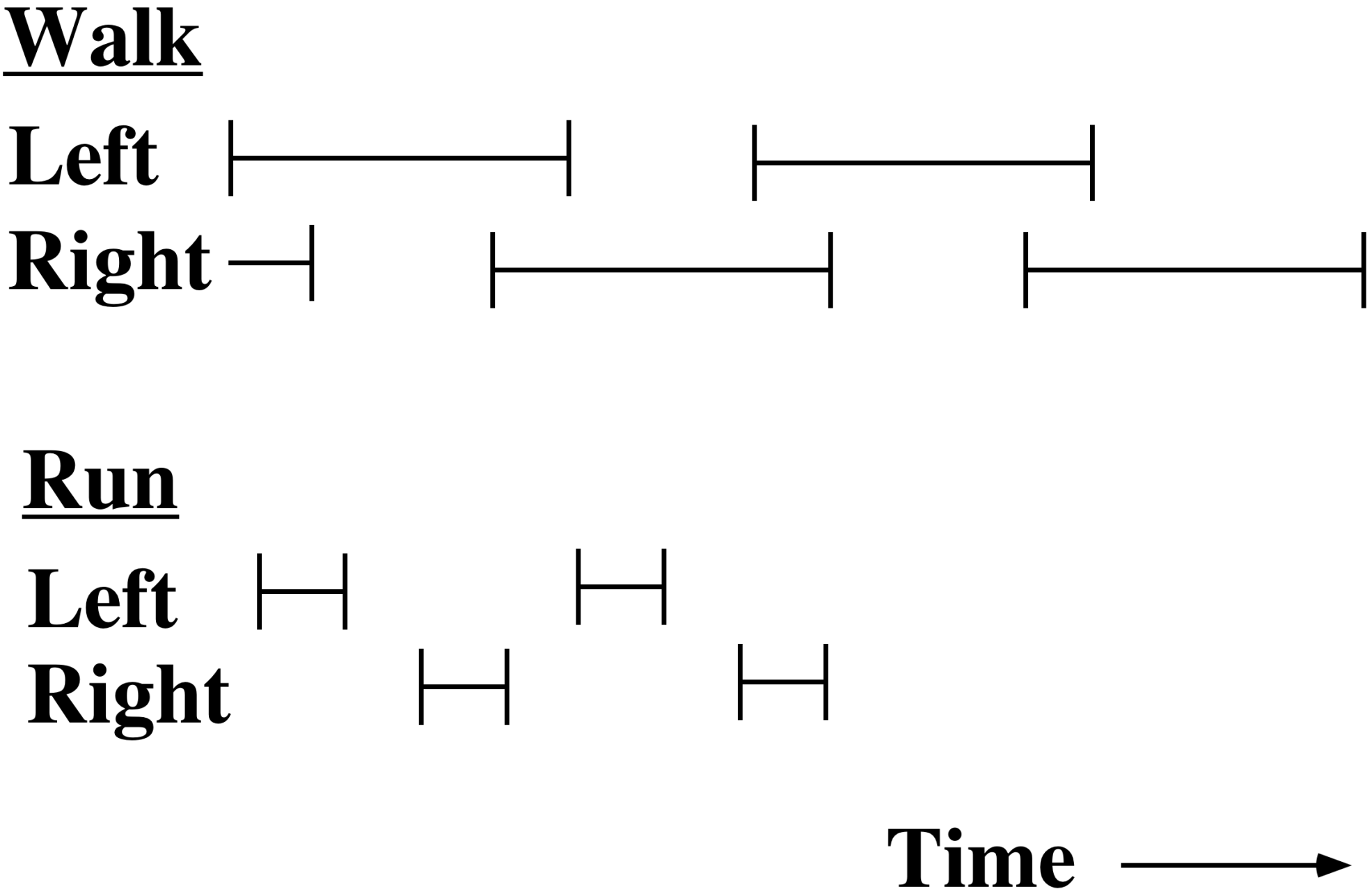
Swing phase


Double support
Walk
Stride time
Stance time
Left
Right
Time

Run



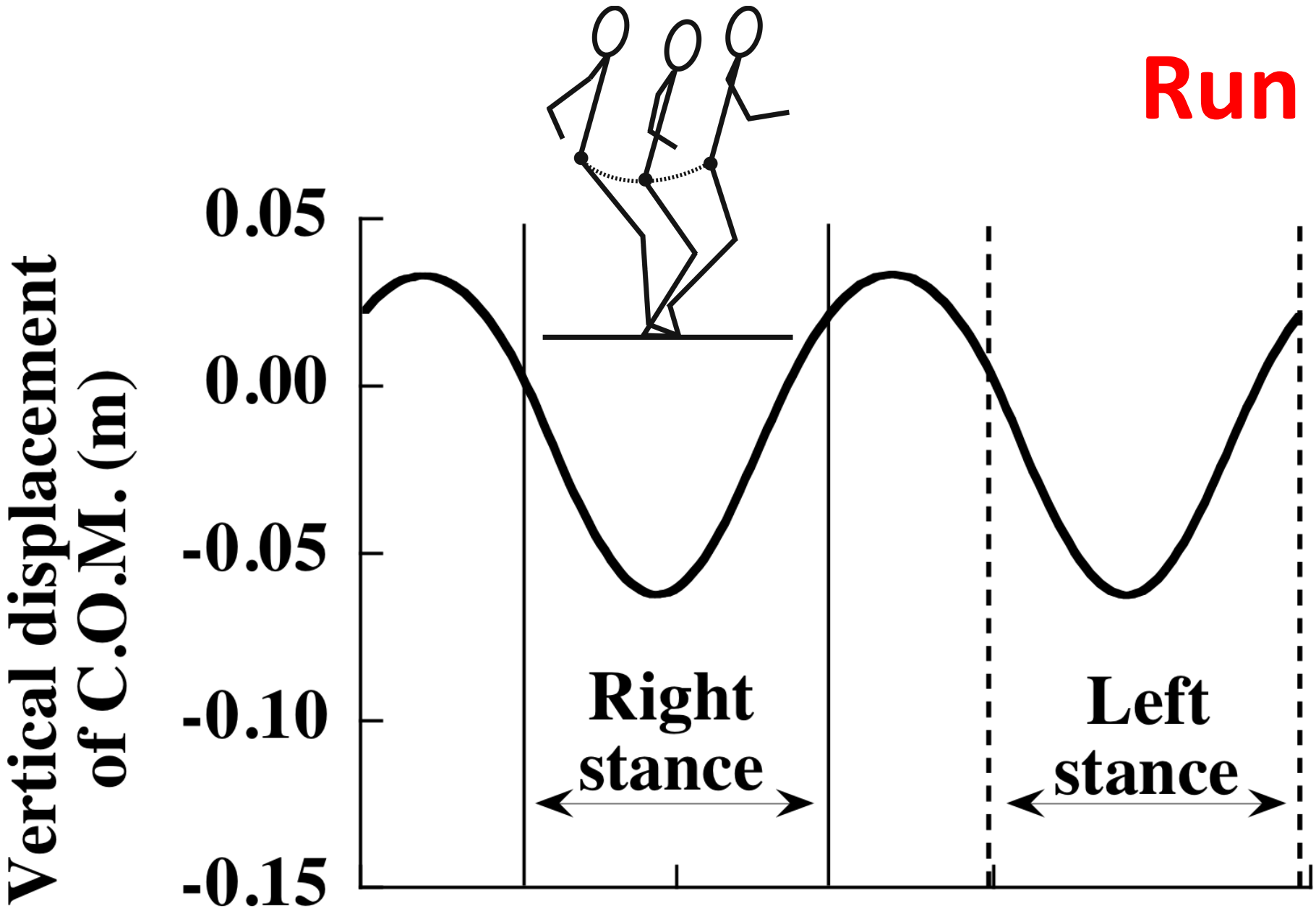
Right		**R. swing**	
Left	**L. swing**		**L. swing**
Overall	**Aerial**		**Aerial**

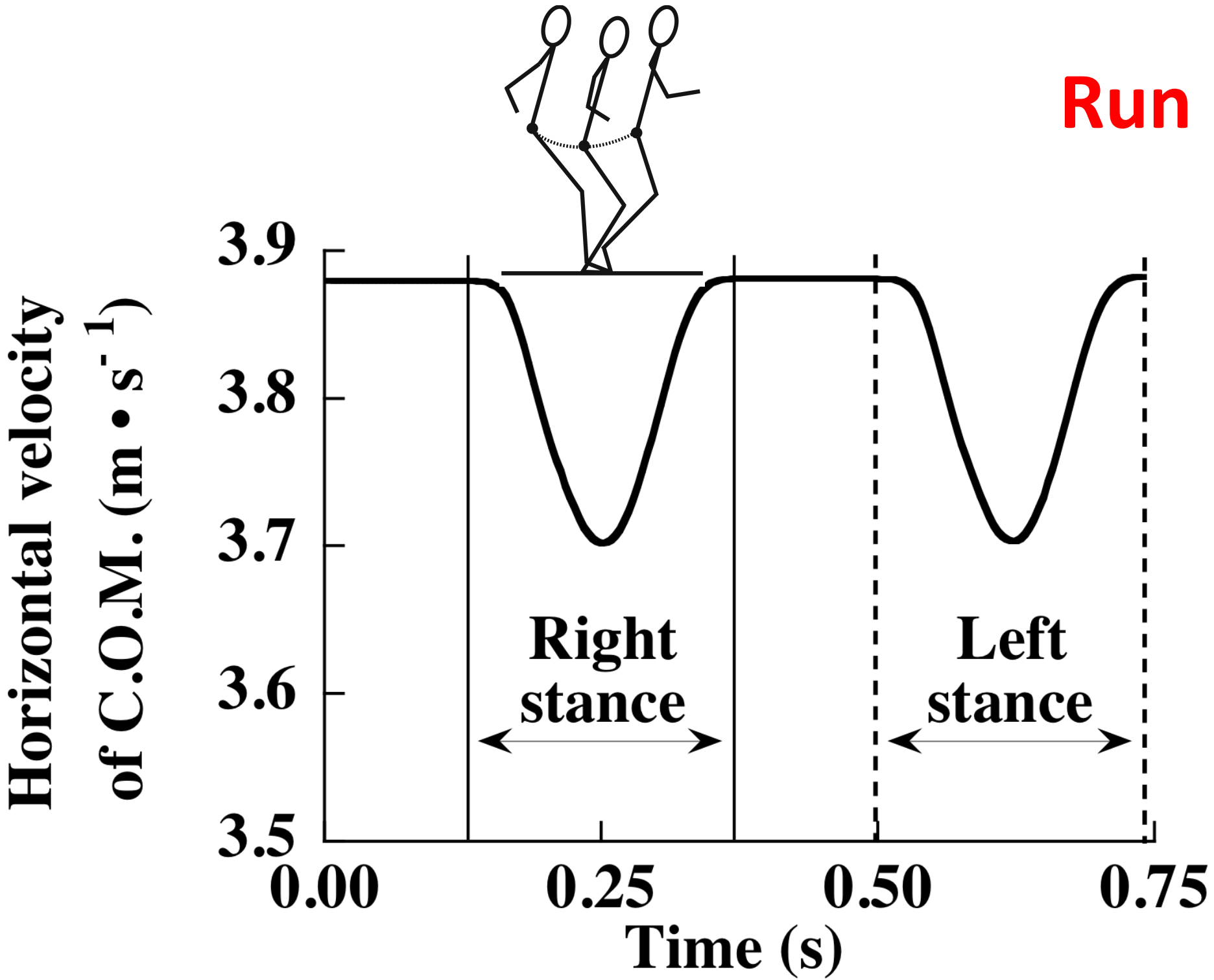

Walk
Left
Right
Run
Left
Right
Time

Comparison of walk vs. run

- stance time: run < walk
- swing time: run > walk
- stride time: run << walk

- aerial time: run >> walk (0)
- double support: run (0) << walk


Run
Vertical displacement of C.O.M. (m)
0.05
0.00
-0.05
-0.10
-0.15
Right stance
Left stance


Run
Horizontal velocity of C.O.M. (m • s-1)
3.9
3.8
3.7
3.6
3.5
Right stance
Left stance
0.00
0.25
0.50
0.75
Time (s)

Walk and Run

Forward velocity fluctuates, reaching its slowest value at the middle of the stance phase.

V_x never reaches zero

Walking vs. running

Double stance?

Aerial phase?

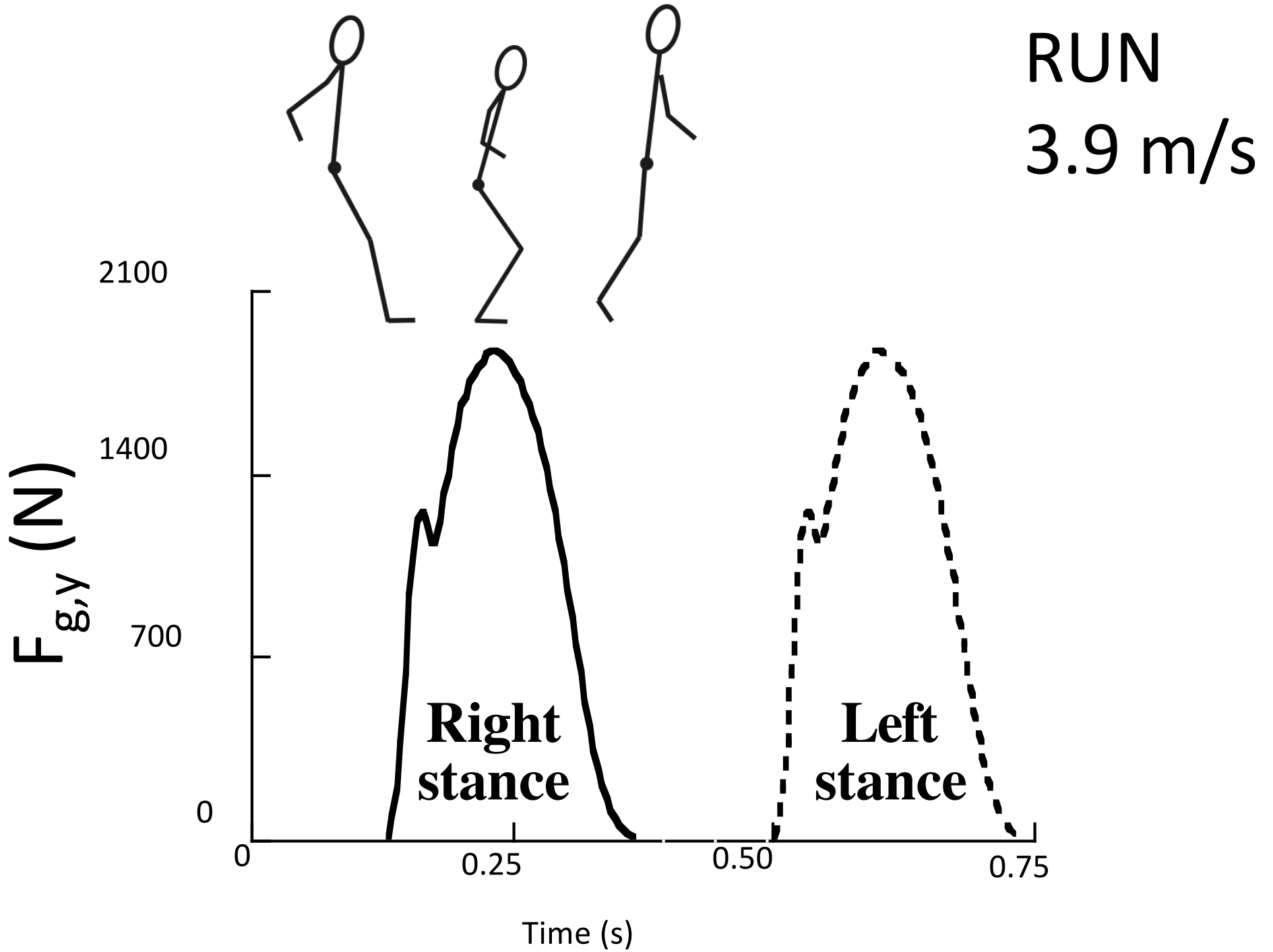
Position of hip:

- highest at mid-stance in running.
- lowest at mid-stance in walking.

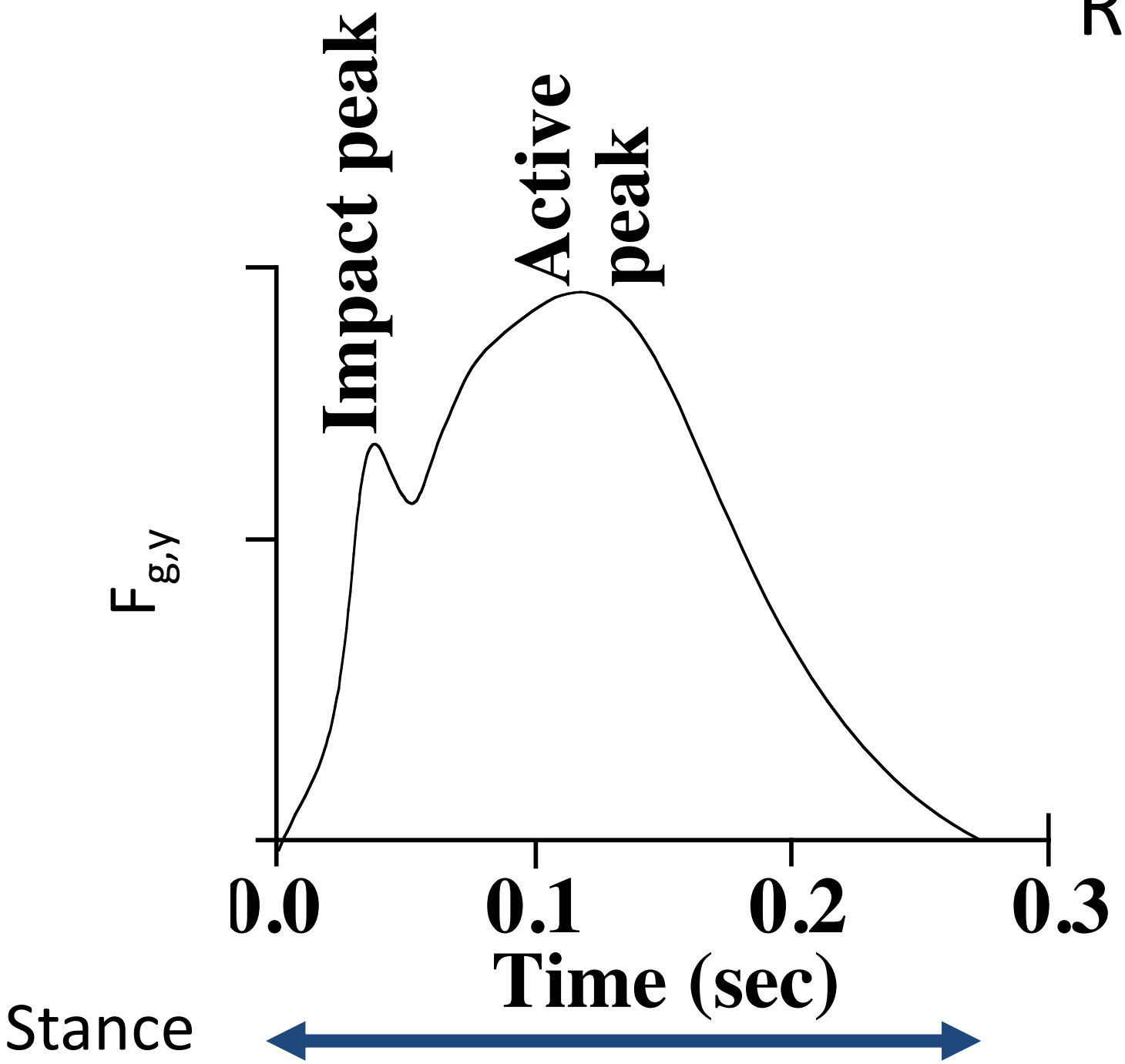
Leg posture during stance phase.

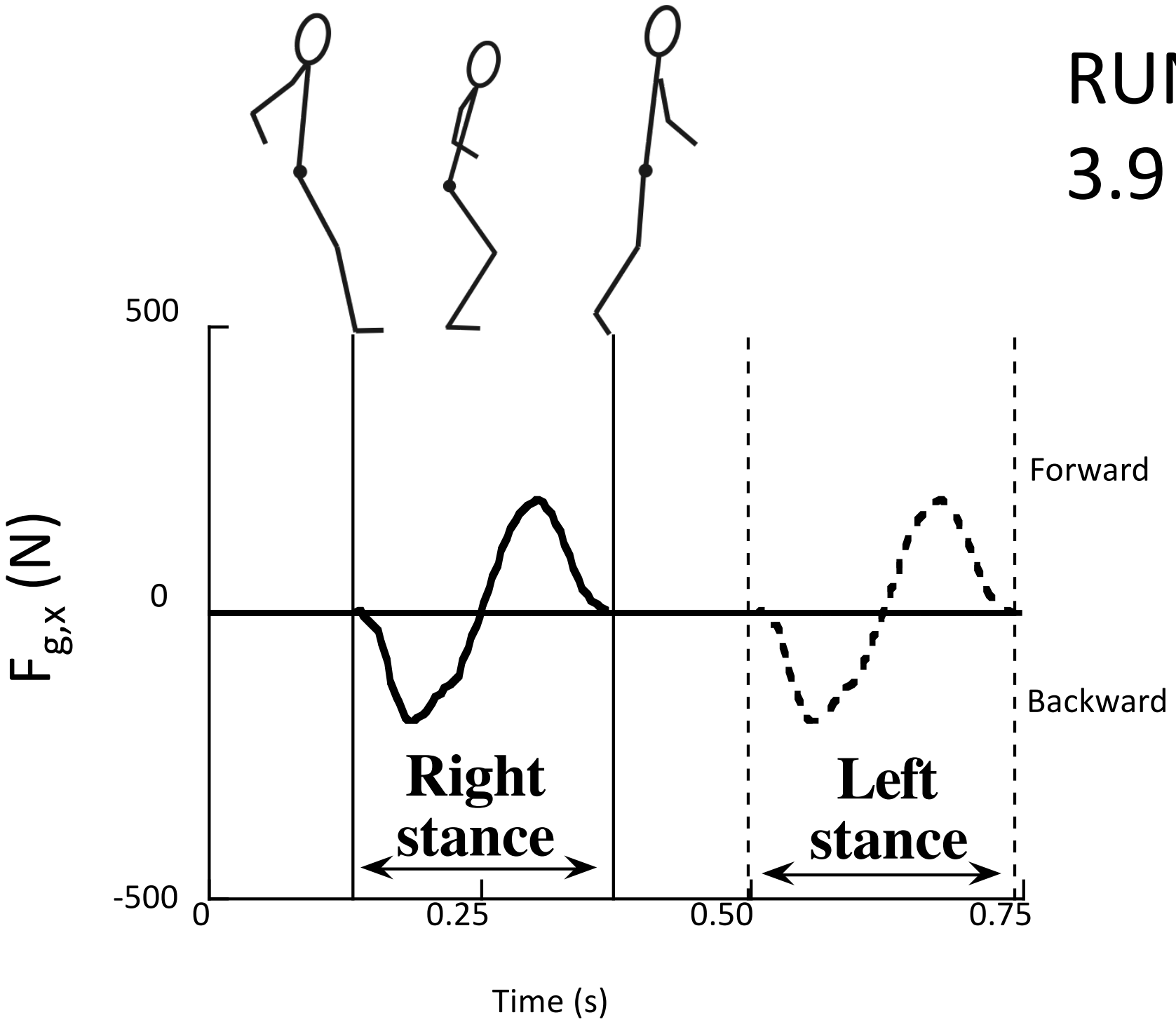
- straighter in walking than running

Both walk & run: forward velocity reaches minimum at the middle of the stance phase.

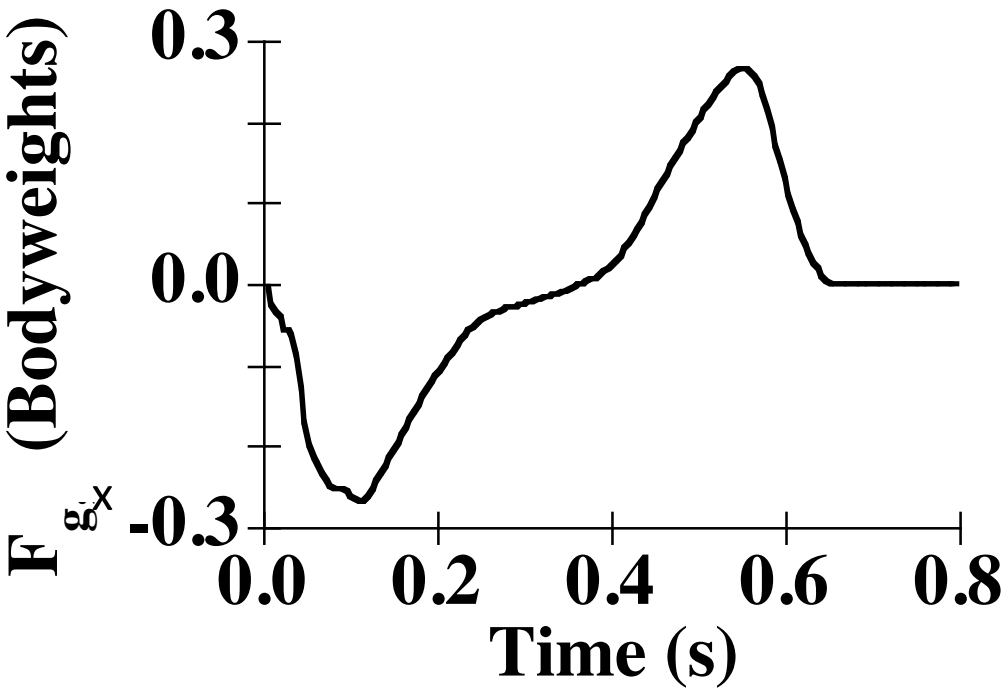

RUN
3.9 m/s
2100
1400
700
0
$F_{g,y}$ (N)
Right stance
Left stance
0
0.25
0.50
0.75
Time (s)

RUN

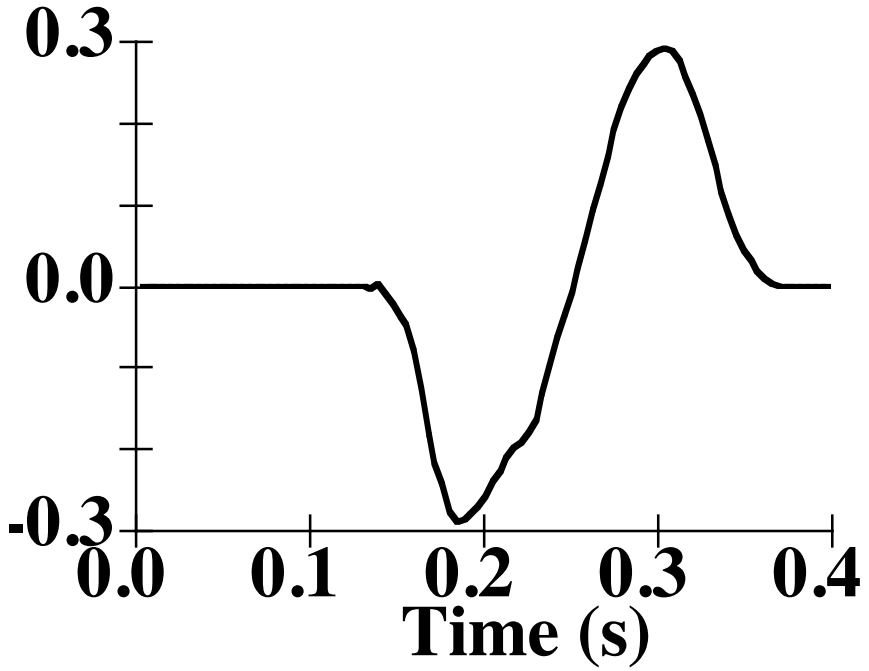


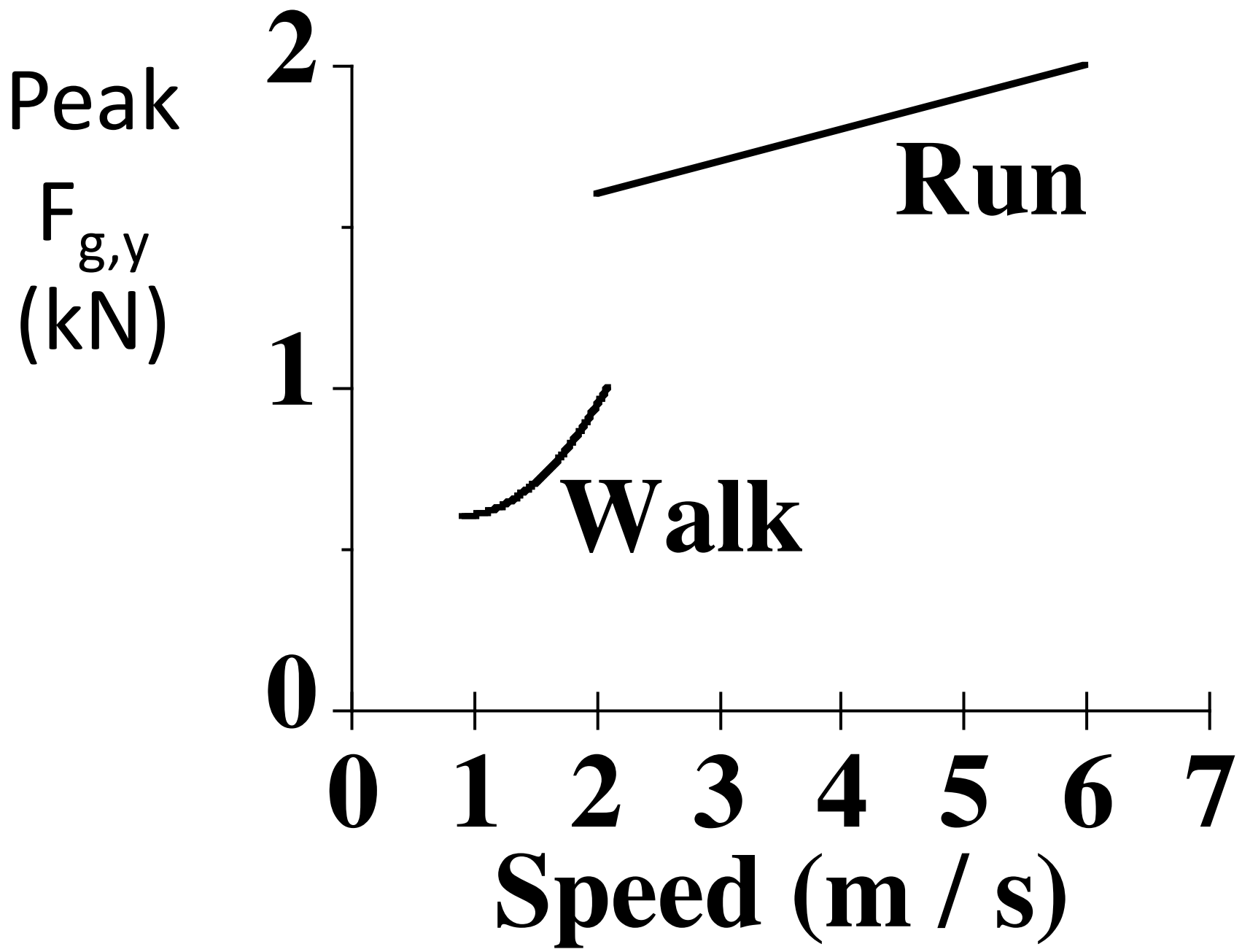

RUN
3.9 m/s
500
0
-500
$F_{g,x}$ (N)
Forward
Backward
Right stance
Left stance
0
0.25
0.50
0.75
Time (s)

Walk: 1.25 m/s



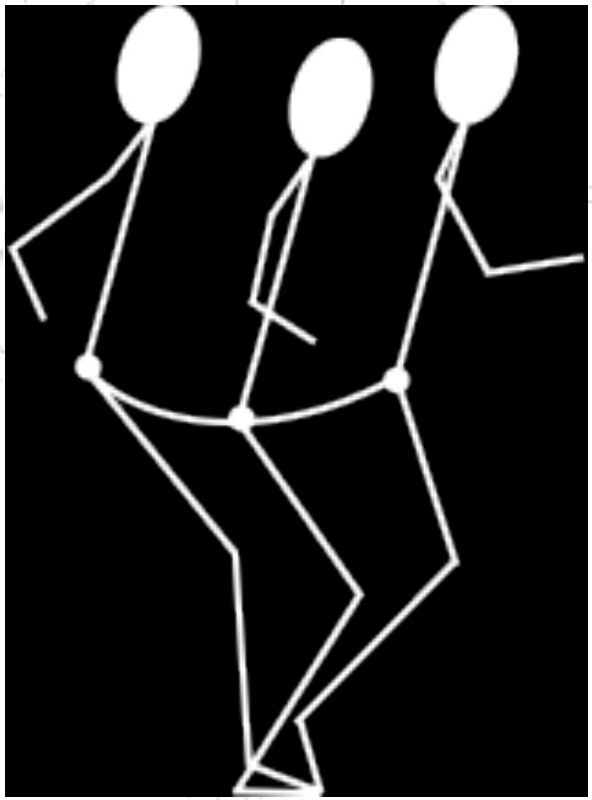
Run: 3.9 m/s



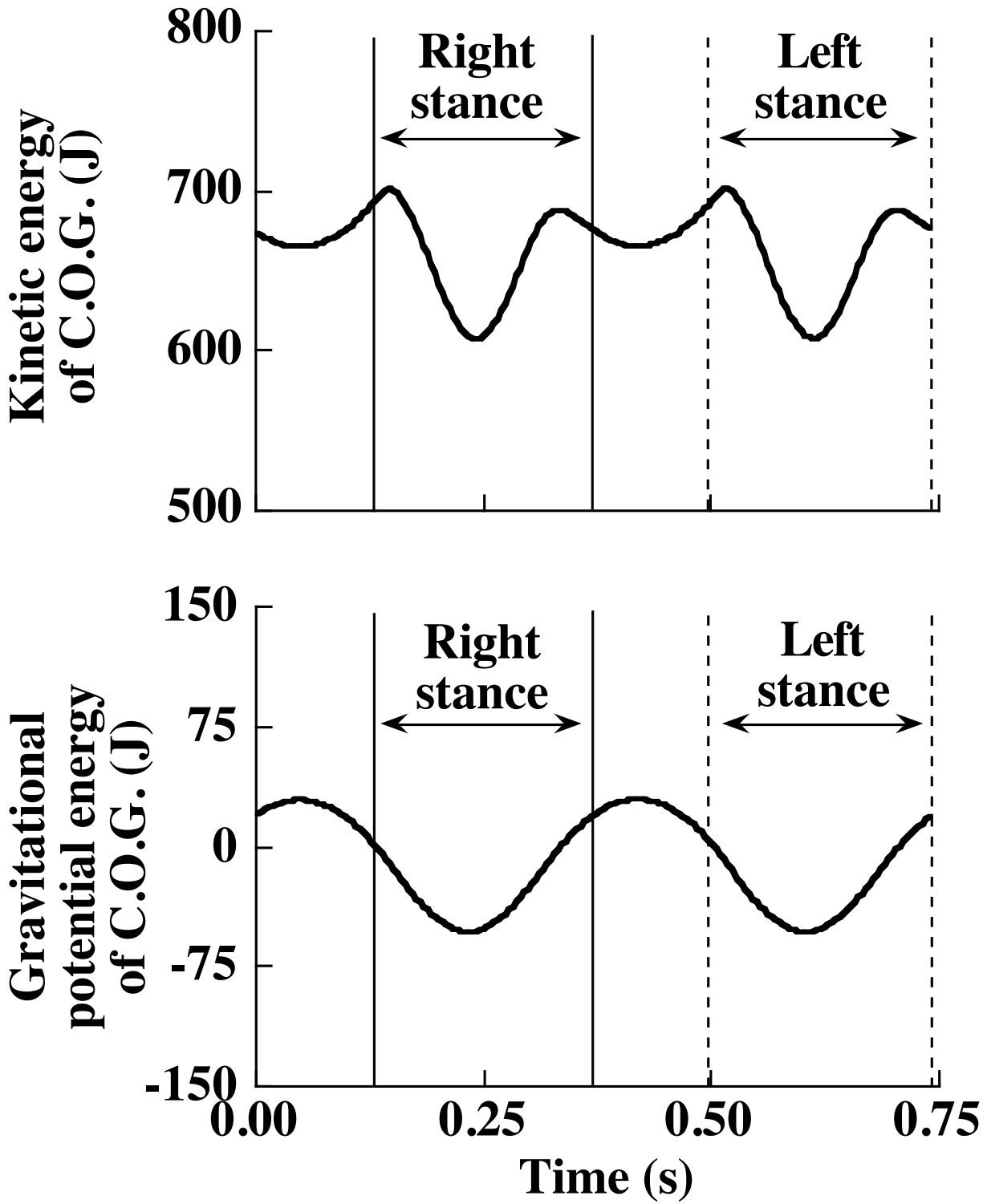

Peak
$F_{g,y}$
(kN)
2
1
0
Run
Walk
0 1 2 3 4 5 6 7
Speed (m / s)

v_x & KE decrease
r_y & GPE decrease

v_x & KE increase
r_y & GPE increase



RUN


800
700
600
500
Kinetic energy of C.O.G. (J)
Right stance
Left stance
150
75
0
-75
-150
Gravitational potential energy of C.O.G. (J)
Right stance
Left stance
0.00
0.25
0.50
0.75
Time (s)

RUN

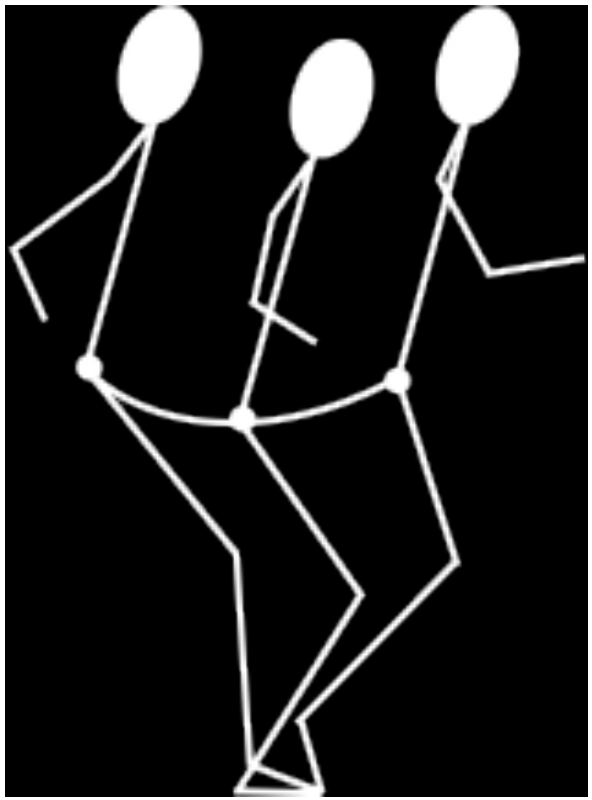
KE (J)

GPE (J)

E_{tot} (J)

Time (s)

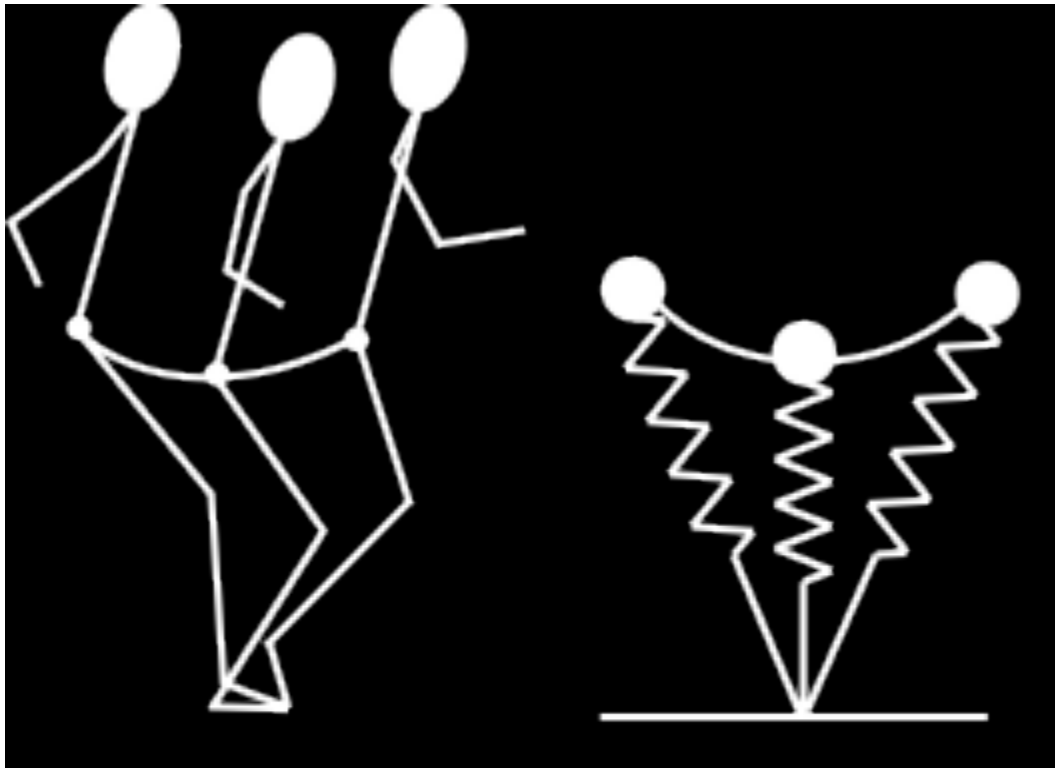
Run



But what about EE?

Run: spring mechanism

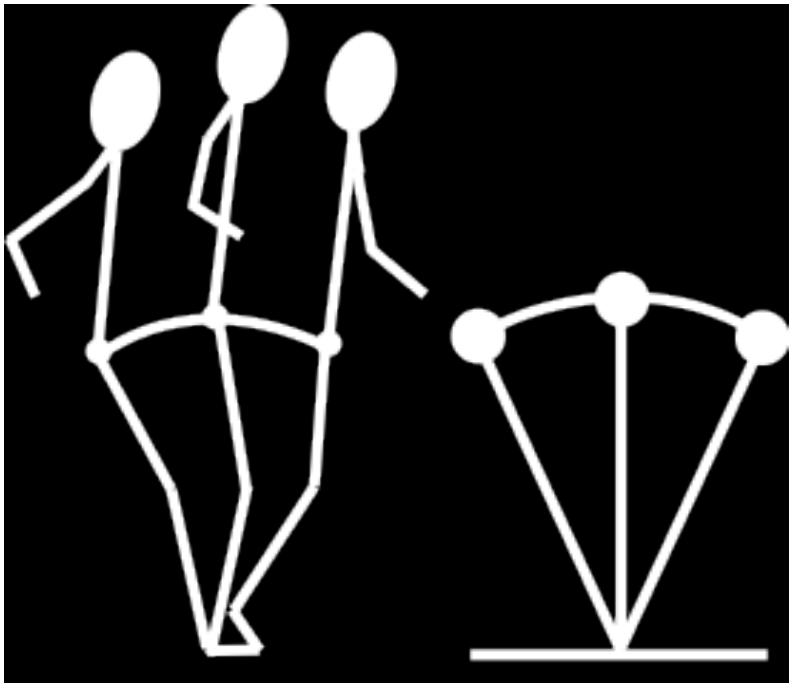
$E_{k,t}$ & $E_{p,g}$ are in phase. Elastic energy is stored in leg.



C.O.M.

Leg (spring)

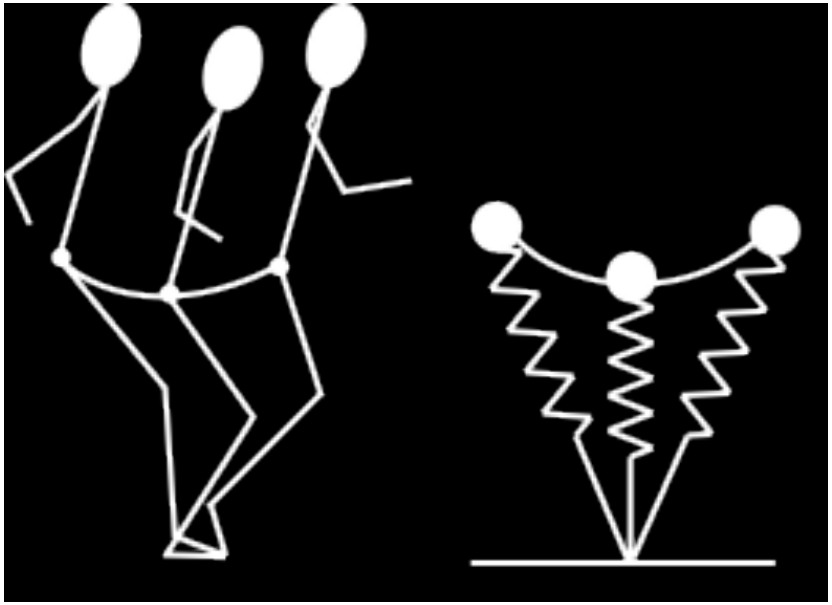
Walk
Inverted pendulum



C.O.M.

Leg

Run
Spring mechanism



C.O.M.

Leg