When Can I Run?

Chris Johnson PT
“I’m going to have to science the s#%! out of this.”
The Biomechanics of Running
Walking

Double Support (10%)

Stance (60%)

Swing (40%)

Loading Response

Midstance

Terminal Stance

Preswing

Initial Swing

Midswing

Terminal Swing

Stride (100%)

Toe Off
40/60
MM MOST ACTIVE...

In anticipation of IC
Just after IC
Sagittal Plane

WALKING > RUNNING
> SPRINTING

Shift into flexion & COM is lowered
MAX HIP EXTENSION

Similar b/w walking, running, & sprinting

Occurs later in the gait cycle
ROM - Foot & Ankle

WHAT CAN WE AGREE ON?

It’s complex :-)

ANKLE HAS TO PROGRESS OVER THE FOOT

~20° DF

Net ankle mobility

Running 50°

Walking 30°

FULL DF OF MTP JTS UNNECESSARY FOR WALKING & RUNNING

<30° of great toe extension potentially problematic

James S & Jones Human Kinetic 1990
Dicharry Clin Sports Med 2010
ROM - Knee

CLOSED CHAIN - 20–45°

OPEN CHAIN - 90–130°

Extends to ~10–20° of full extension @ TS

In sprinting the absorption is shorter & knee flexes less

Novacheck Gait & Posture 1998
Dicharry Clin Sports Med 2010
Pink et al AJSM 1994
Rom - Lumbopelvic-Hip

Hip cycles through flex-ext arc of ~40-60° in recreational runners

Hip flexion ROM ↑ as velocity ↑

Hip can be flexed up to 65° in swing phase & extend to 11°

Hip extension is a coordinated mvmt

Mean trunk flexion angle ranges from 2.4-13°

Mean pelvic A-P tilt angle usually b/w 15-20° of anterior tilt.
Anterior pelvic tilt in normal standing ~11°

Dicharry Clin Sports Med 2010
Schache et al Gait & Posture 1999
Levine & Whittle JOSPT 1996
Pink et al AJSM 1994
Max Knee Flexion

WALKING = 60

RUNNING = 90

SPRINTING = 105

World class sprinters may reach 130
Energy Sources - Walking

- Ankle: 53%
- Hip Ext: 30%
- Hp Flex: 7%
- Knee: 4%
- Hip Abd: 6%
Energy Sources - Sprinting

- Hip Abd: 34%
- Ankle: 14%
- Hip Ext: 25%
- Hip Flex: 3%
- Knee: 24%
Muscular strategy shift in human running:
Dependence of running speed on hip and ankle muscle performance
Mean (±1 s.d) magnitudes of stride length, stride frequency, ground contact time, peak muscle forces and peak muscle contributions to the vertical ground reaction force

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>SPEED 1 3.49±0.12 m s⁻¹ (N=9)</th>
<th>SPEED 2 5.17±0.13 m s⁻¹ (N=9)</th>
<th>SPEED 3 6.96±0.13 m s⁻¹ (N=8)</th>
<th>SPEED 4 8.99±0.67 m s⁻¹ (N=7)</th>
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</thead>
<tbody>
<tr>
<td>Stride Characteristics</td>
<td></td>
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<tr>
<td>Stride Length (m)</td>
<td>2.62±0.10bcd</td>
<td>3.42±0.13abcd</td>
<td>3.99±0.22ab</td>
<td>4.10±0.26abc</td>
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<tr>
<td>Stride Frequency (s⁻¹)</td>
<td>1.31±0.03bcd</td>
<td>1.47±0.05abcd</td>
<td>1.75±0.10ab</td>
<td>2.18±0.10abc</td>
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<tr>
<td>Ground Contact Time (s)</td>
<td>0.243±0.022bcd</td>
<td>0.188±0.015abcd</td>
<td>0.145±0.009abcd</td>
<td>0.118±0.011abcd</td>
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<tr>
<td>Peak Forces Developed by Muscles (BW)</td>
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<tr>
<td>ILPSO (swing)</td>
<td>1.97±0.37bcd</td>
<td>3.49±0.51abcd</td>
<td>5.91±0.98abcd</td>
<td>9.04±1.71abcd</td>
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<tr>
<td>GMAX (swing)</td>
<td>0.38±0.12bcd</td>
<td>0.64±0.17abcd</td>
<td>1.03±0.29abcd</td>
<td>2.22±0.60abcd</td>
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<tr>
<td>HAMS (swing)</td>
<td>2.10±0.38bcd</td>
<td>2.66±0.31abcd</td>
<td>4.61±0.4abcd</td>
<td>8.95±1.66abcd</td>
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<tr>
<td>RF (swing)</td>
<td>0.67±0.06bcd</td>
<td>1.19±0.17abcd</td>
<td>1.81±0.28abcd</td>
<td>2.80±0.39abcd</td>
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<tr>
<td>VAS (stance)</td>
<td>4.70±0.57</td>
<td>5.35±1.21abcd</td>
<td>4.93±0.94</td>
<td>4.89±0.89</td>
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<tr>
<td>GAS (stance)</td>
<td>1.94±0.25bcd</td>
<td>2.65±0.44abc</td>
<td>3.23±0.49ab</td>
<td>2.97±0.34a</td>
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<tr>
<td>SOL (stance)</td>
<td>6.70±0.66bcd</td>
<td>7.92±0.82abcd</td>
<td>8.71±0.83abcd</td>
<td>7.34±0.72abcd</td>
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<tr>
<td>TIBANT (swing)</td>
<td>0.17±0.14bcd</td>
<td>0.22±0.16d</td>
<td>0.31±0.10d</td>
<td>0.50±0.11abcd</td>
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<tr>
<td>Peak Forces Contributions to the Vertical Ground Force</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>VAS</td>
<td>1.12±0.26</td>
<td>1.02±0.29</td>
<td>0.92±0.23</td>
<td>0.74±0.21</td>
</tr>
<tr>
<td>GAS</td>
<td>0.53±0.10bcd</td>
<td>0.73±0.16a</td>
<td>0.81±0.12a</td>
<td>0.74±0.08a</td>
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<tr>
<td>SOL</td>
<td>1.61±0.32bcd</td>
<td>1.98±0.53a</td>
<td>2.40±0.55a</td>
<td>2.30±0.59a</td>
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<tr>
<td>Total Vertical Ground Force</td>
<td>2.71±0.46bcd</td>
<td>3.14±0.55abcd</td>
<td>3.58±0.67ab</td>
<td>3.59±0.71ab</td>
</tr>
</tbody>
</table>
Muscle Forces During Running

GMax
1.5-2.8 BW force

GMed
2.6-3.5 BW force

Hams
2.1-9 BW force

Gastroc
2.5-3.0 BW force

Soleus
6.5-8.0 BW force

Quadriceps
4-6 BW

Conclusions

<7.0 m/s
PFs contribute most sig to vertical support forces & ↑’s in stride length

Near 7.0 m/s
Contractile conditions for these mm deteriorate because of ↑’d shortening velocities

>7.0 m/s
Strategy shifts from ↑’ing stride length to ↑’ing stride f
Achieved by the synergistic actions of the ipsi & contra hip mm
The Propulsive

Plantarflexors

Largely responsible for pushing on ground forcefully during running

Soleus & gastroc combined are responsible for a large portion of GRF

- 49.0% – 62.3% in vertical direction
- Nearly all of the propulsive component in A-P direction
Lower – limb muscular strategies
For increasing running speed
## Running

<table>
<thead>
<tr>
<th>TYPE</th>
<th>M/S</th>
<th>MPH</th>
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</thead>
<tbody>
<tr>
<td>Jogging</td>
<td>2.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Slow Running</td>
<td>3.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Med Running</td>
<td>5.0</td>
<td>11</td>
</tr>
<tr>
<td>Fast Running</td>
<td>7.0</td>
<td>15</td>
</tr>
<tr>
<td>Sprinting</td>
<td>8.0</td>
<td>17.9</td>
</tr>
</tbody>
</table>
Stride Length, m

- 2.06±0.12 with 63% increase
- 3.48±0.06 with 30% increase
- 5.03±0.10
- 6.97±0.09 with 18% increase
- 8.95±0.70 with 2% increase

Running Speed, m/s
Increasing Running Speed

RUNNING SPEED CAN BE ↑’D BY...

- Pushing more forcefully
- Pushing more frequently
- Combination of these 2 strategies
**Steady State VS. Sprinting**

**Steady State**

Lower limbs behave like springs  
No net change in avg mechanical energy

**Accelerating**

Lower limbs function like motors  
Do (+) work to generate power to increase kinetic energy
Running technique is an important component of running economy and performance.
Conclusions

STRIDE PARAMETERS

Lower DF
Shorter GCT
Shorter stride length

LOWER LIMB ANGLES

More vertical shank & plantar-flexed foot @ touchdown
Smaller ROM of the knee and hip during stance

PELVIC MOVEMENT

Minimal braking, vertical oscillation & transverse rotation
Physical Performance Tests (PPTs)

AKA “FUNCTIONAL TESTS”

ASSESS MVMT PATTERNS IN WHICH THE ATHLETE FUNCTIONS

USED TO...

- Identify impairments
- Distinguish b/w injured & healthy athletes
- Establish proportional relationship to symptoms
- Assess return to play readiness
- Refine decision making

LOW IN COST

VALID & RELIABLE

REQUIRE MINIMAL TRAINING TO PERFORM

TIME EFFICIENT


Okada et al, J Strength Cond Res 2011

ARE YOU READY?
Physical Performance Tests (PPTs)

TOE DEXTERTITY
SINGLE LEG STANCE
AIR SQUAT
LATERAL STEP DOWN
CALF RAISE
SIDE PLANK
BRIDGE + SLR
POGO JUMPS
SINGLE LEG HOPPING
PUSH UP PLANK
PPT – Toe Dexterity

Success:
Isolated DF/PP of the great toe & lesser toes as well as splaying
Success: Hold for 20s on each side in a relatively wobble-free manner
Success: Completing 10 full depth squats
Success: Completing 10 reps/side w/o a LOB loss of balance or compensatory strategies while staying in sync to a metronome @ 30bpm
Success: Completing 10 reps/side w/o a LOB loss of balance or compensatory strategies while staying in sync to a metronome @ 30bpm
PPT - Calf
# Calf raise – Normative Values

<table>
<thead>
<tr>
<th>AGE</th>
<th>CALF RAISES</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
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<tr>
<td>20–29</td>
<td>37</td>
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<td>60–69</td>
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<td>70–79</td>
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</tr>
<tr>
<td>80–89</td>
<td>10</td>
<td>13</td>
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</tbody>
</table>

Adapted from Herbert-Losier et al. 2017
**Success:** Holding the position for 30s on each side while maintaining a level pelvis w/o sinking into hip flexion
PPT - Bridge + SLR - HS
PPT - Bridge + SLR Long
**Success:** Hold for 30s on each side w/o letting the hips sink to the ground
Success: Completing pogo jumps to a metronome set @ 150bpm for 1’ while maintaining short GCTs
**Success:** Completing 30s of continuous hopping on each side @ 150bps while maintaining short GCTs w/o using the arms to augment balance
Success: Completing a one-minute hold
Physical performance & clearance considerations for distance runners following injury

1. SINGLE LEG BALANCE
Success: Maintaining single leg balance for 20s on each leg in a relatively wobble-free manner without having to hold one’s breath or resort to the use of the arms to offset any loss of balance. Additionally, the performer should maintain their shoulders and hips square and level.

2. LATERAL STEP DOWN
Success: Completing a minimum of 10 repetitions on each side with no loss of balance or compensatory strategies while staying in sync to the metronome. In competitive runners, the practitioner should also consider increasing the number of reps to 20+ in one minute.

3. CALF/HEEL RAISE
Success:
- <50 y/o: Completing greater than ≥25 repetitions for men and women
- 50-60 y/o: Completing ≥20 reps would be the target
- 60-69 y/o: Completing 15-20 reps
- 70+ y/o: Completing 10-15 reps
*Lastly the test should be stopped if the runner is unable to stay in sync with the metronome or if they cannot reach the peak amplitude at the top of the range.

4. BRIDGE + STRAIGHT LEG RAISE
Success: Holding the bridge + SLR position for 30s on each side while maintaining a level pelvis without allowing the bottom to fall towards the ground or sink into hip flexion.

5. SIDE PLANK
Success:
PART 1: Holding the side plank position with knees straight and legs staggered for one minute on each side without letting the pelvis sink towards the ground.
PART 2: Holding the side plank combined with hip abduction without losing one’s balance or allowing the pelvis to sink towards the ground for 30s on each side.

6. POGO JUMPS
Success: Completing pogo jumps to a metronome set at 150 bpms for one minute while maintaining short GCTs.

7. SINGLE LEG HOPPING
Success: Completing 30s of continuous hopping on each side to a metronome set at 150 bpms while maintaining short GCTs without using the arms to augment balance. For competitive runners, aim for one minute of continuous hopping.

8. RUNNING IN PLACE
Success: Running in place for one minute while maintaining reciprocity of the arms and legs while in sync to a metronome set at 170 bpms.
NOW WHAT?
What's the issue???

FLEXIBILITY

MOBILITY

Structural vs. Incomplete Rehab?

STRENGTH

ENDURANCE

NEUROMOTOR CONTROL

EXPLOSIVENESS

PRIORITIY