Clinical Observational
Gait Analysis

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Gait analysis is often undertaken as part of the physical examination of patients with musculoskeletal related lower limb and lower back symptomology (Barker 2007).
• It can be generally defined as the evaluation of the manner or style of walking, usually done by observing the individual walking naturally in a straight line (Miller-Keen & O’Toole 2003)

• Magee (1997) states that analysis of gait takes ‘a great deal of time, practice, and technical skill combined with standardization for the clinician to develop the necessary skills’.
Richards and Levine (2012) assert the purpose of gait analysis is to be used to ‘make detailed diagnoses and to plan optimal treatment’.

Historically it is proposed that when used in conjunction with patient history and general physical examination, it will aid in diagnosis of musculoskeletal pain, and predict successful treatment of related pathologies (Harris & Wetch 1994; Whittle 1996, 2002)
Some authors state that gait analysis is not only a powerful investigative tool, but even comparable in diagnostic reliability and validity to an X-ray or blood test (Sweeting and Mock, 2007).
Clinical examination of gait in relation to injury is a common occurrence in Podiatric, Physiotherapy, Orthopaedic and general musculoskeletal clinics (and running and walking stores!).
Introduction - Clinical Gait Analysis

• Often with only a small clinical space, plinth and short walkway we are expected to take a history, and then diagnose not only the current injury, but also the aetiological factors linking to this injury.

• A simple inversion sprain may be straightforward, but a lateral ankle pain after 3 miles walking with no history of trauma is less so.
The vast majority of these assessments are conducted by practitioners without immediate access to ‘gait analysis equipment’. Methodology remains vague and varied, with no systematic or standardised process available to observe adult patients' gait.
What if we were to......

- Ask one of you to walk up and down this stage, and we were to all write down our gait analysis.

- What would that show do you think?
Presentation aims

1. To highlight the need for gait analysis in a clinical setting
2. To introduce the lack of normative data and research in this clinical area
3. To use available research, clinical reasoning and possibly even common sense in Clinical Gait Analysis
4. To introduce a clinically valid clinical gait analysis method within the framework of our current knowledge and research base
If we want to know how people walk....why can’t we watch them walk?

Because at the moment that’s not as easy as it seems, but that doesn’t mean it can’t be made to be as simple as it sounds.....
If we want to know how people walk….why can’t we watch them walk?

- There have only been attempts to categorise visual gait patterns by researchers in the physical therapy and surgical communities for neurological disorders such as cerebral palsy, stroke or Parkinson disease (Taro et al, 2007; Roggendorf et al, 2012)

- Each of these assessment tools utilises observing gait markers which link to a particular gait dysfunction related to the specific disease process.
If we want to know how people walk....why can’t we watch them walk?

• Even in this more specifically researched area, Taro et al (2007) state a critical issue is the lack of a standardised method of gait classification.

• There remains no systematic method of locomotion assessment for the general and sporting MSK caseload, even though lower limb function in gait is frequently linked to injury (Chuter et al, 2012; Glazer, 2009; Irving et al, 2007; Barton et al, 2011; Menz et al, 2013)
1. Define and Understand ‘normal Gait’

2. Rationalise Elements of normal gait we can assess

3. Devise a reliable method to assess Gait

4. Possibly link gait findings, or patterns of gait, to injury
How do we walk?

Before understanding ABNORMAL, we must have an understanding of NORMAL.
How do we walk?

What do we (think we) know now?
Normal lower limb function in walking gait

1. The 1\textsuperscript{st} (Heel) Rocker
2. Internal hip rotation with foot pronation
3. The reverse windlass
4. The 2\textsuperscript{nd} (Ankle) Rocker
5. External hip rotation with foot supination
6. The 3\textsuperscript{rd} (Digits) Rocker
7. The Windlass mechanism with medial column propulsion
8. Adequate hip and knee extension for normal posture and swing phase
Normal lower limb function in gait

1. The 1st (Heel) Rocker

2. Internal hip rotation and foot pronation

• The medial longitudinal arch (MLA) lowers and lengthens initially during stance phase of walking gait. The rearfoot everts (pronates) and then inverts (supinates) through a normal stance phase. Eversion occurs for the first 50-60% of the stance phase, followed by inversion (Leardini et al, 2007).

• The hip internally rotates during contact and mid stance and externally rotates throughout the terminal stance phase (Kadaba et al, 1990).
2. Internal hip rotation and foot pronation

- This motion has been proposed to couple with rearfoot complex pronation and supination, with pronation linked to internal rotation of the lower limb and supination with external rotation (Souza et al, 2010).
Normal lower limb function in gait

3. The reverse windlass

Supination raises and shortens the arch

Pronation lowers and lengthens the arch
3. The reverse windlass

As the arch lowers it becomes longer and the plantar structures (in this example the plantar fascia) become more taut. This in turn applies a compressive force longitudinally.
Normal lower limb function in gait

4. The 2\textsuperscript{nd} (Ankle) Rocker
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- The ankle is the 2\textsuperscript{nd} rocker, used as the body progresses over the weightbearing limb.

- Motion of the ankle in gait is predominantly in the sagittal plane, consisting initially of plantarflexion, then dorsiflexion (the ‘second rocker’), and then plantar flexion again.

- In swing phase, the ankle dorsiflexes to ensure ground clearance of the swing limb.
5. External hip rotation and foot supination

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6. The 3rd (Digits) Rocker

- Dorsiflexion of the digits provides this third rocker, allowing the foot to pivot correctly and the lower limb to obtain normal hip and knee extension.
7. The Windlass mechanism with medial column propulsion

- Enough weight needs to pass medially through the foot to dorsiflex the hallux, and wind the windlass at heel lift. This increased tension in the medial and central bands of the plantar fascia maintains midfoot stability through the propulsive phase of gait (Harradine and Bevan, 2009)
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8. Adequate knee extension for normal posture and swing phase

- The knee is extended at heel strike, flexed during loading response and reaches the first flexion peak during early midstance.

- Thereafter, the knee begins to extend until about 40% of stance phase and remains slightly hyperextended (average 3.5°) throughout the remaining midstance.

- Approximately halfway through the terminal stance the knee flexes again and the flexion continued throughout the pre-swing and peaked at toeoff when the stance phase ended. (Kozanek et al, 2009. Lafortune et al, 1992)
8. Adequate hip extension for normal posture and swing phase

- The total range of motion is around 20-30 degrees, with contact phase flexion being approximately 10-15 degrees and maximum extension approximately 10-15 degrees also.

- This is measured from vertical to the floor, with half of this motion being stated to come from the hip itself, the other from a combination of pelvic rotation and anterior pelvic tilt (Bergmann et al, 2001. Foucher et al, 2012)
8. AND the Lower back and Pelvis

- There is a large range of reported normal motion occurring in the back and pelvis in the asymptomatic population. There appears to be a general consensus on inclination of the trunk in the sagittal plane, a lateroflexion on each side per cycle in the frontal plane and a phase opposition between higher and lower trunk rotations in the horizontal plane. (Callaghan et al, 1999; Feipel et al, 2001; Lamoth et al, 2002; Ceccato et al, 2009)
Normal ‘lower limb’ function in gait

8. AND the Upper Limb!

- The arm at the shoulder flexes and extends during each stride. Maximum extension is reached during ipsilateral heel contact, and peak flexion occurs with contralateral initial contact (Murray et al, 1967).

- Although considerable variation occurs amongst individuals, Perry and Burnfield (2010) quote Murray et al's (1967) previous work that during moderate walking speed the average arc of motion is 32 degrees. A normal amount of extension to be 24 degrees and flexion to be 8 degrees. Faster walking increases the total arc of motion (Murray et al, 1967)
Meynes et al (2013) concluded in a thorough literature review that arm swing should be seen as an integral part of human bipedal gait, and that arm swinging during normal bipedal gait most likely serves to reduce energy expenditure.
1. The 1\textsuperscript{st} (Heel) Rocker
2. Internal hip rotation with foot pronation
3. The reverse windlass
4. The 2\textsuperscript{nd} (Ankle) Rocker
5. External hip rotation with foot supination
6. The 3\textsuperscript{rd} (Digits) Rocker
7. The Windlass mechanism with medial column propulsion
8. Adequate hip and knee extension for normal posture and swing phase
1. The digits

- Limitation of 1\textsuperscript{st} MTPJ dorsiflexion will prevent the windlass mechanism from occurring, increasing the trend of STJ pronation, rather than the required supination at this time. (Harradine et al, 2006 & 2009)

- For the windlass to function effectively, dorsiflexion of the hallux via medial column propulsion must occur. If a limitation of 1\textsuperscript{st} MTPJ dorsiflexion is present, whether structural or functional, a lack of windlass mechanism may arise with resultant compensatory outcomes. (Durrant & Chockalingam, 2009)
1. The digits – Pronation limits hallux dorsiflexion
1. The digits

- Visually several compensatory mechanisms may be observed, such as reduced Knee and hip extension due to the inability to engage medial column propulsion at the 3rd rocker, and increased pronation due to failure of the windlass mechanism (Harradine & Bevan 2009; Dananberg 1993).
2. The Foot

- If supination moments resisting STJ pronation (and so arch lowering) are not of adequate magnitude, abnormal pronation may occur.

Inverted see-saw analogy (Harradine et al, 2009)
2. The Foot

- In relation to the ground, the leg normally externally rotates and applies supinatory moment to the STJ from midstance. For the leg to externally rotate the foot must supinate, and so the supinatory moment must be greater than the pronatory moment across the STJ. If there is a lack of applied supinatory moments or increased pronatory moments this may not occur.

- The leg may remain internally rotated, and visually the rearfoot fails to resupinate. (Harradine and Bevan, 2009; Harradine et al, 2006)
2. The Foot

- In addition, an abnormally supinated foot may invert at heel strike couple with external hip rotation, when a normal parameter at this time would be eversion with internal hip rotation.

- Causative factors for this abnormal amount of supination include a laterally deviated subtalar joint axis (Kirby, 1997) and a weak peroneal muscle group (Rosenbaum, 2013)
3. The Ankle

- Can result in an early heel raise or compensatory mechanisms seen for limited mobility at the ankle, such as resultant pronation with equinus (Evans & Catanzariti, 2014).
4. The Knee

- Normally, the knee extends until about 40% of stance phase and remained in slight hyperextension (average 3.5°) throughout midstance (Lafortune et al, 1992; Kozanek et al, 2009)

- A lack of full extension here may be due to a failure of the 3rd rocker of the foot, but also more intrinsic issues such as a fixed knee flexion deformity. A clinical static assessment would help detect or exclude this finding.
5. The Hip

• The lower limb (and so the hip and knee) internally rotates during contact and mid stance and externally rotates throughout the terminal stance phase (Kadaba et al, 1990; Benedetti et al, 1998; Nester, 2000).

• Increased internal rotation moment via foot pronation (Nester, 2000; Carter and Harradine, 2006; Harradine et al, 2009) or weak lateral rotators (Bowling et al, 2009; Snyder et al, 2009; Souza et al, 2010) or a combination of both may lead to abnormal transverse plane hip motion / position.
5. The Hip

- Adequate hip (and also knee) extension has been cited as a crucial occurrence for normal walking gait. (Dananberg 1993; Harradine et al, 2006; Harradine and Bevan 2009; Perry and Burnfield, 2010. )

- Hip extension can be limited via intrinsic factors (tight hip flexors, Osteoarthritis), a limitation to the 3rd Rocker of the foot (FnHL, Hallux Valgus, Hallux rigidus) and footwear (Solid footwear with no forefoot rocker)
6. The Lower back and Pelvis

- A functionally weaker gluteal complex leads to increased motion of the pelvis in the frontal plane, but also has the effect of increasing pronation (Souza et al, 2010; Carter and Harradine, 2003; Leetun et al, 2004; Elphiston, 2008; Chuter 2012; Danaberg, 1993).

- An inability to use the 3rd rocker can lead to excessive pelvic rotation.
6. The Lower back and Pelvis

- Frontal plane trunk bending, or a ‘side sway’, has been cited as a demonstration of abnormal gait (Dananberg, 1993). Patients demonstrate this via trunk bending from the ipsilateral restricted side to the contralateral side at ipsilateral toe off. It is described as a process to ‘drag’ the trailing limb into a swing phase.

- This compensatory mechanism permits hip extension over a foot with a limited ability to function as a pivot, such as a lack of ankle or hallux dorsiflexion.
7. The Upper Limb

Abnormal

• Due to the lack of research and range or normal values, assessing arm swing theoretically assumes the better the arm swing, the more efficient and normal gait will be. Due to fascial attachments of the upper to lower limb and theory on these working together to increase efficiency and stability of gait (DeRosa and Porterfield, 2007; Gracovetsky, 1988; Yizhar et al, 2009) there may be a correlation between a lack of hip extension and reduced arm swing

• Arm swing would therefore not be expected to decrease following treatment provided to ‘improve gait’.
But, how can we use this knowledge **clinically**?
Putting it all together... when we assess Gait we look at:

1. Head Position
2. Arm Swing
3. Lower Back and Pelvis
4. Hip
5. Knee
6. Foot and Ankle
Putting it all together

1. Head Position
2. Arm Swing
3. Lower Back and Pelvis
4. Hip
5. Knee
6. Foot and Ankle

- This is all very well... but what are we actually looking for.
- Can we look for specific gait patterns in the adult MSK injury population.
- And if so, can we be reliable in their assessment.
- And would it be valid?
“Pronation Patterns of Gait”

1. Excessive Pelvic Rotation
2. Vertical Heel Lift
3. Lack of Hip and Knee Extension
4. Reduced Arm swing
5. Abductory Twist
6. Lateral Pronation
7. Lack of resupination
8. Side sway

These ‘patterns’ link into abnormal internal rotation (or lack of external lower limb rotation) and functional limitation of the 1st MTPJ.
Pronation patter gait dysfunction examples

- excessive pelvic rotation
- flattened lordosis
- lack of hip extension
- vertical heel lift
- Abductory twist
- MTJ Dorsiflexion
- 1st IPJ Dorsiflexion
- lateral column propulsion side sway
- Side sway
Pronation pattern gait dysfunction examples

- excessive pelvic rotation
- flattened lordosis
- lack of hip extension
- vertical heel lift
- Abductory twist
- MTJ Dorsiflexion
- 1st IPJ Dorsiflexion
- lateral column propulsion (Bevan and Harradine 2004)
- side sway
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- 1st IPJ Dorsiflexion
- lateral column propulsion
- side sway
Supination Patterns of Gait

1. Lack of Pronation at contact phase
2. Reduced Hip and knee extension
3. Lateral Propulsion

These ‘patterns’ would link into a lack of internal lower limb rotation and an inability to use the medial column of the foot due to an inverted foot posture.
Is there a way of taking this further, into a systematic gait analysis tool?

Aims would be:

1. Construct a clinical tool / scoring system
2. Research its validity and sensitivity
3. Research its reliability in all clinical setting with all practitioners
But wait....what about running?!?!
In general, runners who exhibit greater foot pronation also:

1. Have greater extent of internal tibial torsion
2. Have significantly greater extent of velocity of knee flexion and pronation.
3. Have significantly greater knee flexion.

But is that the same in distance running and sprinting, what about forefoot strikers, what about running with a ball...!?