Performance & Motor Control
Characteristics of Functional Skills

Part II: Control and Development of Locomotion Skills
Things to Keep in Mind

1) Direction of development
   Proximodistal direction
   Cephalocaudal direction

2) Differentiation, that is, progression from gross, immature movement to precise, well-controlled, intentional movement.

3) Integration, that is, the human is more capable of integrating processes (become coordinated) to produce functional motor and sport skills.

Lastly, the differentiation, and integration (coordination) all regress with age.
Locomotion presentation

Postural Control of Stability
Head Stability & Locomotion
Development of locomotion
  • Walking
  • Running
Rhythmic nature of locomotion
Gait transition
Vision & locomotion
  • Contacting & avoiding objects
  • Tau
Development of Postural Control Stability

Emerging Head Control
- At 2 mos Neck muscles can control the head
- Development of visual system contributes to head control

Emerging Independent Sitting
- Takes about 8 mos to be able to control the neck & Trunk
- Development of visual and vestibular system contributes to independent sitting but mostly vision

Transition to Independent Stance
- Need to be able to balance and strength in legs and thigh (contribution strength makes)
- Early on Vision should be contributing greatly to one’s independent stance but once it is attained we then switch to somatosensory information

Quiet Stance
Quiet Stance

• From the ages 2 to 14 years of age, swayng declines
• Two types of sway:
  – Eye closer swaying
  – Open eye swaying
• Children reach adult levels
  - by 9 – 12 years of age in eye open
  - By 12 – 15 in eyes closed
Stability Control

• Children studies with a moveable platform or moving walls found
  – Slower muscle responses, and
  – More rapid rates of sways when the platform moved to that of adults

• Children 1.5 to 3 years of age produced well organized muscle responses to postural perturbations while standing but from ages 4 to 6 they declined.
  – Why?

• By the time they are 7 they regain all that was lost in stability during 4 – 6 and in up right static posture
Head Stability & Locomotion

Head stability is key factor of the Gait.

The head contains the sensory and motor nervous system components that helps us navigate through an environment and in maintaining one posture.

Maintaining a stable head during locomotion optimizes the use of vision so we can tracking a ball, catch an object, and avoiding objects.

Adults with neurological impairment adopt an abnormal posture and gait as a means to maintain head stability (Holt, et al., 1995) such as Parkinson’s disease.
Recently published article in the Journal of Vestibular Research involved 17 adults over the age of 69.
- They walked with their eye open (EO)
- They walked with their eye closed (EC)
- They walked with fixed eye gaze (FG).

Head stability was measured via infrared camera.
- What head-on-trunk strategies did these older adults use to maintain their upright walking ability (velocity and cadence)?
  - In EO condition, the subjects had head stability (control condition)
  - In FC the subjects had poor head stability resulting in slower velocity and fewer steps
  - In FG the subjects had the greatest head stability with increased walking ability
Development of Locomotion

People put too much emphasis on the emergence of upright independent walking.

People assume that if the child walks sooner, he or she is advanced in their motor development. This notion has not been proven.

Let’s examine the stages one take in developing an upright independent walk and various related motor control issues.
Development of the Upright Independent Walking

We need to first understand the acquisition of voluntary starts with head movements.
- **1 month** of age little or not control
- **2 months** elevates the head when phone with effort
- **3 months** positions head left to right or right to left when prone
- **5 months** elevates head when spine

Control of the head enables infants to scan their surroundings.
Head Control

Little or no control of the head. The head and neck needs to be supported by the child care giver.
Head Control

2 months
Head Control

When the baby can raise the head while lying on his back. The baby will be strong enough to hold up his head while sitting in a car seat or front pack. Wait until he can hold his head up steadily without any support from you to use a jogging stroller or a backpack.

2–3 months
Head Control

By 5 months the child should be able to control their head. At 5 months the child can raise their head when in the supine position (lying on one’s back).
Development of the Upright Independent Walking

Once the child has the ability to elevate their chest and head, the child has gained some control of their arms, hands, and fingers.

Once the chest can be elevated the child will attempt to roll from a supine position to a prone position. This is important because it enables the child to attain a proper position for crawling.
Development of the Upright Independent Gait

Upright independent sitting is an important milestone. It frees the hands so the child can reach, grasp, and release objects.

For early sitting to occur one must support the lower back and abdomen.

By 5 months the lumbar control has stabilized and the child can hold an external object.

By 8 months the child has gained sufficient movement ability to set independently without assistance.
Development of the Upright Independent Gait

6-7 months
Development of the Upright Independent Walking

Self-support sitting is associated with eye-hand coordination (Rohart, 1992). Upright posture will follow self-support sitting. Following skills will then emerge:

- ability to pull their body from a sitting to standing position
- period of experimental standing with the aid of external objects such as a chair or furniture
- Standing position will be characterized with a high arm carriage and wide base of support.
Development of the Upright Independent Gait
Development of the Upright Independent Gait

Being able to position the body so one can move from one location to another occurs is a predictable progression:

First Crawling
- emerges around 7 to 8 months of age
- involves thrusting the arms forward and then flexing so they drag their body along the surface

Then Creeping
- is elevated crawling with the only the arms and knees.
- contralateral (limbs in opposition) or homolateral (limbs on the same side moving in the direction).
Development of the Upright Independent Gait

8-10 months
Development of Upright Independent Walking

1. **7-10 months** - Walk with assistance
2. **11 months** – Walk by being led
3. **12 months** – Walking independently

Children who have smaller bones or linear frames walk somewhat earlier than large boned or large framed children.

Keys to developing walking is lateral stability. Heel strike and ground reaction forces pattern of walking similar to that of an adult occurs between 2-3 years of age.
Stages of Upright Walking

7 months

10 months
Stages of Upright Walking

11 months
Stages of Upright Walking
Walking

Progressive alternation of leading legs and continuous contact with the supporting surface.

In evaluating one walk, the walking cycle or gait cycle needs to involve to two phases:

- Swing phase
- Support phase
Development of the Upright Independent Gait

When the child begins to walk:
- the arms have a high carriage
- very wide base of support
- knees are in the flexed position
- toes pointed out
- length of strides are highly inconsistent.
- lateral stability is poor
Interesting Facts

Walking solo typically begins between 9 and 17 months of age.

As balance improves, the base of support narrows.

Degree of toe-out deceases as we become more efficient.

Toe-in foot angle is considered to be always abnormal.

Until one gains sufficient neuromuscular control, he or she will take more steps per unit of time to increase walking speed.
Walking

• http://highered.mcgraw-hill.com/sites/0073523623/student_view0/video_clips.html
Walking Criteria

Teachable Points
1. Head is up and eyes looking in the direction of walking
2. Body and limbs move in a straight line in the direction of the movement
3. Feet are straight when in contact with the ground
4. Arms are slightly bent at the elbow
5. Hands are relaxed.
6. Arms drive actively in opposition to the swinging leg.
7. Child or adult lands on the heel, then moves up onto the toes.

Walking Faults
1. Steps taken are too short.
2. Feet turned too far outward.
3. Walking on toes instead of heel-toe movement.
4. Landing too heavily.
5. Arms not moving in opposition to the legs.
6. Hands clenched in a fist.
7. Head moving and the eyes not facing forward.
8. Jerky walking action
9. Wide base of support
10. Lateral movement from side to side
11. High arm carriage
12. Little hip flexion
Running

Has a period of flight when neither foot is touching the ground.

The patient or child needs lower limb strength both to propel themselves through the air and to when the foot strikes the ground.
Run

Consists of three phases:
1. The support phase
2. The flight phase
3. The recovery phase
Interesting Fact About Running

Boys run faster than girls at all ages.
Girls running speed peaks at 14 to 15 years of age where as boys running speed continues beyond 17 years of age.

Children exhibit minimal running form 6 to 12 months after the onset of solo walking.

*Insufficient hip flexion* causes the thigh from forming a right angle with the body’s trunk.
Running

- http://highered.mcgraw-hill.com/sites/0073523623/student_view0/video_clips.html#
Running

Teachable Points
1. Head remains up, with eyes looking forward in the direction of the movement.
2. Feet and legs move in a straight line in the direction of movement.
3. Arms are bent 90 degrees at the elbow.
4. Arms drive actively in opposition to the legs.
5. Knee lift is close to right angles during the recovery phase.
6. Both feet are off the ground for a brief time.
7. Body is leaning slightly forward.

Running Faults
1. Poor drive and push off the forefoot.
2. Length of the step is too small.
3. Legs and arms not moving straight forward, but outward, or across the body, causing too much upper body movement.
4. Flat-footed running
5. The foot being placed on the ground pointing outward.
6. Non-support leg does not flex sufficiently toward the buttock; therefore the knee lift becomes too low.
7. Trunk too upright or too far forward.
8. The arms are not flexed enough.
9. Arms not moving in opposition to the legs.
10. Head moving and eyes not facing forward.
Motor Control of Upright Independent Gait 
(Walking & Running)

Central pattern generators in the spinal cord controls human gait. Evidence is found:

- Decerebrated cats (severing the spinal cord from the brain) can still walk and perform locomotion rhythmic muscular activity (Sherrington, 1906).
- Spinal cord plays a significant role in control of locomotion
Rhythmic Structure of Locomotion

Between the arms and legs due to walking speed.
- 2:1 ratio (two arms swing to each leg stride) exists for slow walking and pelvis and thorax move as one.
- 1:1 ratio exists for fast walking but pelvis and thorax are independent in fast walking.

Knowing that distinct rhythmic relationship exist is important in measuring locomotion coordination:
- problem in Parkinson’s disease patients
- determine the effectiveness of reconstructive knee surgery.
- patients with have ACL surgery walking phase is greatly altered due to segments of the leg have been changed.
- post stroke patients need for treadmill walking retraining to move both their arms and legs.
Gait Transitions

Walk to run or run to walk transitions occur at different speeds.

These changes are spontaneous transitions but they vary between people. Why?

It is not due to physical limitations. The spontaneous transition occurs at a speed where we minimize metabolic energy consumption (VO2).

This assumption has not been totally supported but spontaneous transition remains a puzzle for researchers to solve.
Vision & Locomotion

• Contacting an object

• Avoiding contact with an object
What type of information is being used?

• Optical variable tau is Time to contact or distance based information

• Tau is amount of time remaining until the object contacts the person (or vice versa) from a specific distance.

• Tau is predictive function which allows action initiation and object contact to occur automatically at a specific time to contact regardless of the speed of the object and person.

  – E.g. breaking to avoid hitting a car……process time needed by visual information to brake rather than knowledge of how much distance there is between you and oncoming car.
Vision & Contacting Objects

As you walk rapidly down a hallway attempt to make contact with a target placed on the floor.

1) Visional information is used to determine the amount of time it will take to contact the target (time to contact)

2) Time to contact is used to make stride-length adjustments during the last few steps to correct any errors.

3) Time contract is a quality we possess that is not dependent on experience.
First phase of the run-up the stride length correction occurs while the jumper is accelerating followed by a zeroing-in phase where the jumper changes stride pattern to eliminate errors.

**Long Jump Study**

![Graph showing stride length vs. stride number before take-off](image)

Lee, Leshman, Thomson, 1982
Avoiding Objects As we walk

- If one is to maintain foot speed while avoiding an object three time periods are critical
  - Recognize that an object needs to be avoided*
  - Adjust the foot
  - Turn the foot to avoid the obstacle

*The most critical period is recognizing the object that needs to be avoided

*Training implication is a person must recognize objects sufficiently early to allow appropriate movement adjustments.
End of Part II