Motor control & Learning
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Motor control theories

- Reflex theory
  - Reflexes are the building blocks of complex movements, basic reflexes chained together to produce movement
- Hierarchical theory
  - Motor control that emerges from reflexes and is controlled by a hierarchical CNS

Motor control theories

- Motor programming
  - Reflexes alone are not the driver for movement
  - Central pattern generators CPG (spinal level programs) can produce movement in isolation
  - Two ideas are connected using this terminology
    - Central Pattern Generators producing hardwired rhythmic movement
    - Abstract higher level CNS motor program that provides a modifiable movement framework which sensory feedback can influence to produce task specific actions

Motor control theories

- Systems
  - Hierarchical CNS process, drives muscle synergies to work together to control the body’s degrees of freedom
  - Considers internal & external forces
  - The same command can lead to different motor outcome based on forces placed on the body or the body position

Motor control theories

- Dynamical action theory
  - Movement can emerge without CNS master control
  - Control parameters, such as velocity dictate system change
    - Attractor states or common patterns of movement will be the norm unless a control parameter changes
    - Attractor wells are the norms of movements, the depth of the well determines the flexibility of the patterns of movement & the ease of change

Motor control theories summary

- One theory does not explain the complexity and adaptability of human movement
- Taking elements from each may better explain movement
- Motor programming has a good support to explain CNS driven movement
- Dynamical action and systems theory have been able to share some ideas to provide a clear view of the mechanical properties and the nervous system interaction with the variability of movement
- Theories are not necessarily right or wrong, but it is how useful they are in practically providing solutions
Movement interaction factors

- Movement most likely develops from an interaction between the task, individual and environment
- The individual generates movement that is task and environmental specialised
- The ability of the individual to generate movement within the context of the environment and specific task requirements will dictate the person's functional capacity
- Looking at movement without considering all of these factors limits the use of the information

Factors that contribute to movement

- Task
  - Mobility
  - Stability
  - Manipulation
- Individual
  - Cognition
  - Perception
  - Action
- Environment
  - Regulatory
  - Non-regulatory

Individual factors

- Action
  - Output of the nervous system to muscles to create movement, each muscle and joint adds to the degrees of freedom the nervous must control
- Perception
  - Integration of sensory feedback to form vital information about the body's position, forces effecting it and the interaction with the environment
- Cognition
  - Thoughts are not separate from movement, cognitive processes such as attention, motivation and emotional will modify the quality of your movement

Task factors

- Mobility
  - Unstable base of support
    - (walking or any upright movement/exercise)
- Stability
  - Stable base of support
    - (sitting or seated exercise)
- Manipulation
  - The greater the speed and accuracy required the higher the manipulation demand
    - (mostly upper limb control e.g. catching)

Environmental factors

- Regulatory
  - Factors that the movement has to conform to complete the task
  - Examples are, the surface we walk on, the weight & shape of objects we manipulate
- Non-regulatory
  - Factors that the movement does not have to conform to complete the task
  - Examples are, background noise, anything that distracts your attention

Classifications of movement

- Discrete tasks
  - Tasks that have a clear beginning and end
    - (kicking or throwing)
- Continuous
  - Tasks that appear to done in a continuous cycle
    - (walking, cycling or running)
- Closed tasks
  - Performed in a fixed environment, typically habitual with low variability of performance
    - (golf)
- Open tasks
  - Tasks that require an interaction with the environment, typically have large variability & flexibility
    - (any team sport like football)
Classifications of movement

- Closed loop movements
  - Movements that can be modified by sensory feedback from the environment
    - (arm wrestle)

- Open loop movements
  - Movements that cannot be modified by sensory feedback from the environment
    - (baseball bat swing)

How do use all this motor control information?

- Needs analysis
  - If you can classify movement you can develop a strategy to teach & optimise exercise prescription
  - If you identify the skill is discrete, closed task & open loop this will drive exercise choice & practice variables to reflect the movement
    - Using golf as an example
    - Distributed practice (breaks) & constant practice

- Posture assessment
  - How we move has implications for observable posture
  - Exercise prescription
    - You should endeavour to replicate the type of movement and environment in your exercise prescription

How do use all this motor control information?

- Give personal trainers context about how the body moves and interacts with the environment
  - If you know how the body develops movement, then the process of exercise choice & variables is more clearly defined

- Describes the importance of thoughts in observable movement
  - PT should be aware that the quality of movement can be influenced by attention, motivation & emotion. This is transitional and exercise choice or variables can be modified to suit the session requirements

What is Motor Learning

- Learning is a process of acquiring skilled actions
  - It can be re-learning a movement or a new movement

- Results from practice and experience
  - PT’s can modify types of training, practice conditions & feedback to optimise motor learning

What is Motor Learning

- Motor learning cannot be measured directly, expressed by observable behaviour only
  - Remember that fatigue, anxiety & motivation will have an influence on movement

- Behaviour changes have to be relatively long-term to be considered learning
  - We can demonstrate skill proficiency in practice, but in reality transfer of skills to a new environment or different movement conditions will show useful movement learning

Motor Learning theories

- Schmidt’s Schema Theory
  - Linked with the generalised motor program theory of motor control, people have recognition & recall schemas
  - Learning takes place by variability of movement, producing new feedback of which updates recognition & recall schemas that the motor program draws relative timing and force of classes of movements for further movement production
Types of practice

- Massed practice
  - (high repetition practice within session with few breaks)
- Distributed practice
  - (less or equal exercise practice than rest in a session)
- Constant practice
  - (movement specific practice only in the session)
- Variable practice
  - (varied types of movement patterns within session)
- Random practice
  - (random exercise order and type within the session)
- Blocked practice
  - (simple to complex exercise order within the session)

Feedback

- Intrinsic feedback
  - (bodies sensory feedback of movement accuracy, closeness to a throwing target)
- Extrinsic feedback
  - (Feedback from PT, can be verbal or physical guidance)
  - Can be during exercise or after exercise
- Knowledge of results
  - (Accuracy of movement outcome, e.g. in or out tennis shot)
- Knowledge of performance
  - (PT gives feedback about quality of movement used in the exercise)

How does it all come together

- Feedback:
  - Extrinsic feedback can be given in form of manual guidance or verbal
  - Initially manual feedback can be used, but quickly move to post exercise verbal feedback of movement results
- Simple tasks such as isolated single joint exercise
  - Knowledge of results feedback from PT every 15 repetitions
- Complex tasks such as timing a bat swing
  - Knowledge of results feedback from PT every 5 repetitions
  - Can have a longer delay, but don’t do more exercise between

General advice

- Let the client use intrinsic feedback to find movement solutions
  - Don’t jump in and give feedback constantly
- Transfer effects are greatest when movement is variable or random with a medium level of feedback
Biomechanics

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Forces the body has to deal with

- Forces that effect movement
  - Contact
    - Ground reaction force
    - Joint reaction force
  - Friction
  - Fluid resistance
  - Inertial
  - Muscle force
  - Elastic force
- Noncontact (gravity)

Traditional Biomechanics

- Levers
  - First class: Atlanto-occipital (skull on vertebrae)
  - This common with agonist and antagonist muscles on each side of a joint
  - Second class: Triceps surae? (ankle plantar flexion)
  - Mainly muscles loaded eccentrically by gravity, not very common in body
  - Third class: Biceps (elbow flexion)
  - Most common in the body
- Conclusions
  - Our anatomy has not developed for great force through leverage, we sacrifice leverage for moving the distal end of our limbs through space and speed of movement.
  - This model does not explain all movement it has some limitations, due the strength of biological structures found in the Human body.

Tensegrity

- Another way to look at Human movement is to view the bones as compression structures and the soft tissues of connective tissue and muscles as tension structures.
  - If we use this truss model and say that soft tissues provide continuous tension and bones provide discontinuous compression
  - How does this help to explain Human movement
    - Better explains the integrated nature of the body, dynamic interplay between segments and spring nature of soft tissues to help with economy of movement

Cellular Tensegrity

- Cell structures appear to utilise a tensegrity model, and mechanical stress could play a role in communication and modification of cells.
- Difficult to say whether there is a transfer always between micro and macro organisation, but certainly physical stress plays a major role in macro organism modification.

Bone tissue response

- Physical activity & bone remodelling
  - Bone tissue is highly adaptive and is sensitive to activity
  - Anisotropic and Viscoelastic characteristics
  - Osteoporosis is when bone breakdown exceeds new deposits
  - Medium to high intensity impacts facilitate bone adaptation
- Types of bone loads
  - Compression
  - Tension
  - Shear
  - Torsion
  - Bending
What effects the way we move?

- Factors influencing motion
  - Neurological drive (number of motor units & firing frequency)
  - Length-tension relationships
  - Force-velocity relationships
  - Muscle cross-sectional area
  - Moment arm
  - Effective line of pull of muscle

How exercise variables work

- Increasing volume
  - Including sets, repetitions and frequency
  - (total energy)
- Increasing intensity
  - Weight and speed of movement
  - (force velocity relationship & moment arm)
- Increasing distance of weight from body
  - (moment arm)
- Increasing complexity of movement
  - Tri-planar integrated exercises
  - (inertia and stretch shortening cycle)
- Increasing ROM
  - (inertia and moment arm)
- Changing joint position
  - (line of pull of muscle attachment)

Stretch shortening cycle

- Stretch shortening cycle
- What increases force output during stretch-shortening cycle & neural contributions
  - Pre-stretch neural reflex loop increasing force output by 25-30%
  - Elastic energy stored within the muscle, connective tissues and tendon provides 70% of the force output