Strength Training Programme Design In Physiotherapy Practice: What You Need To Know

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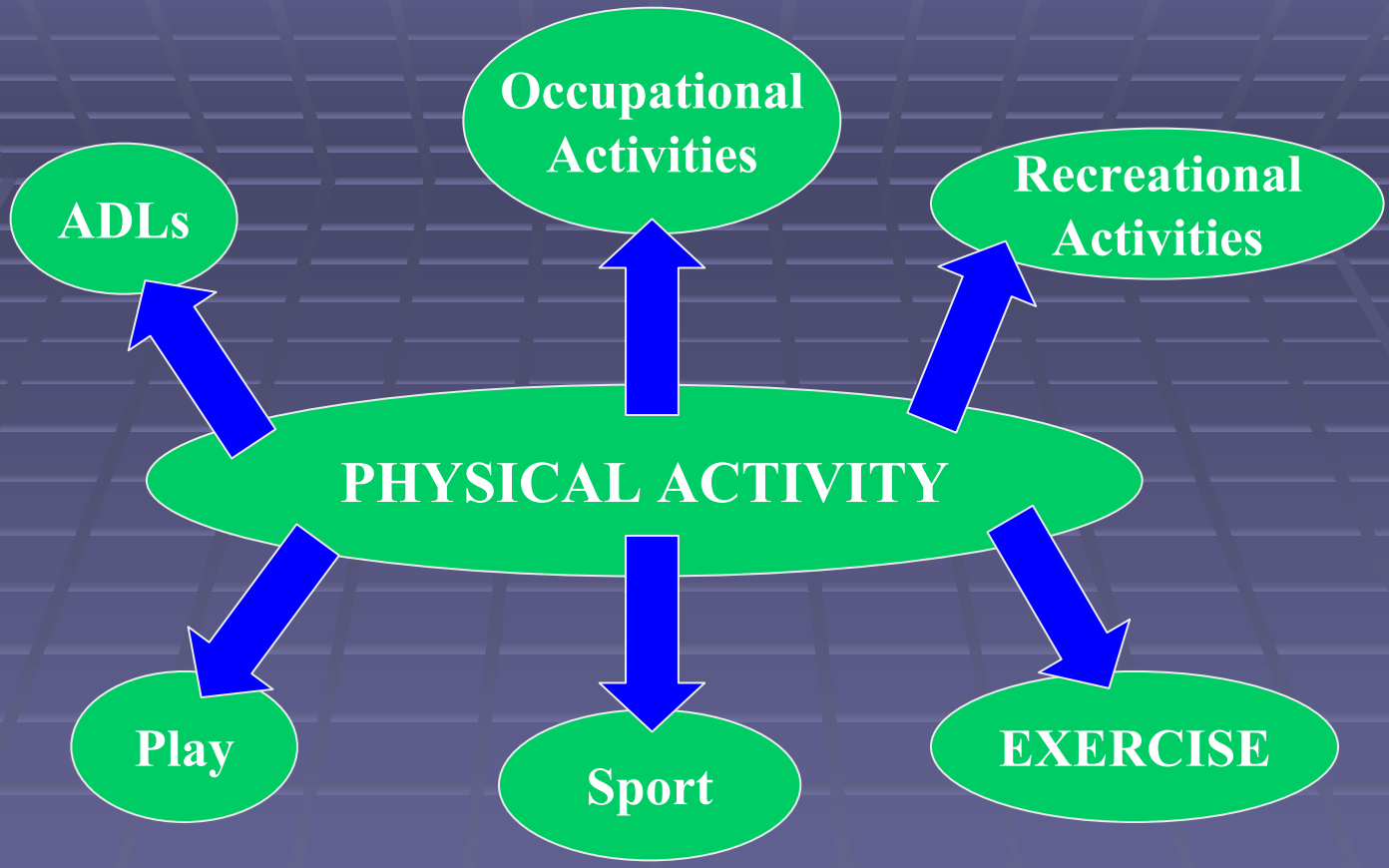
www.acpet.co.uk

ACPET 3rd Exercise Therapy Study Day.
Thursday 18th September 2008.
Exercise & Sports Village.
University of Hertfordshire.
Hatfield. UK.

Physical Activity & Exercise



www.cdc.gov/nccdphp/dnpa/physical/terms

Davis et al, Physical Education and the Study of Sport

Kent, 1994, Oxford Dictionary of Sports Science and Medicine

Physical Activity & Exercise

- **Activities of Daily Living (ADL)**: "the things we normally do in daily living including any daily activity we perform for self-care" (medterms.com)

  e.g. bathing, dressing, shopping, cooking, cleaning, etc.

- **Occupational Activities**: "occupational physical activity is completed regularly as part of one's job" (cdc.gov)

  e.g. hauling, lifting, carrying, pushing, etc.

- **Recreational Activities**: "physical activity which is pursued for enjoyment and in order to refresh health or spirits … more purposeful than play … limited organizational structure" (Kent)

  e.g. walking, hiking, dancing, gardening, etc.

  NOT the same as 'leisure activities'

www.cdc.gov/nccdphp/dnpa/physical/terms [searched September 2007]

Davis et al, Physical Education and the Study of Sport

Kent, 1994, Oxford Dictionary of Sports Science and Medicine

www.medterms.com/script/main/art.asp?articlekey=2152 [searched September 2007]

Physical Activity & Exercise

- **Play**: "spontaneous childlike physical activity from which the individual derives immediate pleasure … no goal other than enjoyment" (Kent)

  e.g. tag, hopscotch, hide-and-seek, etc.

- **Sport**: "any highly structured goal-directed physical activity governed by rules … takes the form of struggle with oneself or involves competition with others" (Kent)

  e.g. rugby, volleyball, 100m sprint, triathlon, darts, chess, etc.

- **Exercise**: "exercise is physical activity that is planned or structured … it involves repetitive bodily movement done to improve or maintain one or more of the components of physical fitness" (cdc.gov)

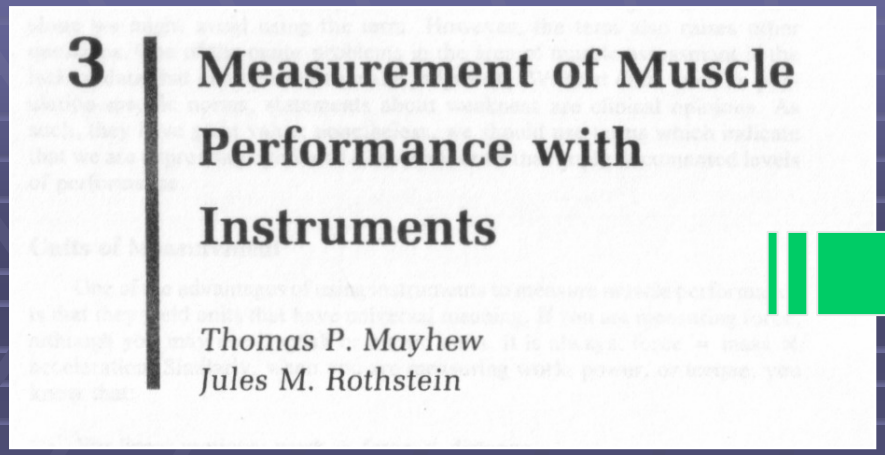
  e.g. callisthenics, weight-training, aerobics, stretching, etc.

www.cdc.gov/nccdphp/dnpa/physical/terms [searched September 2007]

Davis et al, Physical Education and the Study of Sport

Kent, 1994, Oxford Dictionary of Sports Science and Medicine

www.medterms.com/script/main/art.asp?articlekey=2152 [searched September 2007]



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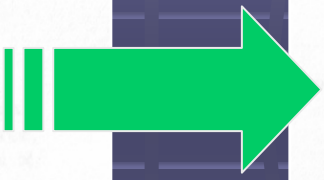
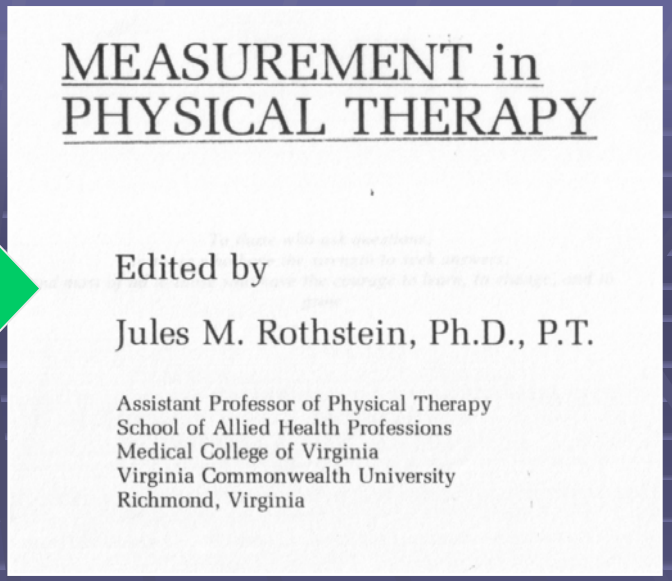
Measurement of Muscle Performance with Instruments

Thomas P. Mayhew
Jules M. Rothstein





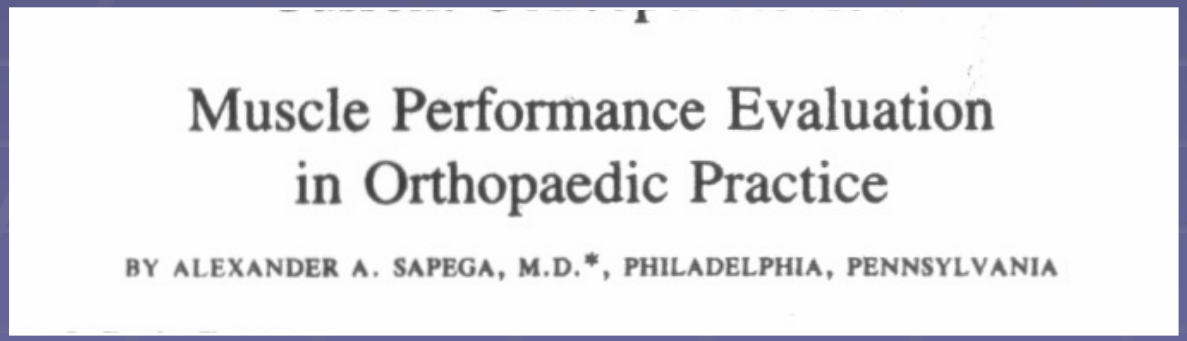
MEASUREMENT in PHYSICAL THERAPY

Edited by

Jules M. Rothstein, Ph.D., P.T.

Assistant Professor of Physical Therapy
School of Allied Health Professions
Medical College of Virginia
Virginia Commonwealth University
Richmond, Virginia

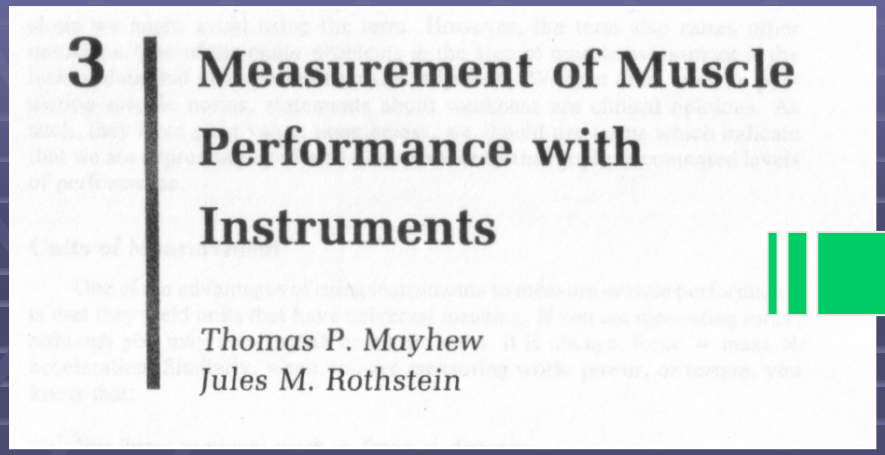
Mayhew T, Rothstein J, 1985, Measurement of Muscle Performance with Instruments, In- Measurement in Physical Therapy, Ed- J Rothstein, Churchill Livingstone, New York, pp 57-102.



Muscle Performance Evaluation in Orthopaedic Practice

BY ALEXANDER A. SAPEGA, M.D.*, PHILADELPHIA, PENNSYLVANIA

Sapega M. 1990. Muscle Performance Evaluation in Orthopaedic Practice. Journal of Bone and Joint Surgery. 72A, 1562-1574.



3 Measurement of Muscle Performance with Instruments

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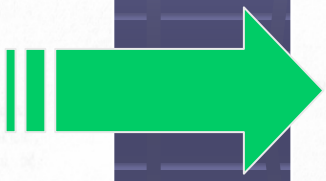

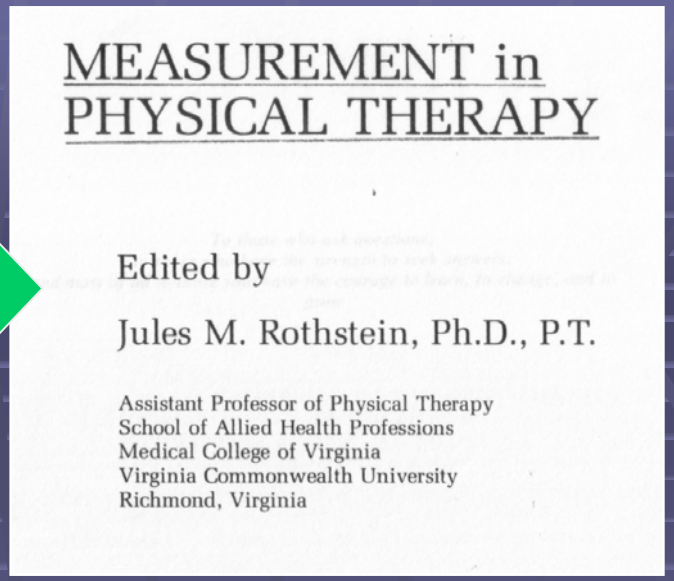

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Mayhew T, Rothstein J, 1985, Measurement of Muscle Performance with Instruments, In- Measurement in Physical Therapy, Ed- J Rothstein, Churchill Livingstone, New York, pp 57-102.

"The terms most used to describe muscle performance are "strength" and "weakness". Yet there are no units of measurement associated with either … Strength is a non-scientific descriptor when applied to muscle … If we attempt to assess strength we must ***define it operationally*** … There is no one operational definition of strength currently in use … we believe that the use of the term "strength" has encouraged a ***chaotic approach*** to measurement" (p58)

Basic Concepts & Definition – Muscle Strength

- **Muscle strength:** "the ability of a muscle to produce force"
  Clark, 2001, Phys Ther Sp, 2, 96

ANY exercise which is intended to ↑ 'the ability of a muscle to produce force' is a strength training exercise

- **Maximum strength:** force generated in a ***single*** maximum voluntary muscle action (MVMA)
- **Absolute Strength:** force generated irrespective of bodyweight
- **Relative strength:** force generated relative to bodyweight
- **Elastic strength:** force generated at high velocity of anisometric muscle action → muscle 'power'
- **Strength endurance:** force generated for sustained (isometric) or repeated (anisometric) muscle actions against a ***sub-maximal*** resistance

Clark, 2000, Muscle performance and strength training

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Dick, 1989, Sports training principles

Sapega, 1990, J Bone Joint Surg, 72A, 1562-1574

From: Taylor R et al, 2000, Lumbar Segmental Instability: Pathology, Diagnosis, and Conservative Management, In- Physical Therapy of the Low Back, 3rd Edition, Eds- L Twomey, J Taylor, Churchill Livingstone, New York, p230.

ANY exercise which is intended to ↑ 'the ability of a muscle to produce force' is a strength training exercise

IF these exercises are intended to increase the ability of the trunk muscles to produce force, then even these exercises CAN be considered 'strength training' exercises

BUT as 'strength ENDURANCE' exercises

From: Richardson C et al, 2004, Therapeutic Exercise for Lumbopelvic Stabilization, 2nd Edition, Churchill Livingstone, Edinburgh, p239

ELSEVIER

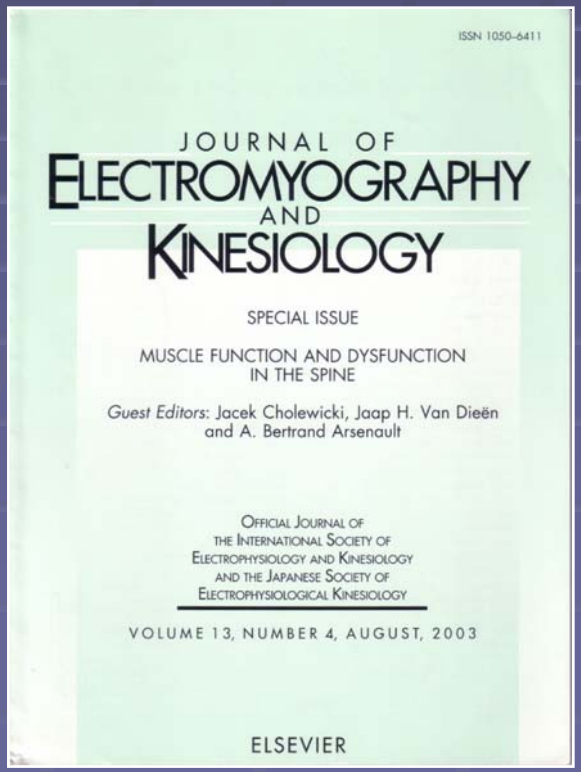
Journal of Electromyography and Kinesiology 13 (2003) 361–370

JOURNAL OF ELECTROMYOGRAPHY AND KINESIOLOGY

www.elsevier.com/locate/jelekin

Pain and motor control of the lumbopelvic region: effect and possible mechanisms

Paul W. Hodges [a,*], G. Lorimer Moseley [a,b]



"Trunk muscles must have sufficient strength and endurance to satisfy the demands of control"

(Hodges & Moseley, 2003, p362)

Basic Concepts & Definition – Muscle Performance

- **Muscle performance** = type of muscle action + type of muscle strength

- Stair ascent (2 × 15 stairs)
  → lower limb extensor concentric relative strength endurance
- Single leg static ¼ squat
  → lower limb extensor isometric relative strength endurance
- Parachute jump landing
  → lower limb extensor eccentric relative / maximum strength

Many different 'contexts' in which muscles can express force

Implications for exercise selection?

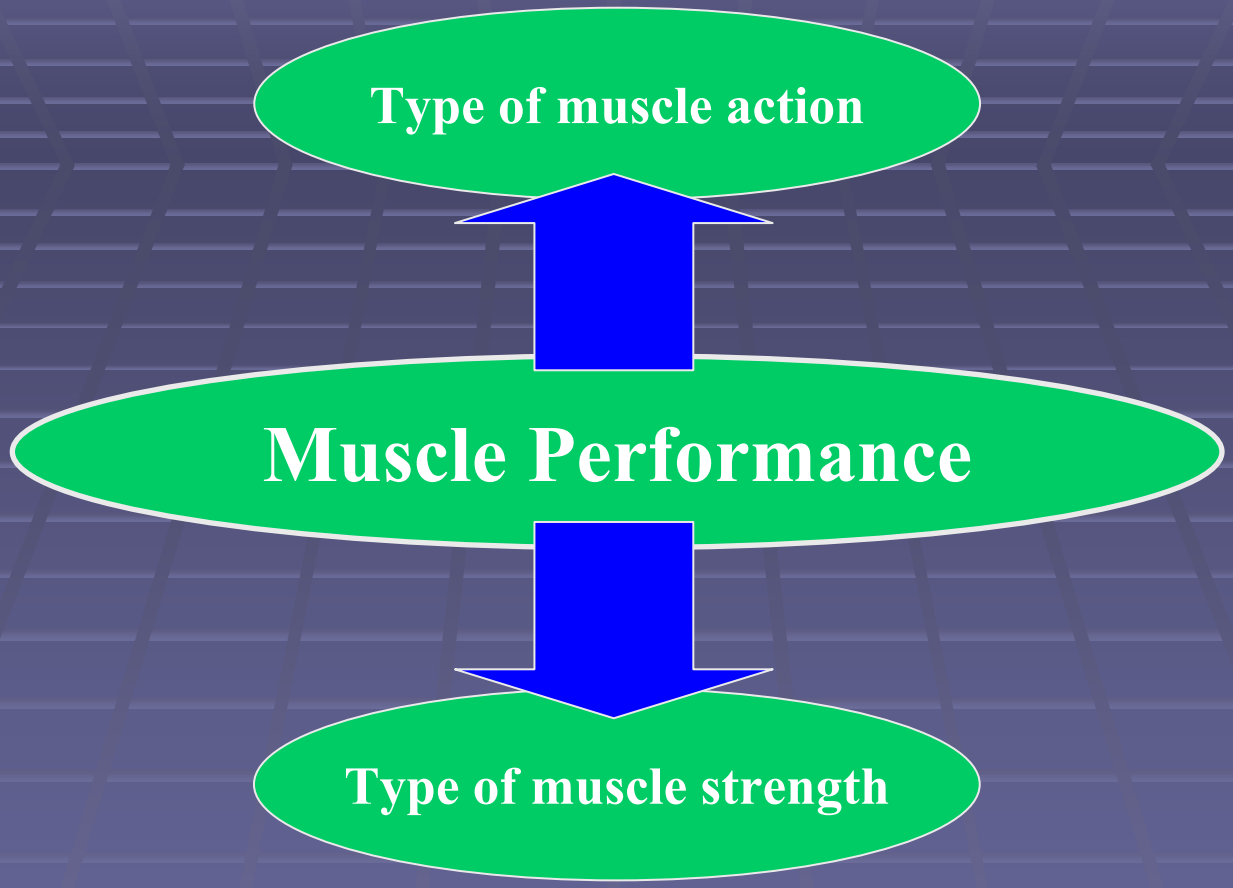
Clark, 2000, Muscle performance and strength training

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Dick, 1989, Sports training principles

Sapega, 1990, J Bone Joint Surg, 72A, 1562-1574

Basic Concepts & Definition – Muscle Performance



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Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Dick, 1989, Sports training principles

Sapega, 1990, J Bone Joint Surg, 72A, 1562-1574

Basic Concepts – It's Not Just About Muscle 'Strength'

- Exercise and, in particular, strength training, has a highly beneficial effect on the mechanical properties of the musculoskeletal system

IF it is applied with strict attention to the principle of progressive overload and within the limits of patient symptoms

Bloomfield, 1997, Med Sci Sp Ex, 29, 197-206

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Greenleaf, 1997, Med Sci Sp Ex, 29, 207-215

Grimby, 1992, Clinical aspects of strength and power training

Basic Concepts – It's Not Just About Muscle 'Strength'

- Strength training is a highly useful intervention for influencing the mechanical properties of:

  bone
  cartilage
  ligament
  joint stiffness
  tendon

"TISSUE CONDITIONING"
(Clark 2003 – Present)

Bloomfield, 1997, Med Sci Sp Ex, 29, 197-206
Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation
Greenleaf, 1997, Med Sci Sp Ex, 29, 207-215
Grimby, 1992, Clinical aspects of strength and power training

Basic Concepts – It's Not Just About Muscle 'Strength'

- Many 'formal recommendations' and/or 'position stands' stating that ↑ habitual 'RECREATIONAL physical activity' is 'best' for increasing health and fitness…

  e.g. walking, gardening, hiking, etc.

  → CV/Cardirespiratory/Aerobic 'fitness'

  → … 'The Engine' …

  → "Can't condition the engine if the chassis breaks down first…" (N Clark)

  *Author's opinion vs. actual ACPET Position Stand!

  ☺

ACSM, 1995, Med Sci Sp Ex, 27, i-vii

Khan et al, 2001, Physical activity and bone health

Layne & Nelson, 1999, Med Sci Sp Ex, 31, 25-30

Nordin & Frankel, 1989, Biomechanics of bone

Basic Concepts – It's Not Just About Muscle 'Strength'

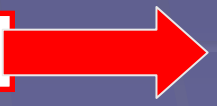
- Effort required during strength/resistance/weight training in order to increase bone density and mechanical strength = 60-80% maximum effort at ***any*** point-in-time

Muscle Strength and the elderly…

"The elderly person is like an Olympic athlete. Both must perform frequently and consistently at the very limit of their physical ability" (Young 1999).

Young, A. (1999) Strength, Power, and Functional Performance in Old Age. In- *Proceedings of Muscle Power: Scientific and Practical Perspectives*. (Eds- S. Harridge, S. Dinan, R. Woledge). University of London. London. UK.

Incorrect exercise type/selection = ↑ clinical risk?



ACSM, 1995, Med Sci Sp Ex, 27, i-vii

ACSM, 2002, Med Sci Sp Ex, 34, 364-380

Khan et al, 2001, Physical activity and bone health

Layne & Nelson, 1999, Med Sci Sp Ex, 31, 25-30

Bone

- Bone mineral density (BMD) measured by dual-energy X-ray absorptiometry (DXA)
  ↓ 10-20% in femur, patella, tibia, and calcaneus following ACL injury → post-traumatic osteopenia

  Sievanen et al 1994

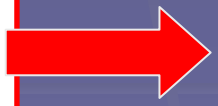
- > 1 year to recover pre-injury BMD

  Sievanen et al 1994

- Femoral, patellar, tibial, and calcaneal BMD and bone mineral content (BMC) ↑ *in the trained limb only* after strength training

  Vuori et al 1994

Implications for sub-chondral osteoenia/osteoporosis and ↑ risk overlying cartilage 'collapse' = OA?



Sievanen et al, 1994, Bone, 15, 85-90

Vuori et al, 1994, Calcified Tissue Int, 55, 59-67

Exercise Programme Design

Definition & Methods of Strength Training

- Strength training is exercise primarily directed at increasing **local** muscle strength by sustained (isometric) or repeated (anisometric) muscle actions against an opposing force (load / resistance)

- Methods:
  - segment / limb-weight
  - body-weight
  - elastic
  - sand-bag
  - dumb-bell / bar-bell
  - resistance machine (e.g. metal plate / pneumatic / hydraulic, etc.)
  - manual resistance (e.g. PNF)

Clark, 2000, Muscle performance and strength training

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Fleck & Kraemer, 1997, Designing resistance training programs

Fry et al, 2002, Special considerations in strength training

Kraemer & Fleck, 1988, Phys Sp Med, 16, 69-81

Acute Programme Variables

- Choice of exercise
- Order of exercise
- Mode of muscle action
- Range of motion
- Intensity (magnitude of load = no. of repetitions)
- Number of sets
- Exercise tempo (e.g. 2-1-5 sec. → concentric-isometric-eccentric sequence)
- Duration of between-set rest periods

- Manipulating the acute programme variables dictates the physiological and functional response → **specificity of training**

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Fleck & Kraemer, 1997, Designing resistance training programs

Fry et al, 2002, Special considerations in strength training

Kraemer & Fleck, 1988, Phys Sp Med, 16, 69-81

Kraemer & Koziris, 1992, Phys Ther Practice, 2, 54-68

Choice of Exercise

- Physiological and functional adaptations are specific to the muscles / muscle groups actually recruited during the exercise session

- ***Clinical Application***: choose exercises which target muscles / muscle groups affected by the injury, or necessary to enhance whole-limb function

- ***Idiotic Example***: don't do triceps pushdowns to strengthen the quadriceps!!!

Most basic decision in exercise programme design

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Fleck & Kraemer, 1997, Designing resistance training programs

Fry et al, 2002, Special considerations in strength training

Kraemer & Fleck, 1988, Phys Sp Med, 16, 69-81

Kraemer & Koziris, 1992, Phys Ther Practice, 2, 54-68

Order of Exercise

- Sequence of exercises within a single training session
- Improper exercise order most frequent error in exercise programme design
- Primary concern for the effects of fatigue on proper technique / skill execution and injury risk

- Large muscle mass → small muscle mass
- Multi-joint → single-joint
- High-power → low-power
- High-skill → low-skill
- High-impact → low-impact → no-impact

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Fleck & Kraemer, 1997, Designing resistance training programs

Fry et al, 2002, Special considerations in strength training

Kraemer & Fleck, 1988, Phys Sp Med, 16, 69-81

Kraemer & Koziris, 1992, Phys Ther Practice, 2, 54-68

Order of Exercise

- Be meticulous with decision-making regarding exercise order because:

1. Muscle fatigue = ↓ max. force generating ability
2. Muscle fatigue = ↓ rate of force development (RFD)
3. Muscle fatigue = ↓ proprioceptive acuity
4. Muscle fatigue = ↓ reflex muscle activity

- Therefore:

  1 + 2 + 3 + 4 = ↓ **joint stability** + ↑ **injury risk**

Clark, 2000, Muscle performance and strength training

Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Clark, 2003-Present, Proprioception and neuromuscular control in exercise rehabilitation for the lower limb

Order of Exercise

Effect of Pre-Exhaustion Exercise on Lower-Extremity Muscle Activation During a Leg Press Exercise

JESPER AUGUSTSSON,[1] ROLAND THOMEÉ,[2] PER HÖRNSTEDT,[3] JENS LINDBLOM,[4] JON KARLSSON,[2] AND GUNNAR GRIMBY,[1]

[1]Department of Rehabilitation Medicine, Göteborg University, Göteborg, Sweden 41345; [2]Department of Orthopaedics, Göteborg University, Göteborg, Sweden 41345; [3]Odda Physical Therapy, Odda, Norway 5750; [4]Kroppsakuten Physical Therapy, Göteborg, Sweden 42750.

"Although weight-trainers frequently use pre-exhaustion exercise, this training technique has …
not been the subject of scientific study …
In our study, pre-exhaustion exercise … resulted in decreased, rather than increased, activation of the
of the quadriceps muscle during a multijoint leg press"
[p412-415]

***Clinical Implications*: ↑ injury risk during functional exercise**

Augustsson et al, 2003, J Strength Cond Res, 17, 411-416

Mode of Muscle Action

- Type of muscle action: isometric
  anisometric
  isokinetic

- Greatest strength gains are demonstrated if the mode of muscle action used in training matches the mode of muscle action used in testing

- ***Clinical Application:*** Muscle action specificity = exercise muscle action should match that of the patient's intended function

Behm, 1995, J Strength Cond Res, 9, 264-274

Fleck & Kraemer, 1997, Designing resistance training programs

Morrissey et al, 1995, Med Sci Sp Ex, 27, 648-660

Sale, 1988, Med Sci Sp Ex, 20, Supplement, S135-S145

Range of Motion (ROM)

- Range of motion in which an exercise is performed

- **Isometric training**: 1. strength gains are demonstrated approx. 10-20˚ either 'side' of the actual training angle ('carryover'); 2. greater carryover is demonstrated with 'harder', 'longer', and 'more' muscle actions

- ***Clinical Application***: 1. loss of full active ROM can be treated with isometric exercise at the 'sticking point', providing that there is no / minimal loss of passive ROM; 2. patients should perform multiple (50-100) isometric muscle actions per day, for 5-10 seconds each, and as 'hard' as possible **within the limits of pain**

Behm, 1995, J Strength Cond Res, 9, 264-274

Fleck & Kraemer, 1997, Designing resistance training programs

Morrissey et al, 1995, Med Sci Sp Ex, 27, 648-660

Sale, 1988, Med Sci Sp Ex, 20, Supplement, S135-S145

Range of Motion (ROM)

- Range of motion in which an exercise is performed

- **Anisometric training:** 1. strength gains are greatest within the ROM in which the exercise is performed; 2. minimal carryover with concentric exercise; 3. carryover is virtually non-existent with eccentric exercise

- ***Clinical Applications*:** 1. exercises should be performed in a ROM specific to the patient's intended function; 2. some carryover can be anticipated with concentric muscle actions; 3. eccentric exercise should be strictly ROM-specific to the patient's intended function

Behm, 1995, J Strength Cond Res, 9, 264-274

Fleck & Kraemer, 1997, Designing resistance training programs

Morrissey et al, 1995, Med Sci Sp Ex, 27, 648-660

Sale, 1988, Med Sci Sp Ex, 20, Supplement, S135-S145

Range of Motion (ROM)

- Range of motion in which an exercise is performed

- **Summary:** ROM specificity
- 1. isometric and anisometric muscle actions should ideally be performed in the ROM specific to the patient's intended function;

  2. isometric training is particularly useful for severe muscle weakness where passive ROM is minimally compromised

Behm, 1995, J Strength Cond Res, 9, 264-274

Fleck & Kraemer, 1997, Designing resistance training programs

Morrissey et al, 1995, Med Sci Sp Ex, 27, 648-660

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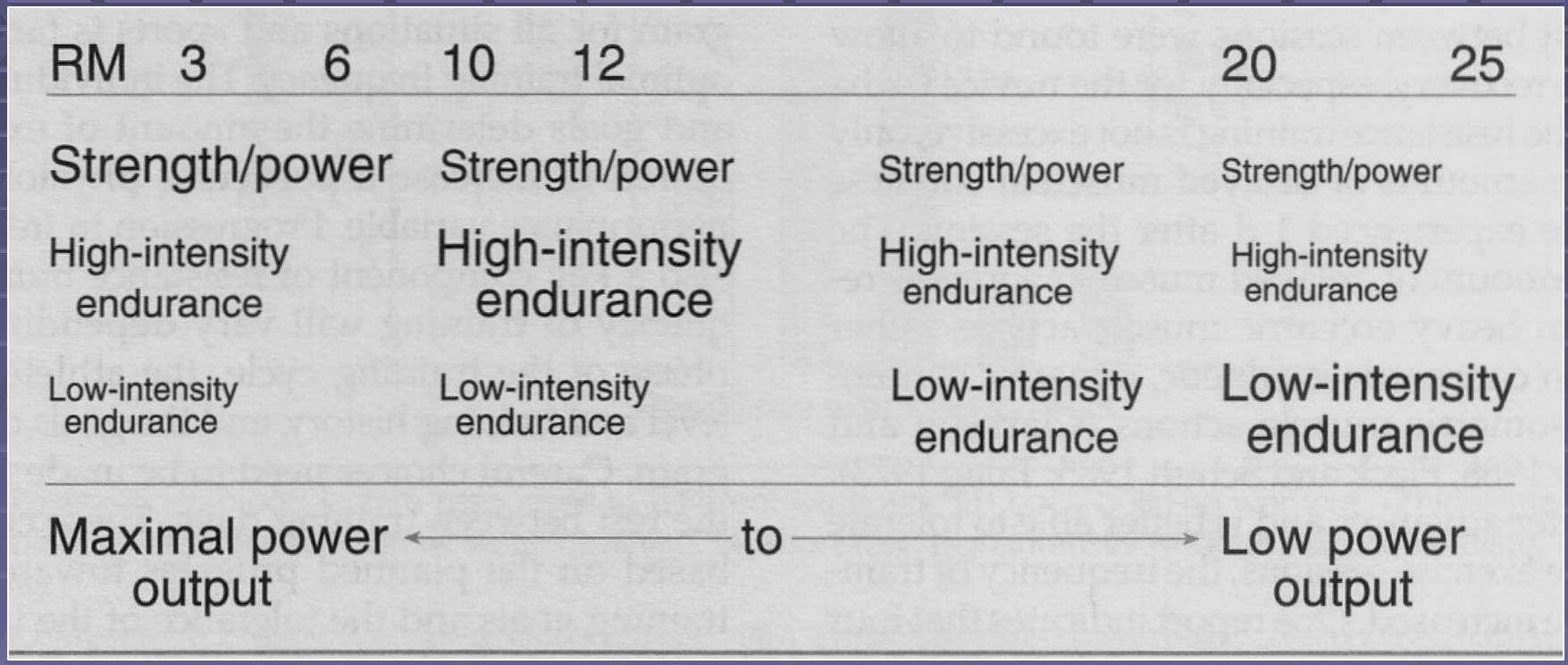
Intensity

- Repetition Continuum



- Heavier load = fewer repetitions

From: Fleck & Kraemer, 1997, Designing resistance training programs, 2nd Edition, Human Kinetics, Illinois

Intensity

- Repetition Continuum

- **Therapeutic Objective**
- ↑ motor unit recruitment = high intensity, low repetition (≤ 8)
  e.g. muscle inhibition

- ↑ muscle hypertrophy = moderate intensity, moderate repetitions (12-15)
  e.g. muscle atrophy

- ↑ muscle strength endurance = low intensity, high repetition (≥ 20)
  e.g. 'stability' muscle function

- **Relative to a muscle's status at a specific point-in-time**

Clark, 2000, Muscle performance and strength training
Clark, 2003, Exercise therapy in neuromusculoskeletal rehabilitation

Number of Sets

- Set = specific number of consecutive repetitions
- Strength gains are greater with > one set per exercise per training session
- Optimal number of sets for strength training following neuromusculoskeletal injury unknown

- **Recommended no. sets in apparently healthy adults = 3-4 sets**

  Kraemer et al, 2002, Med Sci Sp Ex, 34, 364-380

  Rhea et al, 2003, Med Sci Sp Ex, 35, 456-464

Recommendations for injured adults = 2-4 sets · exercise · session
Progressed according to patient response / tolerance

Clark, 2003,
Exercise therapy in neuromusculoskeletal rehabilitation

Byrd et al, 1999, Sport Med, 27, 409-416

Carpinelli & Otto, 1998, Sport Med, 26, 73-84

Fleck & Kraemer, 1997, Designing resistance training programs

Exercise Tempo

- Velocity at which anisometric or isokinetic muscle actions are performed
- Expressed in seconds:

  e.g. 2-1-5 → concentric-isometric-eccentric

- Greatest strength gains are demonstrated if the velocity of muscle action used in training matches the velocity of muscle action used in testing

- ***Clinical Application:*** velocity specificity = exercise velocity should match that of the patient's intended function

Behm, 1995, J Strength Cond Res, 9, 264-274

Behm & Sale, 1993, Sport Med, 15, 374-388

Fleck & Kraemer, 1997, Designing resistance training programs

Morrissey et al, 1995, Med Sci Sp Ex, 27, 648-660

Sale, 1988, Med Sci Sp Ex, 20, Supplement, S135-S145

Between-Set Rest Periods

- Refers to duration of rest between each set of a specific exercise
- Too short rest periods 2nd most frequent error in exercise programme design
- Affects metabolic, hormonal, and cardiovascular responses to strength training
- Greater strength gains with 'long' (2-3 min.) vs. 'short' (30-40 sec.) rest periods

Magnitude of load will affect the duration of between-set rest periods required to ensure adequate recovery

↑ load = ↑ rest period

- **Structural / multi-joint exercises: 2-4 min.**
- **Isolation / single-joint exercises: 1-2 min.**

Fleck & Kraemer, 1997, Designing resistance training programs

Fry et al, 2002, Special considerations in strength training

Kraemer & Fleck, 1988, Phys Sp Med, 16, 69-81

Kraemer & Koziris, 1992, Phys Ther Practice, 2, 54-68

Kraemer et al, 2002, Med Sci Sp Ex, 34, 364-380

Specificity of Strength Training

- **Summary:**
- Muscle group specificity
- Muscle action specificity
- ROM specificity
- Intensity specificity
- Velocity specificity

- Task / movement pattern specificity
  → **functional strength**

Functional Muscle Strength

"whole limb force expression during multi-joint, multi-muscle group movements specific to a person's unique activity or purpose"

Clark, 2003,
SportEx Med, 19, p8

Behm, 1995, J Strength Cond Res, 9, 264-274

Behm & Sale, 1993, Sport Med, 15, 374-388

Fleck & Kraemer, 1997, Designing resistance training programs

Morrissey et al, 1995, Med Sci Sp Ex, 27, 648-660

Sale, 1988, Med Sci Sp Ex, 20, Supplement, S135-S145

Example Programme:

- Patient: 60♀
  (L) knee OA
  Lives in a house with two flights 12 stairs

Exercise Order	Sets	Reps	Load*	ROM*	Rest
Wall-squat	3	10-15	BW	0-45°	2 mins.
Standing calf-raise	3	8-15	BW	Full	2 mins.
Seated knee ext.	3	10-15	2kg	0-90°	90 secs.
Side-lying glute. med.	2	10	45°**	Full	2 mins.

Yellow = Essential information for the patient

* = limited by / progressed according to the presence of pain

** = feet together, 45° hip flexion, 90° knee flexion