Welcome to today’s webinar

Isokinetic Dynamometry for assessment of muscle strength and joint function.

Presented by Bill Baltzopoulos

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About today’s webinar

Today’s webinar is being produced jointly by BASES and Human Kinetics.

It is scheduled to last for about an hour and will be recorded and made available for download and playback. You will receive an email containing a link to the recording when it is available.

You can submit questions by typing them into the question box located in the lower right corner of your screen and click “send.”

Bill will answer as many as possible during a Q&A session at the end.
About today’s presenter

Bill Baltzopoulos is a BASES accredited biomechanist (research) and has served as Chair of the Biomechanics section and representative to the Education & Training Committee. His main interests include the structure and function of the musculoskeletal system and the measurement and modelling of joint and muscle function during different activities, including isokinetic dynamometry, training and rehabilitation exercises and various sports. He is one of the main author of the various BASES guidelines related to muscle strength and isokinetic dynamometry and the organizer of the BASES workshops in these areas. He is also the lead author of the recent BASES expert position statement on assessment of muscle strength with isokinetic dynamometry.
Measurement of Static and Dynamic Muscle Strength
Force-Length-Velocity relationship

Lieber (1992)
Human Movement - joint rotation:

**Moment** = F \times r

Moment (Nm) = Muscle Force (N) \times Moment Arm (m)

Since muscle force depends on muscle length and muscle velocity, moments are affected by joint angle and angular velocity.
Joint Rotation: Muscle Moment (Nm)

\[ M = r x F = r \cdot F \cdot \sin \theta = d \cdot F \]
Joint Rotation: Muscle Moment (Nm)

Joint Moment (Nm) = Muscle Force (N) x Moment Arm (m)

\[ M = F \times d \]
Strength is the maximum joint moment at different joint angles and angular velocities measured with Isokinetic dynamometers.

Very useful for measurement of muscle strength because of the ability to measure the strength-muscle length-velocity relationship.

Signorile & Applegate (2000)
Isokinetic Dynamometry: A bit of history…

Isokinetic Dynamometry: Single Joint Testing
Isokinetic Dynamometry: Control of Angular Velocity
Feedback system to maintain the velocity constant and equal to the required test ang.velocity
Moment of Force: $M = r \times F$
Feedback loop for control of angular velocity

1. Read Ang. Velocity

2. Compare ang. velocity to target ang. velocity
   If Ang. Velocity < Target decrease Resistive Moment
   If Ang. Velocity > Target increase Resistive Moment

3. Apply Resistive Moment
Application of Resistive Moment
Isokinetic Dynamometry: Constant Joint Angular Velocity (not constant muscle contraction linear velocity)

but how is the resistive moment related to the joint (sum of all muscle) moment?
Newton’s Laws of Motion (2D)
Second Law (Rotational Movement):
\[ \Sigma M = I \alpha \]

Isokinetic or Isometric: \( \alpha = 0 \)
\[ M_j = M_D + M_w \]
With Isokinetic Dynamometers we can measure total Joint Moments only (not muscle moments or forces)
Strength Measurements:
With Dynamometers we can measure total Joint Moments only (not muscle forces)
Strength Measurements:
With Dynamometres we can measure total Joint Moments only (not individual muscle forces) (not individual muscle moments)

The Total Joint Moment is the Sum of All Muscle Moments
Growth affects tendon mechanical properties

O'Brien et al. (2010). J Biomech
Achilles tendon stiffness
Musculoskeletal system plasticity: The importance of tendon and muscle health across the life-span
Strength requirements in different sports

Strength-limited sports
Strength-related sports
Strength-independent sports (Wrigley 2000)
Strength requirements in different sports

Performance Criterion

Strength
Isokinetic Dynamometry:
Very useful for measurement of sport-specific strength because of the ability to measure the strength-muscle length-velocity relationship

Signorile & Applegate (2000)
Joint Rotation: Muscle Moment (Nm)

The Total Joint Moment is the Sum of All Muscle Moments

\[ M = F \times d \]
Very important that all moments are measured relative to the same axis of rotation i.e. must have perfect alignment of joint and dynamometer axes of rotation.
Misalignment of joint and dynamometer axes of rotation due to compliance/deformation of soft tissue, seat, attachment & straps and shifting of the knee joint axis with knee motion.
Effects of misalignement of axes of rotation
Errors between measured and resultant joint moments when using isokinetic dynamometers due to axes misalignment

- Herzog (1988): Single subject ~ 2%
- Kaufman et al. (1995): 10-13%
- Arampatzis et al (2004): Isometric 7.3% (range: 1-17%)
Errors between measured and resultant joint moments when using isokinetic dynamometers due to axes misalignment

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All previous studies used external cameras and skin markers to identify knee joint centre/axis of rotation
Measurement of knee joint kinematics during contraction using X-Ray video fluoroscopy

Isometric
Isokinetic Concentric 30 & 60 deg/s
Isokinetic Eccentric 60 deg/s
“Isometric” Knee Extension
@ 90 deg knee flexion angle
Calculation of the actual joint moment

\[ M_J = MD \cdot \frac{\frac{dk}{dD}}{dD} \]
Errors between measured and resultant joint moments when using isokinetic dynamometers due to axes misalignment.

Isokinetic Concentric Knee extension @ 30 deg/s
Errors between measured and resultant joint moments when using isokinetic dynamometers due to axes misalignment

Isometric Knee extension
Aaxes misalignment problems

• The joint moment error due to axes misalignment cannot be neglected if the true joint moments need to be determined

• Implications for measurement of dynamic joint function for strength and rehabilitation assessment

• Align axes of rotation:
  – accurately
  – under contraction conditions
  – near the position of expected maximum joint moment
Axes of rotation alignment
Axes of rotation alignment
Define ROM for **safe** axes of rotation alignment
Axes of rotation alignment
Define ROM for safe axes of rotation alignment
Accurate alignment of dynamometer & joint axes of rotation
5 simple steps for valid and reliable isokinetic measurements

Step No 1:

Align axes of rotation:

- accurately
- under contraction conditions
- near the position of expected maximum joint moment
Important Issues during Isokinetic Dynamometry

Stabilisation
Important Issues in Strength Measurement:

Stabilisation problems
&
Effects on Activation
Stabilisation problems: Effects on Activation?
5 simple steps for valid and reliable isokinetic measurements

Step No 2:

Stabilise properly all segments involved in the production of joint movement
Joint moment at different joint positions and angular velocities measured with Isokinetic dynamometers.
Joint moment during concentric knee extension @ 300 deg/s

What is the maximum knee extension moment @ 300 deg/s?
60 deg/s

180 deg/s

300 deg/s
At high joint velocities the isokinetic (constant velocity) movement is very limited or non-existent.

The peak dynamometer moment may not be recorded in isokinetic conditions and at the preset or target velocity.
At high joint velocities the isokinetic (constant velocity) movement is very limited or non-existent!!
System 4:
Windowing function to exclude non-isokinetic conditions
System 4: Windowing function to exclude non-isokinetic conditions
5 simple steps for valid and reliable isokinetic measurements

Step No 3:

Monitor Angular Velocity throughout the ROM and exclude non-isokinetic data from the analysis
Adjacent joint position affects muscle length in two-joint muscles and therefore moment in the tested joint.
Adjacent joint position affects muscle length in two-joint muscles and therefore moment in the tested joint (knee extension or flexion in this example)
Isometric force in supine & seated positions

Maffiuletti & Lepers (2003)
Important Issues in Isokinetic Dynamometry

Worrell et al. (1989)
\[ T_q < T_h \]
\[ T_q < T_h \]

Yang & Lieska (1992)
\[ T_q < T_h \]
\[ T_q < T_h \]

Hopkins et al. (1993)
\[ T_q < T_h \]
\[ T_q < T_h \]

Black et al. (1993)
\[ T_q < T_h \]
\[ T_q < T_h \]

Pavol & Grabiner (2000)
\[ T_q < T_h \]
\[ T_q < T_h \]
Important Issues in Isokinetic Dynamometry: Knee Flexion

Ankle joint position and gastrocnemius muscle length effects on knee flexion moment
Important Issues in Isokinetic Dynamometry: Knee Flexion

Miller et al. (1996)  $T_h < T_h$

Miller et al. (1997)  $T_h < T_h$

Croce et al. (2000)  $T_h < T_h$
5 simple steps for valid and reliable isokinetic measurements

Step No 4:

Plan positioning of adjacent segments and joints appropriately and control properly
5 simple steps for valid and reliable isokinetic measurements

Step No 5:

Record all test settings, subject positioning and stabilisation accurately
5 simple steps for valid and reliable isokinetic measurements

- Axes of Rotation Alignment
- Isokinetic (constant ang. velocity) Phase
- Stabilisation
- Positioning
- Recording of Test Settings
Isokinetic dynamometers are excellent tools and very useful for measuring static & dynamic joint function…

…but users must ensure that some important principles are not violated by following some simple practical steps
Requirements for reduction of measurement variability in isokinetic dynamometry (Best Practice):

- Align axes of rotation:
  - accurately
  - under contraction conditions
  - near the position of expected maximum joint moment
- Calculate and monitor angular velocity independently and use isokinetic data only
- Stabilise segments and reduce extraneous movement
- Position and control second joint when biarticular muscles are involved
- Record all test settings and subject positioning
References


Thank You

Any Questions?

We have already received a high number of questions and we will now try and answer as many as possible in the time remaining.

Any that remain unanswered will be forwarded to Bill and he’ll try and email you a reply in due course.
Thank you to everyone for joining us today and thanks also to Bill for what I’m sure you will agree was a fascinating and informative presentation.

Please take a few moments when your webinar window closes to complete a short survey on today’s webinar – we appreciate your feedback as it helps us continually improve our webinars.

We will email everyone a link to the recording of today’s presentation, so you can view it yourself or pass it along to friends or colleagues.
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Join us on Wednesday 16th March, 2016 at 10.am GMT, for the next BASES webinar.

“The importance of well-developed physical qualities for rugby players”, presented by Dr Rich Johnston.

You will automatically receive an invitation to this webinar.

Alternatively you can find details on the Human Kinetics website at www.humankinetics.com

Thanks for joining us and enjoy the rest of your day.