

The BASES Expert Statement on Measurement of Muscle Strength with Isokinetic Dynamometry

Produced on behalf of the British Association of Sport and Exercise Sciences by Prof Bill Baltzopoulos, Dr Mark King, Prof Nigel Gleeson and Dr Mark De Ste Croix

Introduction

Isokinetic dynamometry has been established as the preferred technique for the quantification of muscle strength. It allows assessment of joint moments in both static and dynamic conditions before and after specific exercise interventions or rehabilitation from sports injuries. For these reasons isokinetic dynamometers are useful and unique devices that allow the assessment of dynamic muscle and joint function under specific joint velocity conditions. However, there are many factors that can affect the measurements, conclusions and resulting guidance given to athletes and patients. Despite the understanding and significance of these factors for accurate strength measurements reported in the research literature, there is a remarkable lack of implementation of appropriate error prevention techniques in most applications.

Even when appropriate protocols or correction methods are used, the reporting of these details is often poor and not standardised. This makes it difficult for readers or users to determine data quality in most of the published studies that have used isokinetic dynamometry. This expert statement reviews the relevant scientific background and evidence and provides specific and clear recommendations so that the assessment of muscle strength and joint function in athletes and other clinical populations is valid and appropriately reported.

Although there are other interesting issues and debates such as the specificity of isokinetic movement velocity to sports actions, the ecological validity of isokinetic testing for closed chain sports movements, correlations with other measures of dynamic muscle function and its sensitivity to training progression, this statement is focused only on methodological strength measurement issues.

Background and evidence

Isokinetic dynamometers measure muscle strength by recording the resistive moment required to counter balance the joint moment applied by the participant and maintain a constant joint angular velocity (isokinetic or isovelocit). This is the total moment attributable to the forces produced by all the structures acting around the joint (agonist and antagonist muscles as well as passive structures like ligaments) and, therefore, strength is always quantified using total or net joint moment (Nm) during a particular motion. Direct measurement of a single muscle or even muscle group moment or force is not possible with any external dynamometer, so strength measurements should be reported accurately using joint motion terms and nomenclature (e.g., knee extension moment, ankle plantar flexion moment, rather than quadriceps force or gastrocnemius moment, for example).

The dynamometer moment is measured around its fixed axis of rotation assuming that the tested joint axis is always in alignment with this. However, there is usually misalignment of the joint and dynamometer axes of rotation that arises from the non-rigid connection between the segments and the dynamometer arm and seat because of the compliance of the soft tissues and the dynamometer padding. The resulting movement of the segment relative to the dynamometer is one of the main factors for misalignment of axes of rotation and the resulting differences

between measured and actual joint moments (Tsaopoulos *et al.*, 2011). These depend on the testing conditions and typical errors range from 10%-13% during isokinetic knee extensions (Kaufman *et al.*, 1995) and from 1-17% (mean 7.3%) in isometric conditions (Arampatzis *et al.*, 2004). Given that most strength training effects that need to be quantified with isokinetics are typically in the order of 10-20% but much lower in elite athletes, it is clear that increasing measurement accuracy and minimising axes misalignment error are crucial issues. The best method to achieve this would be to align the joint and dynamometer axis under active (e.g. sub-maximal isometric) rather than passive conditions, and with the segment close to the anticipated maximum strength joint position (usually in the middle of the range of motion). If there is misalignment of axes because the dynamometer measurement unit or head is twisted due to insufficient rigidity of the dynamometer frame and large moments applied by powerful participants, then the frame and head must be secured with extra support to a fixed structure in the lab. Stabilisation of the participant with appropriate and well-fitted belts or straps is also important to avoid extraneous motion and to secure the skeletal segment(s) where the activated muscle(s) originate.



Above: Participant positioned for an ankle joint strength test on an isokinetic dynamometer
Courtesy Prof B. Baltzopoulos

The dynamometer moment can also be affected by several other factors such as gravitational forces, the effect of biarticular muscles and the angle of the adjacent joint they span, antagonistic activity and the familiarisation and motivation of the participant, so it is important to include appropriate correction and standardisation procedures and to report relevant techniques or settings (e.g., control and report ankle joint angle during knee flexion tests to standardise the contribution of gastrocnemius to knee flexion moment). Verbal motivation and/or visual feedback can be provided to maximise activation but they must be consistent and standardised for all participants with clear instructions on how to use visual feedback. There are also mechanical issues related to the acceleration of the segments and since the dynamometer moment is equal to the joint moment only during the isovelocit period, the angular velocity must be monitored throughout the joint motion and any acceleration phases should be discarded, so that moment data are measured only from the isokinetic phase of the movement (see Baltzopoulos, 2008).

Isokinetic dynamometers should be serviced and calibrated regularly. Independent criterion-based measurements of moment, angle and angular velocity should be compared with dynamometer readings so that data accuracy after calibration can be quantified (see Baltzopoulos, 2008). Raw moment and angle data should be smoothed with appropriate filters to remove high frequency noise. If a model of joint moment output is required (e.g., for simulation purposes), then each isovelocit moment-angle region should be identified and interpolated to provide moment as a function of angle at intervals of 1°. A nine-parameter moment-angle-angular velocity function fitted to isovelocit moment-angle-angular velocity data is adequate for obtaining a participant-specific representation of maximal voluntary moment as a function of angle and angular velocity (King *et al.*, 2006; Yeadon *et al.*, 2006).

Isokinetic assessment of children provides researchers with additional challenges relating to changing and individual rates of growth and maturation. Modifications are necessary for isokinetic dynamometer seat and attachments and stabilisation and testing procedures (e.g. static or anthropometry-based procedures instead of dynamic gravity correction). Isokinetic testing of children, irrespective of muscle action or muscle joint assessed, has a test-retest variation of around 5-10% similar to adult variation. Generally it is reproducible and reliable as long as equipment and protocols are properly adapted for their size and good habituation procedures are in place, especially during eccentric actions (De Ste Croix *et al.*, 2003). Interpretation of isokinetic moment data during growth and maturation requires comparisons among individuals of different sizes. It is therefore important that a size-free moment variable is used for interpretive purposes. Current evidence suggests that allometric scaling factors should be derived from careful modelling of individual data sets, and therefore be sample specific rather than adopting conventional ratio-standard scaling indices.

Isokinetic dynamometry has also been used in clinical applications to assess the effects of surgical and rehabilitative interventions on neuromuscular performance. It has been deployed most often as a secondary outcome (mainly peak moment) alongside primary outcomes of functionality and minimised pain. In experimental designs for clinical interventions and meaningful changes, effect sizes of indices of neuromuscular performance involving isokinetic dynamometry are approximately 0.3 to 2.5. Raw effects associated with monitoring clinical changes in performance might exceed those observed for asymptomatic populations because of potentially lower disease-, injury- or de-conditioning-related baselines. However, the greater heterogeneity of responses in clinical evaluations at given stages of treatment might work against favourable or robust relative effect sizes. Thus, considerations for establishing appropriate experimental design sensitivity and avoidance of inflated Type-II error rates for a given least significant difference or clinical responsiveness might be judged using established procedures (Mercer & Gleeson, 2002). This is notwithstanding the documented limits to measurement precision and reproducibility in asymptomatic and clinical populations associated with isokinetic dynamometry due to the factors explained above.

Conclusions and recommendations

To obtain accurate joint moment-angle-angular velocity data for the assessment of strength and safeguard validity and reliability of strength measurements it is important that:

- dynamometers are serviced regularly and calibrated according to recommended techniques using a range of weights to confirm moment measurements and accurate goniometers are used to confirm angle measurements
- the participant is positioned and stabilised appropriately on the dynamometer including adjacent joints of biarticular muscles
- joint and dynamometer axes are aligned under active and not passive conditions, near the anticipated maximum moment position and separately for reciprocal actions (e.g., extension and flexion tests)
- gravity and any other relevant correction techniques are applied
- an appropriate testing protocol with standardised procedures for habituation, feedback and motivation is used
- maximal range of motion is set, with preloading if necessary, to allow the participant to reach maximum voluntary activation and the preset joint velocity and to maximise the isokinetic phase
- angular velocity is monitored and only isovelocit regions of each trial are used for subsequent analysis (velocity within 10% of the preset value)
- acceleration period data and derived parameters (such as 'torque acceleration energy') should not be used because they are affected by the different velocity control mechanisms of each dynamometer
- stabilisation and joint axes alignment methods, correction techniques, test parameters, and isovelocit assessment method in high angular velocity tests must be reported explicitly. ■

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