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Review Article

# Isokinetic dynamometry beyond the knee: Assessing muscle strength across multiple joints and clinical populations

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## ABSTRACT

Isokinetic dynamometry is a reference method for assessing dynamic muscle performance, yet its clinical application remains concentrated on knee testing. This focus underrepresents the multi-joint nature of disability across neurological, neuromuscular, rheumatological, respiratory, oncological, geriatric, and musculoskeletal populations. This narrative review examines measurement principles, protocol requirements, psychometric evidence, and clinical applications of isokinetic dynamometry beyond the knee, including the shoulder, elbow, wrist, hip, ankle, and trunk. It addresses the interpretation of peak torque, work, power, muscle balance, asymmetry, and fatigue when performance is affected by pain, spasticity, impaired motor control, contracture, cardiopulmonary limitation, or generalized weakness. Available evidence supports reliable measurements at several joints when positioning, stabilization, alignment, gravity correction, range of motion, familiarization, contraction mode, and angular velocity are standardized. However, reliability is protocol-specific, and high intraclass correlation coefficients do not exclude clinically relevant measurement error. Multi-joint assessment should therefore be hypothesis-driven, inform clinical management, and complement measures of function, symptoms, participation, and patient goals. Extending isokinetic testing beyond the knee may improve the characterization of regional and systemic weakness, monitoring of disease progression and rehabilitation response, and precision of exercise prescription. Future research should prioritize consensus protocols, minimal detectable change values, multicenter normative databases, standardized reporting, and links between dynamometry outcomes and meaningful clinical improvements.

**Keywords:** Isokinetic dynamometry, Muscle strength, Peak torque, Multi-joint assessment, Rehabilitation, Neurological disorders

## Introduction

Muscle weakness is not a single-joint phenomenon. It may arise from pain inhibition, disuse, denervation, central motor impairment, altered muscle architecture, systemic inflammation, malnutrition, ageing, treatment toxicity, or combinations of these mechanisms. In clinical practice, weakness is often first identified by manual muscle testing, functional observation, hand-held dynamometry, chair-rise performance, walking tests, or patient-reported difficulty. These approaches are useful, but each answers a different question. Manual muscle testing is rapid and inexpensive, yet it has limited sensitivity near the upper end of the strength scale. Functional tests integrate strength with balance, coordination, cognition, cardiorespiratory reserve, confidence, and task familiarity. Hand-held dynamometry provides quantitative force data but can be influenced by examiner strength and stabilization, particularly

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when large proximal muscle groups are tested. Isokinetic dynamometry offers a complementary laboratory-based method in which the dynamometer controls angular velocity while accommodating the torque produced throughout the available range of motion [1-4].

The principle is straightforward, but its interpretation is not. During an isokinetic contraction, the limb accelerates until it reaches the preset velocity; the device then varies resistance to prevent further acceleration. The resulting torque signal can be used to derive peak torque, average torque, total work, average power, angle-specific torque, time to peak torque, fatigue indices, and agonist-antagonist or bilateral ratios. This controlled environment allows maximal or submaximal assessment across a selected arc and at multiple velocities. It also permits concentric, eccentric, and isometric modes on many modern systems. For these reasons, angular isokinetic dynamometry has long been described as a reference method for dynamic muscle-performance testing [1, 2, 5].

Despite these advantages, isokinetic practice has become strongly associated with the knee. The concentration is understandable: knee flexion and extension are mechanically convenient, the dynamometer axis is comparatively easy to align with the joint axis, stabilization is feasible, large torque values are produced, and the clinical relevance to anterior cruciate ligament reconstruction, knee arthroplasty, osteoarthritis, and sports rehabilitation is immediate. Consequently, knee protocols dominate normative datasets, reliability studies, return-to-sport criteria, and clinical education. This has created an unintended conceptual limitation. Clinicians may equate isokinetic testing with quadriceps and hamstring assessment rather than viewing it as a platform for evaluating muscle performance across the shoulder, elbow, wrist, hip, ankle, and trunk [1, 5, 6].

A multi-joint perspective is particularly important in populations whose disability cannot be explained by knee strength alone. A person after stroke may have weaknesses at the shoulder, elbow, wrist, hip, knee, and ankle, with different contributions from impaired voluntary activation, spasticity, and motor control. A patient with chronic obstructive pulmonary disease may have lower-limb weakness, reduced power, fatigability, and limited ventilatory reserve. A child with cerebral palsy may show selective motor control deficits and contractures that constrain both the feasibility and interpretation of dynamometry. People with multiple sclerosis, Parkinson disease, neuromuscular disorders, cancer, or sarcopenia may present with regional and generalized weakness. In shoulder pathology, ankle instability, hip osteoarthritis, chronic low back pain, or upper-limb overuse, the joint of primary interest is not the knee [6, 7-12].

This narrative review therefore examines isokinetic dynamometry beyond knee-centered practice. Its objectives are to: (1) summarize the measurement principles and methodological controls required for valid multi-joint testing; (2) review clinical applications at the shoulder, elbow, wrist, hip, ankle-foot complex, and trunk; (3) discuss use in neurological, neuromuscular, musculoskeletal, respiratory, oncological, pediatric, and older populations; (4) explain the clinical interpretation of common isokinetic outcomes; and (5) identify practical limitations, reporting priorities, and future research needs. The intention is not to suggest that every patient requires a lengthy multi-joint battery. Rather, it is to show how carefully selected isokinetic tests can answer clinically meaningful questions when simpler assessments are insufficient.

## *Principles of isokinetic muscle assessment*

Isokinetic dynamometry measures the external moment applied to the dynamometer lever arm while angular velocity is controlled. The measured torque is not a direct measure of the force produced by one anatomically isolated muscle. It reflects the net joint moment produced by agonists and antagonists, passive tissue resistance, gravitational effects, segment inertia, mechanical alignment, stabilization, pain, apprehension, motor learning, and the participant's voluntary effort. This distinction is essential when moving beyond the knee, where complex joint motion and compensatory strategies are often more difficult to control [2, 6, 13].

Peak torque is the highest value obtained during a repetition or set and is the most reported outcome. It is straightforward to interpret and often shows good relative reliability. However, it represents a single point and may be sensitive to signal artefact, an isolated effort spike, or the angle at which the value occurs. Average torque and total work provide information across a larger portion of the range. Work reflects torque integrated over angular displacement, whereas power incorporates the time taken to perform work. These outcomes may be useful when weakness is distributed across the arc or when repeated contractions are clinically relevant. Torque-angle curves can reveal whether deficits occur predominantly in shortened, mid-range, or lengthened muscle positions. Such information may be more informative than a single peak value in rotator-cuff disorders, hamstring rehabilitation, spasticity, or joint contracture [6, 13].

Angular velocity changes the physiological and clinical meaning of the test. Lower velocities generally permit higher torque and may be easier for inexperienced, weak, or neurologically impaired participants to understand. Moderate and high velocities reduce available contraction time, usually lower peak torque, and can reveal impairments in rapid force production. Eccentric torque is often higher than concentric torque, but eccentric testing may require more familiarization, closer safety monitoring, and confidence in the participant's ability to resist the moving lever. In children and some clinical populations, faster or eccentric protocols may be less reliable than slower concentric testing [14, 15].

The term “isokinetic” should also be interpreted carefully. The preset velocity is maintained only during the load range after acceleration and before deceleration. At high velocities or within short ranges, a substantial proportion of the movement may occur outside the true isokinetic phase. Consequently, the available ROM, acceleration settings, damping, and data-processing rules affect the measured outcome. Cross-device and cross-laboratory comparisons require comparable acquisition and processing settings. Mechanical validation supports device

accuracy and repeatability, but calibration cannot compensate for a poorly standardized human testing protocol [2, 16, 17].

Relative reliability describes whether individuals retain a similar rank across repeated tests and is often expressed using an ICC. Absolute reliability describes the size of the measurement error in the original unit and is commonly reported using the SEM, coefficient of variation, limits of agreement, or MDC. A high ICC can coexist with substantial absolute error, especially in heterogeneous samples. For clinical monitoring, the important question is not only whether the device is reliable, but whether the observed change exceeds expected measurement error. Systematic reviews have repeatedly emphasized uneven reporting of absolute reliability and insufficient evidence for responsiveness in several populations [18-20]. Therefore, a clinically credible report should include both the measured change and a protocol-specific estimate of error whenever available.

## Standardization: the foundation of reliable multi-joint testing

Reliability belongs to a measurement protocol, not to the dynamometer in isolation. This principle becomes increasingly important as testing moves from the knee to joints with more degrees of freedom. Standardization should begin before the patient enters the device. Medication timing, fatigue, sleep, recent exercise, pain, spasticity, cardiopulmonary symptoms, and the use of assistive devices may influence performance. For longitudinal assessment, these conditions should be reproduced as closely as possible [19, 21].

Positioning determines both the muscle length and the capacity to generate compensatory movement. The pelvis and trunk should be stabilized without compromising breathing or provoking pain. Straps need to be placed consistently, and the chair or attachment settings should be recorded in enough detail to allow replication. The anatomical axis of rotation should be aligned with the dynamometer axis as accurately as possible. Perfect alignment is rarely maintained throughout motion because biological joints do not rotate around a fixed axis. Nevertheless, poor initial alignment changes lever-arm length, introduces shear forces, and can distort torque. This is especially relevant for shoulder rotation, hip movement, ankle inversion-eversion, and trunk rotation [22-24].

Gravity correction is necessary when the weight of the limb and lever arm meaningfully contributes to measured torque. The correction procedure must match the device and position. Omitting gravity correction can overestimate torque in one direction and underestimate it in the opposite direction, thereby altering agonist-antagonist ratios. The passive gravitational moment may also change across the range. Researchers should report whether correction was performed and how it was obtained [1, 2].

Familiarization is a methodological requirement that helps limit learning effects. Participants must understand the movement, the need to exert maximal effort through the whole range, and the sensation of the dynamometer matching their force. Familiarization is particularly important for eccentric testing, high-speed contractions, trunk movements, paediatric assessment, and neurological conditions. Several reliability reviews have recommended practice trials or a separate familiarization session, because early improvements may represent learning rather than physiological change [15, 25, 26].

Warm-up procedures should be standardized and should include submaximal repetitions in the actual test position. Older methodological guidance recommended submaximal warm-up to reduce strain and improve stable performance, and this remains reasonable [2]. The number of maximal repetitions should balance measurement stability against fatigue. Long endurance sets require clear rules for the fatigue index and may be unsuitable for patients with pain, severe weakness, or cardiopulmonary limitations. Rest intervals should be long enough to minimize carryover fatigue and consistent across sessions. In COPD, for example, rest duration can materially influence repeated quadriceps performance [27].

Verbal encouragement, visual feedback, instructions, and the timing of cues can influence maximal voluntary performance. They should be scripted when possible. The same examiner should conduct repeat testing when inter-rater reliability is uncertain. Joint order and limb order should be randomized or kept constant according to the study design. When bilateral testing is used, clinicians should consider whether testing the first limb produces a learning effect and testing the second limb introduces fatigue [2, 28].

Safety requires population-specific screening. Contraindications or reasons to defer maximal testing may include acute injury, unstable cardiovascular disease, uncontrolled hypertension, recent surgery without clearance, severe pain, acute inflammatory exacerbation, high fracture risk, or inability to follow instructions. Testing should be stopped for sharp pain, neurological deterioration, marked dyspnea, dizziness, abnormal cardiovascular responses, or loss of safe positioning. In neurological populations, the examiner should document whether spasticity, clonus, involuntary movement, or impaired selective motor control affected the trace. In all populations, the protocol should be adapted to the patient's capacity rather than forcing the patient into a normative sports-testing template [2, 10, 13].

## Shoulder assessment

The shoulder is one of the most clinically developed areas of isokinetic testing outside the knee. Common protocols examine internal and external rotation in seated, supine, or standing positions, often at different degrees of abduction. Flexion-extension, abduction-adduction, and diagonal patterns can also be tested, although their mechanical complexity and stabilization demands are greater. The clinical rationale includes assessment of rotator-cuff function, glenohumeral muscle balance, postoperative recovery, overhead-sport demands, swimmer's shoulder, breast-cancer-related upper-limb impairment, and generalized upper-limb weakness [13, 29, 30].

A systematic review of shoulder measurement properties found that isokinetic dynamometry generally demonstrated sufficient

reliability across contraction modes, velocities, positions, and rotation directions, but measurement error remained a concern, and the quality of evidence was often moderate or low [19]. An earlier review focusing on shoulder rotator position similarly showed that test position affects results and that protocols should not be treated as interchangeable [22]. These findings support clinical use, but they also caution against universal cut-offs.

Shoulder rotation illustrates why positioning matters. Testing at 90 degrees of abduction may resemble overhead function and place the rotators in a different length-tension relationship than testing with the arm near the trunk. However, the abducted position may be painful or unstable in patients with rotator-cuff pathology, postoperative restrictions, apprehension, or neurological weakness. A scapular-plane position or lower degree of abduction may be better tolerated. The examiner must control trunk rotation, scapular substitution, elbow movement, and grip. The lever arm should be adjusted to avoid excessive pressure at the wrist and to minimize discomfort [19, 29, 30].

The external-rotation to internal-rotation ratio is frequently used as an index of shoulder muscle balance. Conventional ratios compare concentric external rotation with concentric internal rotation, whereas functional ratios may compare eccentric external rotation with concentric internal rotation. These values can be relevant to deceleration demands in throwing or swimming, but they are sensitive to test position, speed, contraction mode, and normalization. A ratio may appear normal even when both muscle groups are weak. Therefore, ratios should be interpreted alongside absolute or normalized torque and not used as a substitute for a complete clinical assessment [19, 22, 29].

Isokinetic shoulder testing can also quantify the shape of the torque curve and the angle of peak torque. These features may help identify range-specific deficits after injury or surgery, although their reliability may be lower than peak torque and they are not yet supported by broadly accepted clinical thresholds. Multi-joint shoulder test batteries have shown promising reliability for flexion, extension, horizontal abduction, and horizontal adduction in asymptomatic adults, suggesting that assessment need not be restricted to axial rotation [31]. Nevertheless, these more complex patterns require strict stabilization and are less easily compared across laboratories.

In breast cancer survivors, shoulder weakness may reflect surgery, pain, radiation, reduced use, lymphatic complications, or fear of movement. Isokinetic testing has been used to compare shoulder rotator performance in breast cancer survivors with and without Tai Chi Qigong training [32]. In these patients, symptom monitoring, comfortable positioning, and avoidance of excessive compression are important. The purpose should be to guide rehabilitation rather than simply to document impairment.

For clinical reporting, shoulder protocols should specify body position, shoulder abduction and plane, elbow angle, ROM, movement direction, contraction mode, speed, repetitions, rest, gravity correction, stabilization, and whether pain or apprehension limited effort. Without these details, apparently similar shoulder torque values may represent meaningfully different tests [19, 22, 30].

## *Elbow, forearm, and wrist assessment*

Isokinetic assessment of the elbow, forearm, and wrist has received less attention than the shoulder and knee, but it can be valuable in neurological rehabilitation, work-related disorders, upper-limb sports, tendon injury, postoperative care, and neuromuscular disease. Elbow flexion-extension testing is mechanically feasible, although shoulder and trunk compensation must be controlled. Forearm pronation-supination and wrist flexion-extension require smaller attachments and careful alignment because the available torque is lower and minor positional errors may have proportionally larger effects [33-37].

Upper-limb testing should preserve a reproducible shoulder position. During elbow flexion-extension, changes in shoulder flexion or humeral rotation alter muscle length and leverage. The forearm position also changes the contribution of the biceps brachii. A pronated, neutral, or supinated forearm should therefore be selected deliberately and reported. The wrist should be positioned consistently because wrist flexor and extensor activity can influence grip and upper-limb stabilization [36, 37].

For wrist testing, the dynamometer axis should be aligned as closely as possible with the wrist's functional axis while the forearm is firmly supported. Range should be restricted to a comfortable, repeatable arc. Test-retest studies have reported good reliability for many concentric and eccentric wrist flexion and extension measures, while identifying weaker reliability for contraction modes or movement directions [33, 34]. These results show that wrist testing is feasible but cannot be assumed to be equally reliable for every variable.

In patients with chronic elbow pain or work-related upper-limb symptoms, torque wrist curves may provide information about effort consistency, pain-limited performance, and regional weakness. Such interpretation must be cautious. Irregular curves or low values do not prove submaximal effort, because pain, fear, motor-control changes, and true impairment can produce similar patterns. Isokinetic "effort indices" should never be used as stand-alone evidence of symptom validity [37, 38].

Neurological conditions create additional opportunities for upper-limb testing. After stroke, weakness is present in both paretic and, to a lesser degree, non-paretic limbs. However, the ability to complete constant-velocity movement may be affected by spasticity, synergy, impaired selective control, sensory loss, and subluxation. Low velocities, limited ROM, supported positions, and isometric testing at selected angles may be more feasible than high-speed dynamic protocols. The objective should be explicit: quantifying voluntary torque, monitoring recovery, or evaluating the response to strengthening. The dynamometer trace should be reviewed rather than relying only on the software-generated peak [7].

In neuromuscular disorders, proximal muscle groups often demonstrate better measurement reliability than distal muscles, partly because distal torque is smaller and positioning is more sensitive [20, 35]. Elbow assessment can therefore contribute to longitudinal monitoring in ambulatory or cooperative patients, but fatigue, disease-specific safety considerations, and the possibility of overwork should be considered. A short protocol with adequate rest is generally preferable to an extensive battery.

## Hip assessment

Hip strength is central to gait, balance, stair negotiation, transfers, pelvic control, and lower-limb alignment. Weakness of the abductors, extensors, flexors, adductors, or rotators may be relevant in hip osteoarthritis, total hip arthroplasty, low back pain, neurological disease, falls, and sports injury. Hip testing is technically challenging. Pelvic movement, trunk compensation, and the depth of the joint complicate axis alignment and stabilization [39-43].

Hip flexion-extension can be assessed in standing, supine, or side-lying configurations depending on the dynamometer attachment. Adduction and internal-external rotation are also possible. Each position changes muscle length, gravitational contribution, comfort, and the compensation opportunity. A systematic review of isokinetic hip flexor and extensor evaluation identified substantial variation in positioning, dynamometer alignment, lever-arm placement, velocities, contraction modes, and reliability statistics [23]. Individual reliability studies have similarly shown that reproducibility depends on the tested muscle group and velocity [39].

For hip abduction, pelvic stabilization is essential. Without it, lateral trunk motion and pelvic hiking can generate apparent torque that does not represent isolated hip-abductor performance. In side-lying, the examiner must control pelvic rotation and ensure that the lever arm does not cause discomfort. In standing, balance and weight-bearing through the support limb become part of the task. This may improve ecological relevance but reduce isolation and feasibility in frail or neurologically impaired patients [39, 43].

Hip flexor and extensor testing can be clinically useful in hip osteoarthritis. Patients with OA have demonstrated lower hip adductor, abductor, and flexor strength than controls, with acceptable repeatability in carefully controlled protocols [40]. However, pain may reduce voluntary activation, and test position may compress the joint or provoke symptoms. Results should therefore be interpreted as pain- and task-specific performance, not as a direct measure of muscle tissue capacity alone.

In older adults, hip weakness is associated with mobility limitation and falls, but an exhaustive isokinetic protocol may be burdensome. A targeted assessment can be justified when it changes management, such as determining whether apparent gait instability is accompanied by severe abductor weakness or monitoring a focused strengthening program. For population studies, normalization to body mass, lean mass, or limb dimensions may facilitate comparison, although no normalization method is universally superior. Absolute torque remains important when the clinical task requires moving the person's actual body mass [43-45].

Portable dynamometers are often used for hip assessment because they are more practical. Systematic reviews suggest that externally stabilized portable methods can be reliable, but criterion validity against isokinetic dynamometry is variable and protocol-dependent [41, 42]. The two methods should therefore not be treated as interchangeable. Isokinetic testing is most defensible when dynamic torque across a controlled range, speed-specific performance, eccentric capacity, or high-quality torque curves are required.

## Ankle-foot complex assessment

Ankle plantar flexors, dorsiflexors, invertors, and evertors contribute to gait propulsion, foot clearance, postural control, adaptation to uneven surfaces, and protection against recurrent ankle injury. Weakness at the ankle is clinically relevant after stroke, in cerebral palsy, peripheral neuropathy, multiple sclerosis, neuromuscular disease, chronic ankle instability, and ageing. Isokinetic assessment can quantify deficits that are difficult to detect with manual muscle testing, particularly in stronger plantar flexors [46-51].

The ankle-foot complex presents several technical challenges. The talocrural and subtalar joints have different axes, and inversion-eversion is not a simple single-plane rotation. Knee position changes gastrocnemius length and therefore plantar-flexion torque. Foot fixation, shoe use, lever-arm placement, and stabilization of the tibia affect results. Small changes in the neutral starting position may alter the available range and the contribution of passive tissues [48, 51].

Reliability studies of ankle dorsiflexion and multi-directional ankle strength generally support the feasibility of isokinetic testing when procedures are standardized [46, 47]. A recent systematic review found that dynamometric ankle strength measurements can be reliable but remain influenced by protocol heterogeneity, with moderate velocities often performing well [24]. Test-retest work across ankle, knee, and hip protocols has also shown that relative reliability may be acceptable while random variation remains clinically important [47]. This reinforces the need to report SEM or MDC, not only ICC.

Plantar-flexion testing is especially sensitive to position. Seated testing with the knee flexed reduces gastrocnemius contribution and may be better tolerated, whereas testing with the knee extended more closely reflects the combined plantar-flexor group used in gait. Prone or supine positions may improve stabilization but can be uncomfortable. The chosen position should match the clinical question [50, 51].

Inversion and eversion testing can be useful after lateral ankle sprain or in chronic instability, but the measured motion is complex, and torque values are lower than plantar flexion. Reliability and measurement error may be affected by knee position, stabilization, velocity, and encouragement [48]. Ratios between evertors and invertors are sometimes used to describe muscle balance, but they should not be interpreted without absolute torque values and symptom information.

After stroke, isokinetic ankle testing may reveal weakness in both the paretic and less-affected limbs. Earlier work found reliable knee and ankle measures for the less-affected limb, while measurement of the paretic side may be more difficult because of spasticity and impaired selective activation. Slow velocities, careful ROM selection, and trace inspection are required. If the patient cannot produce smooth movement through the arc, isometric torque at standardized angles or alternative clinical measures may be more valid [49].

In cerebral palsy, ankle testing must account for contracture, lever-arm dysfunction, selective motor-control impairment, and age. Knee isokinetic testing has demonstrated high reliability in selected ambulatory children, but this does not automatically generalize to ankle protocols or to children with greater functional impairment [15, 52]. Familiarization, child-friendly instructions, and a small number of meaningful outcomes are critical.

## Trunk assessment

Trunk muscle performance supports spinal control, posture, transfers, balance, gait, lifting, and upper- and lower-limb force transmission. Isokinetic trunk testing may assess flexion-extension, lateral flexion, or axial rotation. Clinical applications include chronic low back pain, spinal rehabilitation, occupational assessment, sports performance, neurological disease, and survivorship after childhood cancer. The trunk differs from limb joints because the measured motion is distributed across multiple vertebral segments and the pelvis, and because large muscle groups act through complex moment arms [26, 53].

Trunk flexion-extension can be tested in seated, standing, or semi-standing positions. Pelvic stabilization and control of hip contribution are essential. In standing, the task may be more functional, but balance and lower-limb contribution can influence the result. In seated testing, the pelvis can be more firmly stabilized, but the movement may be less representative of occupational or sporting tasks. A systematic review in people with nonspecific low back pain reported excellent reliability for selected isometric and isokinetic protocols and highlighted the value of familiarization [25]. A broader review similarly concluded that trunk isokinetic measurements can be reliable, while warning that position-specific results should not be compared indiscriminately [26].

Flexor-extensor ratios are widely reported, yet their clinical meaning remains uncertain. A ratio can identify relative imbalance, but it cannot distinguish bilateral weakness from high performance in both groups. Pain-related inhibition may also affect flexion and extension differently. Torque should be considered across the range because patients may avoid specific spinal positions. The angle of peak torque may shift due to posture, fear, or altered movement strategy rather than a change in muscle physiology [6, 26].

Trunk testing can impose substantial cardiovascular and musculoskeletal demand. High-risk patients require screening and conservative progression. The range should avoid painful end positions and excessive spinal loading. Repetitions should be limited when fatigue or symptom exacerbation is likely. In patients with neurological disease, straps should stabilize without worsening tone or restricting respiration [25, 26].

Isokinetic trunk weakness has been described in long-term survivors of childhood malignancy, where endocrine and treatment-related factors may contribute [53]. This illustrates the broader value of trunk testing: weakness may be a late effect of systemic disease or treatment rather than a local back problem. Even so, the test should be linked to functional concerns such as transfer difficulty, reduced lifting tolerance, or impaired postural endurance.

## Neurological populations

Neurological weaknesses are shaped by impaired descending drive, altered motor-unit recruitment, reduced firing rates, disuse, co-contraction, spasticity, contracture, sensory deficits, and fatigue. Isokinetic dynamometry can quantify net voluntary torque, but it does not separate these mechanisms. The clinical value lies in objective characterization and longitudinal monitoring when the task is feasible and standardized [54, 55].

After stroke, systematic review evidence indicates that isokinetic dynamometry can be reliable across muscle groups, contraction modes, and velocities, while confirming substantial weakness in the paretic and the non-paretic side compared with healthy controls [7]. This bilateral finding is clinically important because using the "unaffected" limb as a perfect reference can underestimate systemic and disuse-related impairment. Multi-joint assessment can identify whether walking limitation is dominated by hip, knee, or ankle weakness and whether upper-limb recovery includes meaningful torque generation.

Nevertheless, stroke traces may be distorted by synergy patterns, spasticity, delayed activation, and inability to reverse direction rapidly. Slow concentric testing or isometric assessment at selected angles may be more appropriate early in recovery. The examiner should document assistance, ROM restrictions, tone, and whether the participant reached the preset velocity. Peak torque values produced during irregular movement should not be accepted automatically [7, 49].

In multiple sclerosis, systematic review and meta-analysis have shown high reliability for knee isokinetic assessment and marked impairments in strength, power, and RFD, particularly during moderate-to-fast lower-limb contractions [8]. Strength of the weaker leg may predict walking performance better than the stronger leg [54]. These findings support speed-sensitive assessment, but fatigue, heat sensitivity, fluctuating symptoms, and medication timing must be standardized. A multi-joint approach may be justified when trunk or hip weakness contributes to mobility or balance, although the strongest psychometric evidence remains concentrated at the knee.

In Parkinson disease, strength, power, and RFD are reduced compared with healthy controls, and available dynamometry studies suggest generally high reliability, although the methodological evidence is limited [9]. Bradykinesia and impaired scaling of force may make rapid outcomes particularly relevant. Testing should occur at a consistent medication state and should distinguish between inability to move quickly and inability to generate torque.

In cerebral palsy, selected knee protocols have shown high reliability, and isokinetic testing has been feasible in ambulatory children and athletes with CP. However, performance depends on cognitive understanding, selective motor control, spasticity, contracture, and comfort in the device. Because weaknesses may exist at the hip, knee, and ankle, multi-joint assessment can guide targeted strengthening, but the battery must be short enough to

avoid fatigue and loss of attention. Age-appropriate familiarization and repeat trials are especially important [52, 55]. Across neurological populations, isokinetic results should be integrated with gait, balance, dexterity, motor-control, and participation measures. An increase in torque that does not translate into improved function may still represent a physiological gain, but clinicians should investigate whether motor control, endurance, balance, or environmental barriers remain limiting [7, 54, 55].

## Neuromuscular diseases

Neuromuscular diseases include heterogeneous disorders affecting motor neurons, peripheral nerves, neuromuscular junctions, and muscle. Weaknesses may be proximal or distal, symmetrical or asymmetrical, stable or progressive. Objective strength measurement is valuable for natural-history studies and treatment trials, but the testing procedure must not impose excessive fatigue or risk [20, 35].

A focused review concluded that isokinetic testing was generally appropriate and safe in ambulatory patients with neuromuscular disease, with reported reliability coefficients ranging widely and proximal muscle groups tending to be more reliable [35]. A later systematic review using contemporary measurement-property methods found that the quality of evidence varied substantially and was high only for limited disease categories, emphasizing uncertainty about responsiveness and clinically meaningful change [20]. These conclusions are not contradictory: isokinetic testing can be feasible and promising while the strength of evidence remains insufficient for universal claims.

In progressive disease, measurement error must be small enough to distinguish true decline from day-to-day variability. This requires consistent time of day, medication status, rest, positioning, and examiner procedures. The number of repetitions should be minimized. Endurance protocols may be informative but can be burdensome and difficult to standardize. Isometric testing may be more feasible in very weak patients who cannot reach the preset velocity. Multi-joint testing can characterize the pattern of weakness, such as proximal hip and shoulder involvement versus distal ankle and wrist impairment. However, testing every joint is rarely necessary. Selection should be based on expected disease distribution, functional priorities, and responsiveness to intervention. When torque values approach the lower detection limits of the system, hand-held or fixed dynamometry may be more practical, provided stabilization and measurement properties are adequate [20, 21, 35].

## Musculoskeletal and postoperative populations

In musculoskeletal rehabilitation, isokinetic dynamometry is commonly used to quantify deficits, bilateral asymmetry, agonist-antagonist relationships, and recovery after surgery. Beyond the knee, the method is relevant to rotator-cuff disorders, shoulder instability, hip osteoarthritis, total hip arthroplasty, chronic ankle instability, tendinopathy, and low back pain [48, 56].

Pain is both a symptom and a measurement constraint. A low torque value during a painful test may reflect muscle atrophy, neural inhibition, fear, or a protective strategy. The result remains clinically meaningful as a measure of current performance, but it should not be interpreted as isolated contractile capacity. Pain should be recorded before, during, and after testing. Range and velocity should be modified to avoid provocative positions, and maximal eccentric testing should be used cautiously in irritable conditions [40, 56].

After surgery, the timing of testing depends on tissue healing, surgeon guidance, ROM, and the ability to produce maximal effort safely. Isometric testing at protected angles may precede dynamic assessment. Later, concentric and eccentric tests can characterize recovery across the arc. For total knee arthroplasty, isometric, isokinetic, and isoinertial methods have demonstrated acceptable validity and reliability [56], but the same principle applies to other joints: the method should match the stage of recovery and clinical decision.

Bilateral symmetry indices are popular because they appear intuitive. However, the contralateral limb may be weak because of deconditioning, pain, previous injury, neurological disease, or systemic illness. A patient can achieve an apparently acceptable symmetry score while both limbs remain below expected capacity. Symmetry should therefore be interpreted with absolute torque, body-size normalization, pre-injury data when available, and functional testing [57, 58].

Agonist-antagonist ratios also require caution. They may identify disproportionate weakness, but the ratio is mathematically unstable when the denominator is small and can normalize despite clinically relevant weakness in both muscle groups. Ratios are protocol-specific and depend on contraction mode and velocity. Their greatest value is as one component of a broader profile [19, 22].

Torque-angle analysis may be especially useful in tendon and muscle rehabilitation because it identifies deficits in lengthened positions. Yet angle-specific data are more susceptible to alignment error, acceleration effects, and variability. Clinicians should ensure that the angle corresponds to a true load-range portion of the movement and should avoid overinterpreting small shifts in the angle of peak torque [13, 29].

## Respiratory and systemic disease

Peripheral muscle dysfunction is a major extrapulmonary feature of COPD. It reflects inactivity, hypoxemia, inflammation, corticosteroid exposure, malnutrition, and altered muscle metabolism. Isokinetic dynamometry has been used to assess quadriceps strength, power, and fatigability, and these measures are associated with mobility and high-level functional performance [59-61]. Systematic review evidence indicates that computerized dynamometry is one of the established methods for peripheral strength measurement in COPD, although protocols vary [10].

A multi-joint approach may be relevant because upper-limb tasks can provoke dyspnea and because systemic weakness is not

limited to the quadriceps. However, test burden must be controlled. Oxygen saturation, dyspnea, heart rate, and symptoms should be monitored according to clinical risk. Rest periods may need to be longer than in healthy populations. Repeated maximal sets can be limited by ventilation before local muscle fatigue is reached, so a "fatigue index" may represent combined cardiopulmonary and muscular limitation [62, 63].

Isokinetic testing has also shown that both ventilatory function and leg muscle function contribute to exercise limitation in COPD [64]. This supports combining dynamometry with walking or cycle testing rather than treating either as a complete surrogate for function. Stair-climb power and sit-to-stand tests are clinically valuable, but correlations with laboratory torque are only moderate, confirming that functional and isolated strength tests measure overlapping but distinct constructs [59, 65].

Obesity, sarcopenia, malnutrition, chronic kidney disease, inflammatory disease, and critical illness can similarly produce generalized weakness. In these populations, normalization becomes difficult. Torque divided by total body mass may underestimate relative muscle quality in obesity, while absolute torque remains relevant to moving body mass. Lean-mass normalization may be physiologically informative but requires body-composition assessment. Reporting both absolute and normalized values is often the most transparent approach [66, 67].

## Oncological populations and survivorship

Cancer and its treatments can reduce strength through inactivity, cachexia, neuropathy, endocrine dysfunction, pain, surgery, radiation, and cardiopulmonary toxicity. The pattern may be localized, as in shoulder impairment after breast cancer treatment, or generalized. Isokinetic dynamometry has been used in cancer survivors to evaluate shoulder rotator strength, trunk performance, lower-limb fatigability, and exercise response [32, 53].

Given these regional and systemic effects of cancer and its treatment, the clinical objective should determine which muscle groups and outcomes are tested. After breast cancer surgery, shoulder rotation or elevation may be relevant, while in survivors with generalized fatigue, lower-limb strength and fatigability may be more informative. In childhood cancer survivors, trunk weakness may persist years after treatment and relate to hormonal deficits [53]. These examples illustrate how testing beyond the knee can identify treatment-specific impairments.

Fatigue deserves careful interpretation. Perceived cancer-related fatigue is not identical to local muscle fatigability. A repeated isokinetic protocol may quantify decline in torque across contractions, but the result should be compared with symptom scales and functional endurance. Low tolerance may reflect pain, fear, neuropathy, anemia, sleep disturbance, or cardiopulmonary limitation. Testing should be postponed during acute illness or unstable treatment-related complications and adapted for bone fragility or metastatic risk [11, 68].

## Older adults, sarcopenia, and frailty

Ageing is accompanied by losses in muscle mass, strength, power, and neuromuscular efficiency. Strength often declines faster than mass, making direct performance measurement important. Isokinetic dynamometry can distinguish maximal torque from work, power, and fatigue, and can assess joints that contribute differently to mobility. Hip abductors support frontal-plane stability, ankle plantar flexors contribute to propulsion, knee extensors support transfers, and trunk muscles assist posture and balance [67, 69].

Reliability studies support the use of knee isokinetic testing in older adults, while also showing that observed changes must exceed protocol-specific thresholds before they can be distinguished from measurement error. The same lesson applies to multi-joint assessment. High relative reliability does not mean that a small individual change is clinically real. Older adults may require a separate familiarization session, slower velocities, longer rest, and conservative ROM [69].

In sarcopenia and malnutrition, isokinetic dynamometry may provide information beyond a single handgrip value by quantifying lower-limb performance and power [12]. However, feasibility and burden are important. Frail adults may be unable to safely transfer into complex test positions. A shorter test or alternative fixed dynamometry may be preferable. Isokinetic assessment is most useful when it provides information unavailable from grip strength, chair-rise, gait speed, or routine functional testing.

Normative comparison should account for age, sex, body size, physical activity, joint position, and protocol. Device-specific normative data are not automatically transferable. Clinical interpretation should focus on change over time and relation to function rather than labelling an individual as "normal" or "abnormal" based on an incompatible reference dataset [13, 67].

## Clinical interpretation of isokinetic outcomes

Peak torque should be interpreted as the maximum net joint moment achieved under the exact conditions of the test. It is not a universal property of the muscle group. A patient's peak torque can change because of strength gain, pain reduction, improved confidence, better familiarization, altered ROM, different stabilization, or a change in speed. Longitudinal testing should therefore replicate the protocol and document deviations [6, 13].

Total work can be useful when torque production across the entire arc matters. It may be more sensitive to range limitations or repeated performance than peak torque, but it is also affected by ROM. A patient who moves through a larger arc may perform more work without a proportional increase in torque. Average power is affected by both work and time and is valuable when rapid functional tasks are relevant [2, 13].

Fatigue indices are typically calculated from the decline in work or torque across a repeated set. Different software systems use different formulas, and values are not interchangeable. A high fatigue index can reflect local muscular fatigue, poor pacing, pain, cardiopulmonary limitation, loss of attention, or

inconsistent effort. The raw repetition sequence and torque curves should be reviewed [62, 63].

Bilateral asymmetry is often calculated as the percentage difference between limbs. The direction of the calculation matters, and different formulas yield different percentages. Side-to-side comparison is useful when one limb was clearly healthy before a unilateral injury, but less valid in bilateral or systemic disease. In strokes, MS, COPD, cancer, and ageing, both limbs may be impaired [57, 58].

Normalization can improve comparison, but every method answers a different question. Normalizing to body mass reflects torque relative to the load that must be moved. Normalizing to lean mass or muscle cross-sectional area relates more closely to muscle quality. Allometric scaling may reduce body-size bias in research. For clinical transparency, absolute torque and at least one justified normalized value should be reported [66, 67].

The smallest detectable or minimal detectable change indicates the amount of change required to exceed measurement error at a stated confidence level. It is not the same as the minimal clinically important difference, which requires an anchor related to patient benefit. Many isokinetic protocols have reliability data but lack clinically anchored thresholds. Clinicians should avoid claiming that a statistically reliable change is necessarily meaningful to the patient [21, 69].

Finally, isokinetic outcomes should be linked to a decision. Examples include identifying a specific weak muscle group, determining whether weakness is bilateral, monitoring postoperative recovery, adjusting resistance-training load, documenting disease progression, or evaluating an intervention. Testing without a predefined interpretive purpose risks producing a large volume of precise but clinically unused data [13, 38].

## Comparison with other strength-assessment methods

Manual muscle testing remains appropriate for rapid screening, severe weakness, bedside assessment, and patients who cannot be positioned in a dynamometer. Its limitations are reduced sensitivity among stronger grades and dependence on examiner judgement. Hand-held dynamometry improves quantification and is portable, but examiner strength and stabilization influence results. External fixation substantially improves its utility for large muscle groups [38, 41].

Systematic reviews comparing hand-held and isokinetic dynamometry have found generally good reliability and variable concurrent validity across joints and protocols [4, 41]. Strong correlations do not establish interchangeability. Two devices can rank participants similarly while producing systematically different values. Therefore, serial monitoring should use the same device and protocol whenever possible.

Fixed isometric dynamometry is efficient and may be more feasible for weak or neurologically impaired patients. It measures torque at a selected joint angle but does not capture velocity-specific performance or torque across the range. Functional tests such as chair rise, stair climb, gait speed, throwing, lifting, or walking endurance reflect real-world performance but integrate multiple systems. They should complement rather than replace impairment-level measurement [20, 35].

The choice of method should consider the clinical question, required precision, available space, cost, staff expertise, patient burden, and whether the result will change management. Isokinetic dynamometry is not automatically superior for every purpose. Its advantage is greatest when dynamic, angle-specific, velocity-specific, eccentric, or repeated-contraction information is needed under highly standardized conditions [13, 38].

## Practical multi-joint testing framework

A pragmatic multi-joint assessment can be organized in five steps. First, define the clinical hypothesis. For example: is reduced walking speed associated with plantar-flexor weakness, or does a patient after breast cancer treatment have persistent external-rotation weakness? Second, choose the smallest set of joints and outcomes needed to test that hypothesis. Third, select a protocol supported by reliability evidence in a similar population. Fourth, standardize and document positioning, alignment, stabilization, gravity correction, ROM, velocity, repetitions, rest, instructions, and symptom response. Fifth, interpret the results with measurement error and functional context [6, 13].

For a patient with stroke and walking difficulty, a targeted battery might include hip flexion or extension, knee extension, and ankle plantar flexion or dorsiflexion, using slow concentric or isometric modes depending on control. For a patient with chronic shoulder symptoms, internal and external rotation at a tolerable position may be sufficient. For a person with COPD entering pulmonary rehabilitation, knee extension strength may be paired with a functional test, while additional joints are tested only if upper-limb or generalized weakness is clinically evident [7, 10].

Testing order should prioritize the most clinically important measure before fatigue develops. When several joints are tested, alternating upper and lower limbs or providing longer rest may reduce local fatigue, but transferring between attachments can increase burden. All settings should be saved electronically and recorded on a standardized case form [10, 27].

A high-quality report should include device and software; calibration status; participant position; stabilization; anatomical and dynamometer alignment; lever-arm placement; ROM; gravity correction; contraction mode; velocity; familiarization; warm-up; repetitions; rest; limb and joint order; verbal encouragement; pain or symptom response; whether the preset velocity was reached; data-processing rules; and reliability or MDC values used for interpretation. These details transform a torque number into a reproducible clinical measurement [21-24].

## Limitations and implementation barriers

The most obvious barriers are cost, space, maintenance, calibration, and staff training. Attachment changes and positioning can be time-consuming. The device is not portable and may be inaccessible to patients with severe mobility

limitations. These factors partly explain why hand-held and fixed portable dynamometers are more common in routine practice [13, 38]. Biomechanical limitations also matter. Many joints do not rotate around a fixed axis, and the dynamometer measures external torque at the lever arm rather than individual muscle force. Stabilization can never eliminate all accessory movement. Multi-planar joints are simplified into test motions that may not replicate function. High-speed tests may include limited true isokinetic time, especially over short arcs [1, 2, 6].

Patient-related limitations include pain, fear, impaired cognition, spasticity, contracture, fatigue, dyspnea, and inability to produce maximal voluntary effort. Maximal testing is effort-dependent. Although torque curves can identify obvious irregularities, no single trace can establish motivation or symptom validity [20, 35]. The evidence base is uneven. The knee and shoulder have relatively substantial reliability literature, while elbow, wrist, hip, ankle, and trunk protocols are more heterogeneous. Evidence in neurological and neuromuscular populations often involves small samples and selected ambulatory participants. Responsiveness, MDC, and clinically important differences are less consistently established than relative reliability. Normative datasets are frequently device- and protocol-specific [54, 55].

Finally, publication and clinical practice sometimes emphasize ratios and asymmetry thresholds without sufficient consideration of measurement error, bilateral weakness, or protocol differences. The solution is not to abandon isokinetic testing, but to use it more selectively and report it more rigorously [57, 58].

### *Future directions*

Future research should move beyond demonstrating that a dynamometer can produce repeatable values and establish how multi-joint results improve clinical decisions and outcomes. Consensus protocols are needed for commonly tested non-knee movements, particularly hip rotation, ankle inversion-eversion, wrist function, and trunk rotation. These protocols should include positioning diagrams, alignment rules, gravity correction, familiarization, velocities, repetitions, and data-processing definitions [24, 48]. Measurement studies should report ICC, SEM, coefficient of variation or limits of agreement, and MDC. Responsiveness should be evaluated against clinically relevant anchors. Researchers should determine whether changes in torque predict improvements in walking, transfers, work capacity, upper-limb function, falls, quality of life, or participation [21, 69].

Multicenter normative databases could improve interpretation, but only if device and protocol harmonization is achieved. Data-sharing standards should retain torque-angle-time curves rather than only summary variables. Automated quality checks may identify failure to reach target velocity, excessive artefact, or inconsistent ROM, but they should support rather than replace clinical judgement [19, 24]. Emerging robotic and exoskeleton systems may extend isokinetic testing to more functional multi-joint patterns. Their promise should be evaluated against established dynamometers for mechanical validity, test-retest reliability, safety, and clinical usefulness. Portable technologies may improve access, while laboratory systems remain valuable as criterion measures [6]. Most importantly, future studies should include populations who are often excluded from device-based testing: people with greater neurological impairment, frailty, obesity, pain, and multimorbidity. Adapted protocols may sacrifice some standardization but improve clinical relevance. Transparent reporting will allow clinicians to understand that trade-off [12, 20].

## Conclusion

Isokinetic dynamometry should not be viewed as a knee-only technology. When applied with joint-specific positioning, stabilization, alignment, gravity correction, familiarization, and symptom monitoring, it can quantify muscle performance at the shoulder, elbow, wrist, hip, ankle-foot complex, and trunk. This broader application is clinically relevant because many neurological, neuromuscular, musculoskeletal, respiratory, oncological, pediatric, and geriatric conditions produce multi-joint or systemic weakness. The strongest conclusion is methodological: reliability depends on the protocol and population. A high ICC does not remove measurement error, and a precise torque value is not automatically clinically meaningful. Peak torque, work, power, torque-angle characteristics, fatigue indices, ratios, and asymmetry each provide useful but incomplete information. Their interpretation must consider pain, motor control, ROM, body size, bilateral involvement, cardiopulmonary limitation, and patient goals.

The most defensible expansion beyond the knee is selective rather than exhaustive. Clinicians should identify the joint and outcome most likely to influence management, use a reproducible protocol, quantify measurement error, and pair laboratory findings with function and participation. Used in this way, multi-joint isokinetic dynamometry can improve the characterization of weakness, guide exercise prescription, monitor rehabilitation and disease progression, and strengthen the link between objective measurement and individualized care.

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