BOX 2.1 Reflections and Commentaries on 20 Years of Research

The reports selected for Box 2.1 were chosen for their illustrative value in highlighting a number of key aspects of MET usage in clinical settings. They are presented in chronological order, from older to most recent, to demonstrate the evolution of our understanding of MET.

Note: This is not meant to be a comprehensive listing.

- Wells et al. (1999) investigated the immediate effects of a single session of MET (together with articulation and myofascial release) on the gait of people with Parkinson disease. Twenty subjects with Parkinson disease enrolled in the study, with 10 randomised to an osteopathic manipulative therapy group and 10 to a sham control group. Eight normal subjects free of Parkinson disease also participated. All subjects with Parkinson disease stopped medications for 12 h before starting gait analysis. The treatment group and the eight normal subjects received one standardised session lasting approximately 30 min. The techniques used in the study were direct, articulatory MET and myofascial techniques, targeting the spine, shoulder and joints of the external limbs, including the ankles and wrists. Gait analysis was performed pre- and post-treatment. Those subjects receiving the active treatment protocol had a significant increase in gait parameters relating to stride length and limb velocity for both upper and lower limbs. The study showed that these methods improve gait parameters in people with Parkinson disease. More research is needed to investigate the longer-term effects and which techniques, or combinations of techniques, work best for improving gait in Parkinson disease. A more current study (Yao et al., 2013) confirmed benefits for this condition.

Comment: This small study highlights the potential for MET, together with other modalities, being usefully employed in treatment of patients with serious neurological problems. Since this study was published, ongoing research (Carnevali et al., 2020; Cerritelli et al., 2020; Tramontano et al., 2020) investigated the interface of manual therapy such as MET with neurological stimulation and processing.

- Knebl et al. (2002) conducted a randomised controlled clinical trial testing the effectiveness of a series of shoulder mobilisations known as the Spencer technique, a traditional osteopathic protocol for treating chronic shoulder restriction and pain. In the study, 29 elderly patients with pre-existing shoulder problems were randomly assigned to Spencer treatment, combined with the additional feature of isometric muscle contractions during treatment, or a control group without MET. The placebo group were placed in the same positions as those receiving the active treatment, but without MET ('corrective force') being part of the protocol. Following five treatment sessions, each of 30 min duration, over a period of 14 weeks, both groups showed significant improvement in shoulder range of motion (ROM) and reduced pain by week 14. However, when the subjects returned 5 weeks following the end of the study, the treatment group (those with added MET) were found to have maintained significant improvements in (ROM), while the placebo group did not: 'Those subjects who had received MET demonstrated continued improvement in ROM, while the ROM of the placebo group decreased'.

Comment: (1) The successful use of MET in this population group highlights its ease of application, safety and comfort. (2) The continued improvement of function following the treatment period in the treatment group hints at an ongoing self-regulating process and is deserving of further study. Current research (Iqbal et al., 2020; Schwerla et al., 2020) supports the findings related to management of shoulder pain and limits in motion.

- Lenehan et al. (2003) examined whether a single application of thoracic MET could significantly increase ROM in asymptomatic volunteers with restricted active trunk rotation. Fifty-nine volunteers were randomly assigned to either treatment (MET) or control groups. Blinded pre- and post-active trunk rotation measures were recorded using a reliable measuring device (see Fig. 2.2).

The participant was instructed to place his or her hands on opposite shoulders and to relax. The treating examiner used palpatory assessment to achieve a spinal neutral range, and when this was achieved the restricted rotation barrier was engaged. The treating examiner resisted a five-second isometric contraction of side-bending by the participant. After each isometric effort, a new rotation barrier was engaged, and the participant repeated the isometric contraction. Four repetitions were completed on each volunteer. Immediately following treatment post-test ROM measures were recorded.

Results showed that a significantly increased range of active trunk rotation ($P < .0005$) was achieved in the direction of restricted rotation, but not on the non-restricted side or in the untreated controls. This study supports the use of MET to increase restricted spinal rotation ROM.

Comment: The use of a resisted side-bending contraction, which allowed immediate increased range into previously restricted rotation, is of particular interest and

BOX 2.1 **Reflections and Commentaries on 20 Years of Research—cont'd**

Fig. 2.1 Muscle energy techniques *(MET)* treatment of a restriction involving limitation of L3 flexion, side flexion and rotation to the right. Practitioner palpates for barrier with contacts on the transverse processes of L3.

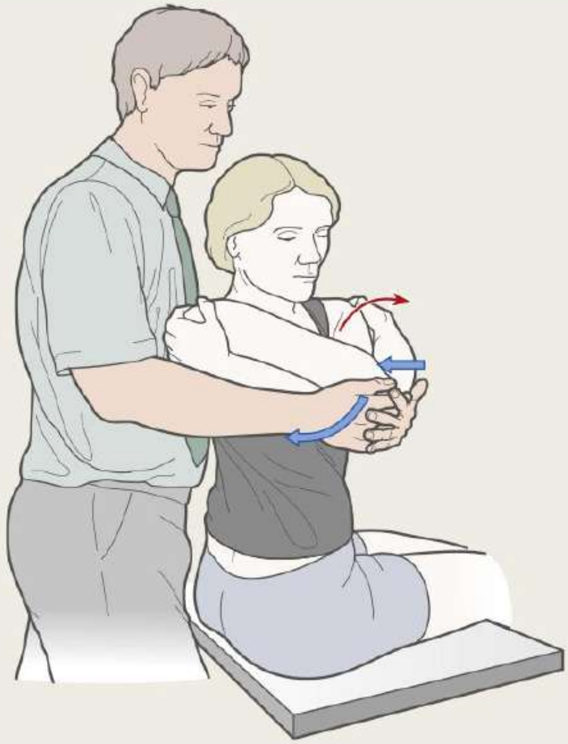

Fig. 2.2 Practitioner eases seated patient into rotation to easy, first-sign-of-resistance barrier. A side-bending isometric contraction is then introduced followed by engagement of new rotation barrier.

significance in this study. This phenomenon is discussed in more detail in Chapter 6, where use of counter-intuitive directions of isometric effort are recommended, in addition to the more obvious possibilities, for example, the use of a resisted rotation contraction, towards or away from the barrier, for a rotation restriction (Figs. 2.1 and 2.2).

- Murphy et al. (2006) described the clinical outcomes of patients with cervical radiculopathy treated non-surgically, including the use of MET or high velocity low amplitude (HVLA) manipulation, together with various exercise strategies, neural mobilisation, self-applied over-the-door traction, ice applications and/or medication (see Chapter 8 for more on Murphy's work).

The overall approach was minimalist in nature; only those treatment approaches that were deemed to be necessary as a result of specific clinical findings were applied. The decision as to which treatments were to be used in any particular patient was made on an individual basis.

The outcomes showed:

Seventeen patients (49%) reported their improvement as 'excellent' and another 14 (40%) did so as 'good'… 24 of 31 (77.4%) patients had a clinically significant improvement from baseline to the end of treatment… [and] at long-term follow-up [improvement] was clinically significant for 25 of the 27 (92.6%) patients.

Comment: This example of patients with serious pain conditions being treated in ways that matched their clinical needs epitomises ideal good practice. The fact that MET played a part in this eclectic therapeutic mix, in those cases where HVLA was deemed unwise, emphasises (1) its relative safety features, (2) its ease of use in highly sensitive settings and (3) the importance of seeing MET as a flexible, safe and effective modality, sometimes used alone, but more often complementing

(Continued)

BOX 2.1 Reflections and Commentaries on 20 Years of Research—cont'd

other manual methods of patient management. Current evidence (Degenhardt et al., 2018; Smith et al., 2019) indicates that the overall incidence of serious adverse events in manual therapies is low.

- Smith & Fryer (2008) tested the usefulness of extending a hamstring muscle stretch, following a MET contraction, from 5 s, as suggested by Greenman, to 30 s, as suggested by Chaitow:

  Both techniques appeared to be equally effective in increasing hamstring extensibility, [with] sustained improvement one week following the initial treatment. The findings suggest that altering the duration of the passive stretch component does not have a significant impact on the efficacy of MET for short-term increases in muscle extensibility. Both these post-isometric techniques were superior to passive stretching in this group of subjects.

Comment: Both sustained (30 s) and brief (5 s) post-isometric contraction stretching of the hamstrings produced lasting extensibility in asymptomatic individuals, and more effectively than passive stretching. Whether the brief (5 s) stretching protocol would be equally beneficial in situations involving chronic, indurated muscles remains an open question. The hamstrings have been an ongoing target area for MET research, as seen in Joshi et al. (2017) and Naweed et al. (2020).

- Wright and Drysdale (2008) employed a randomised, controlled protocol in order to evaluate whether either or both of the two MET variations (1) use of the agonist (piriformis itself), supposedly to assess postisometric relaxation effect (PIR), or (2) use of the antagonist, supposedly to assess reciprocal inhibition effects (RI), could significantly enhance hip internal rotation ROM, when applied to the piriformis muscle in asymptomatic young men. The outcomes showed that these methods were equally successful in producing significant increases in ROM ($P < .0001$) (see Fig. 2.3).

Comment: (1) The purported mechanisms (PIR and RI) are disputed as being the means whereby increased ROM is achieved following MET. This is fully discussed in Chapter 4 and elsewhere, including in this chapter. (2) Despite PIR and RI being questioned as the actual mechanisms involved, the results, showing that use of the agonist, or the antagonist, in the isometric contraction, can be equally influential. This has potential clinical relevance; for example, in a setting where one of these contractions proves difficult or painful to perform, the other might offer an alternative choice. Despite the subjects being asymptomatic, these findings point to a potential clinical strategy where piriformis ROM is limited, or where pain is present.

Fig. 2.3 Practitioner eases patient's leg into internal rotation at the hip, until the resistance barrier for piriformis is reached. The patient introduces external hip rotation by lightly bringing the foot/lower leg towards a neutral position against firm resistance from the practitioner.

- Murphy et al. (2009) describe, in the treatment of 49 patients with lumbar radiculopathy, secondary to herniated disc followed-up for 14.5 months post-cessation of treatment. The use of MET is noted as follows:

  Joint manipulation may be used if segmental provocation manoeuvres reproduced all, or part of a patient's pain and centralization of pain was not found on end-range loading examination. This treatment typically involved lying the patient in the side posture position with the side being treated up and applying either a high-velocity, low amplitude 'thrust' or a low-velocity muscle energy manoeuvre.

Outcomes were impressive:

  In this study, clinically meaningful improvement in pain was found in 79% of patients, and clinically meaningful improvement in disability was found in 70% of patients.

BOX 2.1 Reflections and Commentaries on 20 Years of Research—cont'd

The authors further comment that:

The fact that outcomes were as good or better at long-term follow-up is significant because it suggests that patients treated according to the [diagnosis-based clinical decision rule] generally do not need ongoing 'maintenance' or 'supportive' care to maintain functional improvement.

Comment: (1) Once again, MET is seen as part of the therapeutic mix, selected according to assessed and perceived clinical needs, and in this clinical setting, not as a stand-alone approach. (2) The practical relevance of integrated protocols such as these is demonstrated by the long-term outcomes. See Chapter 8 for the therapeutic perspective of MET, by the lead author (Dr D. Murphy) of this and the previously reported research study.

- Shadmehr et al. (2009) compared the effects of 10 sessions of static stretching (15 subjects) and 10 sessions of MET (15 subjects) using 50% voluntary isometric contractions of the hamstring to assess the effects on extensibility in asymptomatic young females (aged 20–25 years). Both treatment methods produced significant improvement in the flexibility of the hamstrings ($P < .01$), with no appreciable difference observed between the two methods.

Comment: (1) Once again, we have asymptomatic individuals as the subjects, making interpretation into clinical work difficult. (2) The claim that those treated with MET utilised 50% of available strength requires consideration. A study by Sheard et al. (2009) demonstrated that athletes who were asked to produce varying degrees of voluntary contraction forces were wildly inaccurate in the degree of force that they actually produced. Contraction intensities of between 10% and 100% of maximal voluntary contraction (MVC) have been proposed for use in MET and PNF protocols (Sheard et al., 2009).

The researchers reported that:

Our findings indicate that this group of athletes displayed a poor level of compliance to varying therapist requested contraction intensities with respect to both accuracy and consistency.

This does not negate the outcomes of the Shadmehr study, reported above, but raises a question regarding the use of requests/instructions, such as 'I would like you to push in this direction, with half (or whatever) your available strength'.

- Hunt and Legal (2010) conducted a randomised, single-blinded, controlled study, involving 80 subjects assessed as presenting with piriformis spasm, together with the presence of myofascial trigger points in that muscle. Twenty-eight subjects were treated using MET, with the objective of relaxing piriformis; 27 subjects were treated with a thrust technique that applied rapid stretch to piriformis; the remainder (controls) were treated by a placebo measure involving a HVLA thrust technique applied to T4. Outcomes involved assessment of pressure pain threshold (using algometry); hip internal rotation range (goniometry); and pain levels using a visual analogue scale (VAS). The MET and HVLA thrust methods both produced an equally significant increase in piriformis extensibility, together with pain relief, compared with the placebo group ($P > .05$).

Comment: MET in treatment of trigger points has been shown in many studies to be an effective means of achieving increased ROM, as well as of trigger point deactivation. Recent research (Alghadir et al., 2020; Wendt & Małgorzata, 2020) also appears to support this.

See Chapters 5 and 6 for additional options involving MET in treatment of piriformis and of myofascial pain.

- Moore et al. (2011) studied the effects of MET in treatment of shoulder ROM of amateur (college) baseball players. A single application of MET was used on the glenohumeral joint (GHJ) horizontal abductors (19 subjects) and the GHJ external rotators, to improve ROM (22 subjects). The results showed single applications of an MET for the GHJ horizontal abductors provides immediate improvements in both GHJ horizontal adduction and internal rotation ROM, in asymptomatic collegiate baseball players.

Comment: (1) ROM increased significantly in both external rotation and horizontal adduction movement, followed a single MET application *involving isometric contraction of only the horizontal abductors*, suggesting a process that offers benefit to other soft tissues than those directly involved in the contraction. This phenomenon will be echoed elsewhere in the book, suggesting that our understanding of the mechanisms involved in MET remain incomplete. (2) How this study of the effects of MET in asymptomatic individuals would translate into settings with symptomatic subjects is open to question; however, the study by Knebl et al. (above) hints at the likelihood of a beneficial influence on dysfunction.

- Rajadurai (2011) conducted a randomised clinical trial to evaluate the effectiveness of MET in reducing pain and improving maximal mouth opening (MMO) in patients with temporomandibular dysfunction (TMD). The sample consisted of 40 participants, aged 20–30 years

(Continued)

BOX 2.1 Reflections and Commentaries on 20 Years of Research—cont'd

(mean age 25.5 ± 2.96) diagnosed with TMD of less than 3 months' duration. Participants were treated with MET, which included postisometric relaxation and reciprocal inhibition (contractions away from, and towards the restriction barrier) on alternate days, for 5 weeks. Before the commencement of the treatment, and at the end of each week, subjects were evaluated for pain intensity using a VAS, and MMO by measuring the inter-incisal distance. There was a significant reduction of pain ($P < .05$) at the end of each week as measured by the VAS. The MMO measurements showed significant and continued improvement in ROM ($P < .05$) at the end of each week when compared to the baseline measurements.

Comment: The successful outcomes achieved via application of MET in treatment of a painful joint restriction, illustrates the potential value of this approach and hints at simple self-application possibilities. Such possibilities are discussed further in Chapter 14. There was no control group in this study, limiting its significance.

- Parmar et al. (2011) evaluated the relative benefits of isolytic MET (isotonic eccentric) stretching compared with standard passive stretching, in order to increase knee ROM and decreased pain in over 50 cases following surgery for hip fracture. It was found that MET was more effective in pain reduction ($P = .003$) and that both methods increased ROM equally ($P \geq .05$).

Comment: As explained in the notes on mechanotransduction elsewhere in this and other chapters, the use of isotonic eccentric contractions is a key part of MET methodology, and this study offers validation in a complex clinical setting.

- Zuil Escobar et al. (2010) evaluated the effects of MET applied to the upper trapezius (see Fig. 2.4) of 35 asymptomatic subjects with latent upper trapezius myofascial trigger points. The subjects were randomised into two groups: one was treated with an MET, while the other was not treated. Pressure pain threshold was evaluated using an analogue algometer before the intervention, 5 min post-intervention and 24 h post-intervention. The treatment group showed a significant increase in pressure pain threshold 5 min after intervention but this disappeared at 24 h post-intervention. Studies investigating MET and efficacy related to treatment of myofascial trigger points are ongoing (Abd El-Azeim et al., 2018; Vivanco-Coke et al., 2020).

Comment: This study highlights several frustrating features of MET research studies, as well as several possibly significant pieces of information. (1) The finding that in a large group of asymptomatic individuals it was possible to identify latent trigger points in upper trapezius muscles, which clinical experience suggests is one of the most common sites of these features, was of particular interest. (2) The asymptomatic nature of the subjects involved in the study makes it more difficult to relate the outcomes of the study to real-life clinical settings, since few such patients (asymptomatic) present for treatment. (3) The findings suggest that, while briefly beneficial, MET alone may not be the ideal method for treatment of myofascial pain. However, a combined approach may be more beneficial, thus highlighting the importance of integrated approaches that may usefully incorporate MET, such as the integrated neuromuscular inhibition technique (INIT) (Chaitow, 1994) methods detailed in Chapter 14 and now validated following a randomised controlled study in which active trigger points in upper trapezius were successfully treated (Nagrale et al., 2010). INIT continues to be an important point of study. Abd El-Azeim et al. (2018) found that INIT was superior to kinesiotaping. However, a combination of both would seem to be more beneficial. A further study on integrated INIT demonstrated positive results (Chavan et al., 2019), as did a 2020 study on INIT combined with ice massage (Al-Najjar et al., 2020).

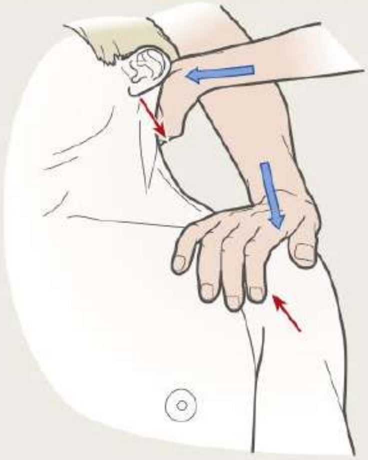

Fig. 2.4 The patient's head and neck are side-flexed and rotated right to the first-sign-of-resistance barrier of upper trapezius. The practitioner offers counter-pressure as the patient attempts to bring the shoulder and neck towards each other in an isometric contraction, after which a new barrier is engaged, or stretching is introduced depending on the status of dysfunction, whether acute or chronic, as explained in the text.

It is becoming clearer that combined methods provide more efficacy than any one single approach. The present study, along with the other three mentioned here, appear

BOX 2.1 **Reflections and Commentaries on 20 Years of Research—cont'd**

to conclude that INIT coupled with conventional treatment plays an important role in reduction of trigger point activity.

- Küçükşen et al. (2013) conducted a comparison study to determine the short- and long-term effectiveness of the MET compared with corticosteroid injections for chronic lateral epicondylitis. The study looked at 82 patients treated with either eight sessions of MET or one corticosteroid injection. A variety of outcome measures were used, and importantly, there was a 1-year follow-up. Measurements were performed before beginning treatment and at 6, 26 and 52 weeks afterwards. Statistically significant improvements were observed in both groups over time. The patients who received a corticosteroid injection showed significantly better effects at 6 weeks, but benefits declined thereafter. Interestingly, at the 26- and 52-week follow-ups, the patients who received MET were statistically significantly better in terms of grip strength and pain scores than those who received the injection.

Comment: This study has multiple points of interest. The 1-year follow-up indicated that MET has the potential for sustained benefits. Many studies indicate that manual therapy tends to offer only short-term results. The comparison to steroid injections is also interesting. Since there are side-effects related to these types of injections, having evidence that MET can provide long-term benefits, as opposed to the more short-lived injection benefits, supports more treatment options. It is also important to note that MET was successful in supporting function and reducing symptoms in an inflammatory-based condition that often becomes more fibrotic in chronic conditions. It may be possible to cautiously extrapolate this information to similar conditions.

- A study by Sewani & Shinde (2017) investigated the effect of hot pack hydrotherapy and MET in subjects with sacroiliac joint dysfunction compared to conventional therapy. Thirty-four subjects aged between 20 and 45 years were allocated into two groups and treated with moist hot packs (MHP), MET, core muscle strengthening and general mobility exercises for 10 days. Assessment was done on the 1st day pre-treatment and 10th day post-treatment. Both groups showed improvement but there was significant improvement in group treated with HMP and MET. A more current study also found that MET along with conventional or other physiotherapy treatment can be helpful in reducing pain and improving function in patients with sacroiliac joint dysfunction (Kansagara & Patel, 2019).

Comment: Effectiveness of MET in treating sacroiliac joint dysfunction needs to be more clearly established with higher quality research. However, the two studies taken together highlight MET as an aspect of multimodal care and the cumulative and synergistic effects of such integration.

- Hidalgo et al. (2017) conducted a systematic review related to non-specific neck pain treatment efficacy using a variety of manual therapy methods, including MET alone or in combination with exercise. The review targeted research from 2000 to 2015. Neck pain types from acute to chronic are included. Methods compared HVLA, mobilisation, mobilisation with movement (MET category) and soft-tissue techniques (ischaemic compression, strain-counterstrain). As described by Zuil Escobar et al. (2010), combined and multimodal interventions yielded better results for pain relief, function, satisfaction with care and general health in comparison to exercise or MT alone for patients with chronic neck pain.

Comment: This systematic review is helpful in that, instead of combining all manual therapy techniques within a single group, the authors sub-categorised them into four distinct groups for comparison with or without exercise. Overall, moderate evidence supports methods such as MET when combined with exercise. The review supports using methods such as MET as part of integrated approaches. Application of clinical reasoning to individual cases determines the most appropriate styles and combinations of manual therapy and exercise. It is becoming more evident that combining different forms of manual therapy with exercise is better than using manual therapy alone, demonstrating that both active and passive forms of therapy are synergetic.

- A systematic review by Thomas et al. (2019) analyses multiple studies to assess the efficacy of MET. The literature search covered the time period between 1981 and 2018. A total of 26 studies were considered eligible and included in the quantitative synthesis: 14 regarding symptomatic patients and 12 regarding asymptomatic subjects. Quality assessment of the studies through the PEDro scale observed a 'moderate to high' quality of included records. The review concludes that METs are effective in improving reported pain, disability and joint ROM in both asymptomatic and symptomatic patients. The studies evaluated in this review have provided evidence that METs are specifically effective for alleviating chronic pain of the lower back and neck and chronic lateral

(Continued)

BOX 2.1 Reflections and Commentaries on 20 Years of Research—cont'd

epicondylitis. There is also evidence supporting MET as a beneficial therapy for reducing acute lower back pain and improving the related disability indexes. However, further evidence is needed to confirm MET as an effective treatment for plantar fasciitis and other musculoskeletal disorders.

Comment: As concisely described in the systematic review:

> *The exact mechanism for MET-induced pain relief is still unknown, although it has been proposed that MET act on joint proprioceptors and mechanoreceptors that will result in an effect on descending pathways, changing the motor programming of the target joint. It has also been advocated that the reduction of pain and increased mobility are due to changes in the viscoelastic properties of the soft tissue followed by the application of the technique; the mechanism for increased flexibility has been attributed to an increase in stretch tolerance.*

In practice, the clinician may use a variety of MET applications to reduce pain and increase ROM. These are applied to a variety of pathological conditions and on asymptomatic subjects. There is, however, limited knowledge on their effectiveness and which protocol may be the most beneficial. The review did provide guidance to support the clinical reasoning process helpful to determine when MET approaches are indicated and what combinations of methods to use. Dosing was described by the number of sessions for a typical MET prescription. In this review that number varied from 1 to 18 sessions.

- Park and Lim (2020) looked at proprioceptive neuromuscular facilitation (PNF) stretching at low intensities, targeting hamstring flexibility to assess the effect of low intensities (40% and 10% of maximum voluntary isometric contraction, MVIC) of PNF stretching on hamstring muscles and to assess the effect of standing toe touch on the duration of hamstring flexibility. Sixty-four healthy adults were divided into four groups: 40% intensity PNF stretching (P40), 10% intensity PNF stretching (P10), 40% intensity PNF stretching with toe touch (P40 with TT) and 10% intensity PNF stretching with toe touch (P10 with TT). Hamstring flexibility was measured using the active knee extension PNF stretching at low intensity, approaching 40% of MVIC, led to more flexibility than 10% MVIC.

Comment: One of the differences between PNF and MET is strength of contraction. PNF is often described at maximal contraction effort and MET more within the parameters of this study of 10%–40% maximum voluntary isometric contraction. PNF was applied more like MET indicating benefit at low intensities. This study points to a potential blending of the two methods rather than using them as distinct and unique disciplines.

should commence at this point (Stiles, 2009). Parsons and Marcer (2005) note that active movement stops at the 'physiological barrier' determined by the tension ('bind') in the soft tissues around the joint (e.g. fascia, muscles, ligaments, joint capsule), with normal ranges of movement of a joint ('ease') taking place within these physiological barriers. Factors such as exercise, stretching and age – as well as pathology or dysfunction – can modify the normal physiological range; however, it is usually possible to passively ease a joint's range beyond the physiological barrier by stretching the supporting soft tissues until the anatomical limit of tension is reached (see Fig. 2.5A and B).

Clinically, it is worth considering whether restriction barriers ought to be released, in case they might offer some protective benefit.

The elements that make up standard isometric MET therefore always include:

1. Identification of a resistance barrier
2. The use of an isometric, or sometimes isotonic, contraction
3. A response to that contraction, which appears to facilitate easier movement to a new barrier (or past a new barrier, into stretch by reduced resistance to stretch) or an increased tolerance to the stretch sensation (Magnusson et al., 1996a; Weppler & Magnusson, 2010; Singh & Kaushal, 2020).

A number of facilitating elements have also evolved in the clinical application of MET, including the use of respiratory and visual synkinesis. These are briefly outlined in this chapter and explained further in the clinical chapters (see Chapters 5 to 9 and 11).

Variables

The variables that exist within those three MET elements (barrier identification, isometric or isotonic contraction, subsequent action) include the surprisingly contentious decision regarding how to identify the

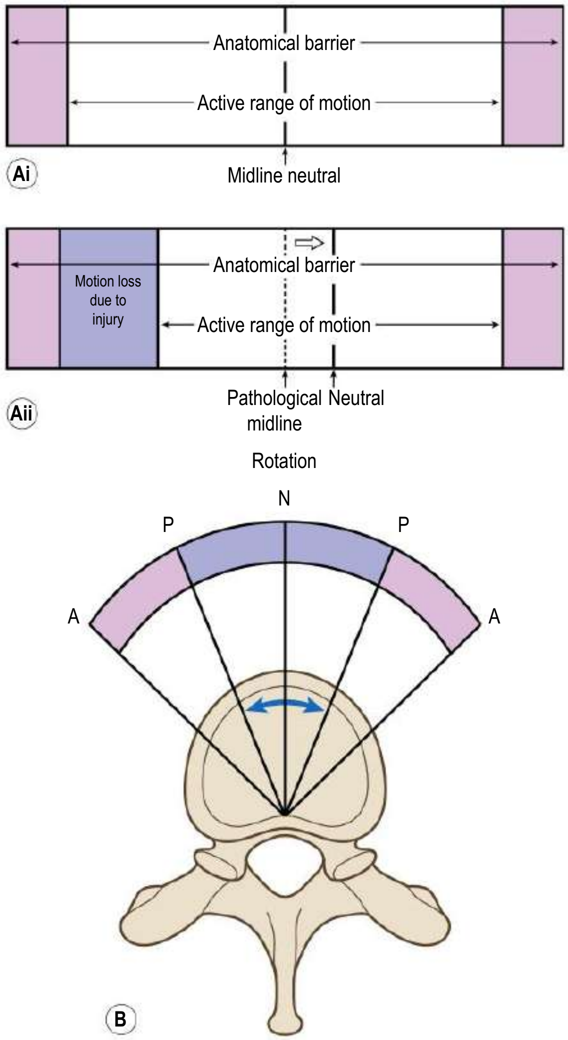

Fig. 2.5 (A) Motion barrier concepts: *Ai,* Normal symmetrical motion. *Aii,* Loss of motion due to injury, with lost motion on one side involving somatic dysfunction. Over time, tissue changes occur (contracture, induration, fibrosis, etc.). Additional adaptations then influence adjacent and distant structures. (Adapted, with permission, from Greenman 1996.) (B) Schematic representation of vertebral rotation barriers. Normal motion occurs between physiological barriers. Any movement beyond anatomical barriers produces physical damage. In muscle energy techniques *(MET)*, usage barriers would commonly be short of the physiological barriers, depending on restraints imposed by soft tissue or structural joint changes. *A,* Anatomical barrier; *N,* neutral; *P,* physiological barrier – where passive motion occurs.

resistance or restriction barrier that should be used as the starting point for the isometric or isotonic contraction. There are descriptions of MET where the barrier commences from an easy 'feather-edge' position, as well as from a position in which the restraining soft tissues are actually stretched (a 'bind' barrier) at the start of the isometric contraction. This latter approach raises several clinical questions:

1. If, as may be the case, the soft tissues held in a stretched position before being required to contract are already hypertonic, and possibly ischaemic, there is a risk that the contraction effort might provoke cramping. This would appear to be a possibility, or even a likelihood, in muscles such as the hamstrings. The author of this chapter suggests that it would be a safer option to employ light contractions, starting with the muscle group at an easy end-of-range barrier, rather than at stretch.
2. The requested contraction effort from the patient would be more easily initiated and achieved, with the muscle (group) in a mid-range or easy end-of-range position, rather than at an end-of-range involving stretch, at the start.

Both comfort and safety issues would appear to support clinical use of the 'ease' barrier rather than a firmer 'bind' barrier, provided the outcomes were not compromised, and clinical experience as well as numerous studies offer support for the 'ease' option.

It is from the identified barrier that the isometric, or possibly isotonic, contraction will be initiated by the patient, on instruction, by the practitioner, with the direction, the degree of force to be employed, and the duration of the contraction, decided and controlled by the practitioner – together with the provision of firm counter-pressure. It is worth emphasising at the outset that the patient's force and '*muscle energy*', – and not that of the practitioner, who offers firm counterforce – should *always* be harnessed; guidelines for ensuring this are provided in later chapters.

Further choices are required following the contraction, including whether a stretch past the barrier should be introduced and, if so, to what extent (amplitude), for how long (duration), and whether the process should be repeated one or more times. Some variables relate to the answers to these questions:

- Is the problem acute or chronic?
- Is the target structure for MET soft tissue or joint?

Some answers to these questions are provided in this chapter, with the issues explored further in Chapters 5 to 7 with evidence offered for the choices that are considered the most appropriate in different settings, *where such evidence exists*. Where it does not, the recommendations are based on clinical experience. In the end, each practitioner's clinical experience will guide therapeutic decision-making, supported by research evidence where this is available, or by the clinical experience of others. This text attempts to offer a broad range of such information from which to choose, and with which to experiment as decisions are made regarding the ideal barrier to employ in different clinical settings.

MET – AN EVOLVING APPROACH

Chapter 3 provides the historical context that helps explain the evolutionary nature of MET, as presented in this text, as well as of the variations that have emerged in a variety of clinical settings in which there is indicative evidence of MET usefulness in treatment of muscle dysfunction (see Chapter 6), joint dysfunction (see Chapter 7), acute spinal trauma (see Chapter 8), chiropractic rehabilitation (see Chapter 9), surgical rehabilitation (see Chapter 10), physical therapy (see Chapter 11), massage (see Chapter 12) and athletic training (see Chapter 13) for example.

ADAPTATION LEADING TO SOMATIC DYSFUNCTION

The tissues of the body respond to applied demands (stressors) originating from previous overuse, misuse, abuse (trauma) and disuse, together with a combination of inherited and acquired features and experiences that will have merged in the individual to create the problem that is being assessed, palpated or observed.

The structures and functions being evaluated represent the unique characteristics of a person's genetic inheritance, involving the biochemical, psychosocial and biomechanical make-up, onto which have been overlaid all the developmental and maturational experiences of life, including acquired habits and patterns of use (e.g. postural or respiratory), ergonomic, work and leisure stresses, as well as the results of injuries, surgeries, emotional burdens and more.

Tissues may gradually change from a state of *normotonicity* to a palpably dysfunctional state, at times involving hypertonicity, and at others hypotonicity, along with altered firing sequences, modified motor control, abnormal postural and/or movement patterns and ultimately dysfunctional chain reactions. What emerges is a picture of impaired or altered function of related components of the somatic framework: skeletal, arthrodial, myofascial, as well as related vascular, lymphatic and neural features. The outcome can be summarised by the term '*somatic dysfunction*' (Ehrenfeuchter et al., 2011). Such changes almost always demonstrate functional, sometimes visible, often palpable evidence that can frequently be assessed in order to guide the practitioner towards clinical decision-making as to what form of management may be most appropriate.

From an osteopathic perspective Parsons and Marcer (2005) note that '*it is through the summation of both quantitative and qualitative findings that one obtains an indication of the nature and age of the underlying dysfunction. Within the context of acute and chronic somatic dysfunction, MET will be seen to offer tools that can assist in normalization of dysfunction, pain management and rehabilitation*'.

Grieve's Decompensation Model

Gregory Grieve became a chartered physiotherapist in 1952. Grieve (1986) presciently offered a perspective on the evolution of chronic dysfunction in many cases. He described the example of a typical patient, presenting with pain, loss of functional movement or altered patterns of strength, power or endurance. Grieve suggested that, all too commonly, this individual would either have suffered major trauma which had overwhelmed the physiological tolerances of relatively healthy tissues, or might be displaying '*gradual decompensation, demonstrating slow exhaustion of the tissue's adaptive potential, with or without trauma*'. As this process continued, Grieve explained that progressive postural adaptation, influenced by time factors and possibly by trauma, would lead to exhaustion of the body's adaptive potential, thus resulting in dysfunction and, ultimately, symptoms.

Grieve has correctly noted that therapeutic attention to the tissues incriminated in producing symptoms often gives excellent short-term results; however, '*unless treatment is also focused towards restoring function in asymptomatic tissues responsible for the original postural adaptation and subsequent decompensation, the symptoms will recur*'.

MET's influence on such a sequence of adaptive changes might include the ability of carefully applied isometric contractions, elongation influencing resting tone and possibility mild stretch, to positively influence features such as excessive tone, fascial shortening, inflammation and pain (Simons, 2002; Hoeger Bement et al., 2008, 2011; Wang et al., 2020).

Repetitive Lumbar Injury – an Example of Failed Adaptation

In discussing a form of low back pain that is described as repetitive lumbar injury (RLI), Solomonow et al. (2011) outline the aetiology of a complex multi-factorial syndrome that fits the model of adaptive overload. This involves an adaptation sequence in which prolonged cyclic loading of the low back can be shown to induce a process of *creep* – defined as continued deformation of a viscoelastic material under constant load over time – in the spinal tissues (Sánchez-Zuriaga et al., 2010; Larson et al., 2020), reduced muscular activity, triggering spasms and reduced stability, followed by acute inflammation and tissue degradation (Fung et al., 2009), as well as muscular hyperexcitability and hyperstability (Li et al., 2007). These adaptive changes are seen, in animal studies (Solomonow, 2011) and in humans (Solomonow et al., 2003), to be a response to rapid movement, bearing high loads, numerous repetitions and short rest periods, behaviours that are not uncommon in many common work and leisure/athletic activities. The conclusion is that viscoelastic tissues ultimately fail via a process involving the triggering of inflammation, due to overuse, a process that appears to initiate the mechanical and neuromuscular characteristic symptoms of the disorder (Bove et al., 2019).

In contrast, Solomonow et al. (2011) found that low magnitude loads, short loading durations, lengthy rest periods, low movement velocity and few repetitions, did not constitute significant risk factors, yet nevertheless triggered transient stability deficits, and pro-inflammatory tissue degradation. It is suggested that it might be more appropriate to designate these conditions as low risk, instead of no risk (Solomonow et al., 2011).

In perspective, RLI is seen to be a complex multi-factorial syndrome, a clear example of adaptation to imposed demands that exceed the ability of the tissues involved to respond. Repeated bending activities in daily living appear to change both structure (ligaments, discs) and function (protective spinal reflexes) (Hodges & Danneels, 2019; Surbeck et al., 2020).

MET can be seen to offer various potential benefits as a therapeutic intervention in such a spectrum of progressive dysfunction. For example, improving restricted mobility (Lenehan et al., 2003; Thomas et al., 2019), possibly reducing excessive inflammatory responses (Fryer & Fossum, 2010; Licciardone et al., 2010), while simultaneously enhancing motor control (Wilson et al., 2003) and balance related to poorly coordinated neuromuscular control, which may alter the normal postural stability of the spine (Hlaing et al., 2020). Altered proprioceptive stimuli elicited increased activation of brain areas involved in threat detection and fear processing in some individuals, which was associated with poor proprioceptive postural control (Goossens et al., 2019). Unless the patterns of use that were fuelling this degenerative process were modified, the MET interventions would offer short-term symptomatic relief at best.

A Therapeutic Formula: Reduce Adaptive Load and Enhance Function

A therapeutic formula is proposed for the clinician who is confronted with chronic adaptive changes of the sort highlighted by Grieve or Solomonow. It is suggested that the focus should be on both reducing adaptive demands – altering the patterns of behaviour that have produced or which are maintaining dysfunction – while at the same time focusing on enhancement of function, working with the self-regulatory systems of the body, so that those adaptive demands can be better managed by the body (Chaitow, 2008). The only other therapeutic possibility would seem to be symptomatic attention. It is in the enhancement of function that MET can be seen to have a potential role. In simple terms, musculoskeletal tissue absorbs or adapts to forces applied to it, and MET can modify these changes (Iqbal et al., 2020). Examples include dysfunctional shoulders of the elderly (Knebl, 2002), following sporting injuries (Curcio et al., 2017) or involving hamstring problems (Smith & Fryer, 2008; Rabia et al., 2019).

Functional Independence

Functional independence is the ideal objective of patient care. This implies the ability to be able to perform the tasks of daily life as well as being socially mobile and active, encompassing household activities, recreational activities and the demands of employment, where appropriate (Waddell & Burton, 2005; Tousignant-Laflamme et al., 2017). Clinical objectives ideally focus on building activity tolerance rather than merely providing symptomatic relief, therefore helping patients to regain independent function. It is within that context that MET operates – as part of a continuum from dysfunction to function – removing or modulating obstacles to recovery (pain, reduced ranges of motion, strength and motor control deficits) and not as an end in itself that is aimed purely at symptomatic relief although, at times, that is a perfectly appropriate clinical objective (LaStayo et al., 2014; Dal Farra et al., 2021).

To be clear, MET is patient-centred and aims to be part of a process that promotes restoration of (ideally pain-free) function. Within that context, attention to local somatic problems that retard functional rehabilitation becomes a priority.

STAR and TART Assessments

Several mnemonics attempt to summarise the findings in somatic dysfunction; none of these is complete, but they are useful as *aides-mémoires*.

In the context of emerging or established somatic dysfunction, two slightly different mnemonics (actually acronyms) are used in osteopathic medicine to remind the clinician of some of the key signs that require evaluation in the process of clinical decision-making, alongside evidence gathered from the patient's history, together with other clinical assessments.

These are STAR and/or TART.

STAR (Dowling, 1998)

Sensibility changes: What subjective changes accompany this dysfunction? Is there pain, stiffness, tenderness, discomfort, weakness, etc.?

Tissue texture abnormality: Are the tissues hot, cold, tense, flabby, oedematous, fibrotic, indurated, in spasm, hypertrophied, etc.?

Asymmetry: Is there an obvious difference compared with contralateral tissues?

Restricted range of motion (ROM): What is the degree (and quality) of pliability, mobility, stability, extensibility, ROM, compared with normal ROM? Does the quality of end-feel offer additionally useful information?

MET methods might be able to modify many of these indicators of dysfunction.

TART (Chase, 2009; Sandhouse, 2011)

Tissue texture abnormality: Are the tissues hot, cold, tense, flabby, oedematous, fibrotic, indurated, in spasm, hypertrophied, etc.?

Asymmetry: Is there an obvious difference compared with contralateral tissues?

ROM abnormality: What is the degree (and quality) of pliability, mobility, stability, extensibility, ROM, compared with normal ROM? Is it hyper- or hypomobile? Does the quality of end-feel offer additional useful information?

Tenderness: Are these tissues unnaturally sensitive, tender, painful (or numb), etc., on applied pressure, or when actively or passively moved?

MET methods might be able to modify many of these indicators of dysfunction.

Differences? There are subtle differences between the constituent elements of these two acronyms, with STAR offering some subjective feedback relative to *Sensibility*, which is not quite the same as *Tenderness* in the TART sequence. Whatever findings emerge from the assessments these sequences demand need to be overlaid on a background of the medical history of the individual, taken together with the findings from normal clinical tests, examinations and evaluations. In particular, the way MET is applied differs markedly in acute and chronic settings.

Are these features of somatic dysfunction real? While the characteristics of STAR and TART may appear elegantly convincing, the validity of the cluster of signs having relevance has also been tested.

Fryer et al. (2004) were able to confirm that sites in the thoracic paravertebral muscles, identified by deep palpation as displaying 'abnormal tissue texture', also showed greater tenderness than adjacent tissues, thus confirming the *Tenderness* of TART and *Sensibility* of STAR, associated with *Texture* changes in both.

In a follow-up study, Fryer et al. (2005) examined the possibility that tissue texture irregularity of paravertebral sites might be due to greater cross-sectional thickness of the paraspinal muscle bulk. Diagnostic ultrasound showed that this was not the case. A further study (Fryer et al., 2006) examined the electromyography (EMG) activity of deep paraspinal muscles lying below paravertebral thoracic muscles with 'altered texture', which were also more tender than surrounding muscles. This demonstrated increased EMG activity in these dysfunctional muscles (i.e. they were hypertonic). However, in a 2010 study no differences in resting EMG activity were found in the deep paraspinal muscles underlying sites that were identified with palpation as either normal or abnormal. The results of this study do not support previous EMG investigations reported in the osteopathic medical literature, but earlier studies used different methodologies and examined different paraspinal muscles. Based on the current results, factors other than muscle activity may be responsible for the apparent abnormality of these deep tissues. Investigation of these regions for increased tissue fluid and inflammatory mediators is recommended (Fryer et al., 2010).

The asymmetry, tenderness and texture changes, as well as ROM elements of both STAR and TART, remain helpful as assessment somatic dysfunction, manifesting with abnormal barriers to free movement even if conflicting research questions what is felt during palpation.

MUSCLE ENERGY TECHNIQUE AND PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION: SIMILARITIES AND DIFFERENCES

MET and PNF are similar yet different methods. The terms are often used interchangeably. Since the focus of this text is MET, it is valid to compare the treatment approaches. Both involve a patient's muscle contraction against a practitioner's counterforce. MET has osteopathic roots and emerged as a form of osteopathic treatment in which the patient is specifically positioned and then muscles are actively contracted on request in a specific direction against a counterforce. It was first described in 1948 by Fred Mitchell, Sr, DO (Ehrenfeuchter et al., 2011), PNF evolved as part of physical therapy. It uses spiral or diagonal movement patterns to indirectly facilitate movement, with the therapist providing maximal resistance to the stronger motor components, thereby facilitating the weaker components of the patterns (Cifu, 2020). In 1946 Herman Kabat, a neurophysiologist, began to look for natural patterns of movement for rehabilitating the muscles of polio patients. Along with physical therapists Margaret Knott and Dorothy Voss, he developed the PNF method of intervention as a specific sequence of movements performed to stimulate muscle and neurologic functions in rehabilitation (Voss et al., 1985). Further detail on this is found in Chapter 3. PNF stretching has currently narrowed PNF away from the original concept to the point that it is incorrectly perceived simply as a muscle contraction prior to stretching.

MET-PNF Similarities

The definitions given above suggest similarities between MET and PNF:

- Both involve the use of isometric contractions prior to (or during) stretching or movement
- Both have the normalisation of a broad range of orthopaedic conditions (physical therapy) or somatic dysfunction (osteopathy), terms that are clearly interchangeable, as objectives.

It is therefore reasonable to enquire whether there is any actual difference between PNF and MET apart from the names given to what appear to be similar approaches delivered by different professions.

MET-PNF Differences

The most basic distinctions between MET and PNF relate to apparently superficial, yet clinically significant differences:

1. MET, in its original osteopathic setting, aimed to restore joint function to normal. It is only in recent years that soft tissue dysfunction – outside of the context of joint dysfunction – has become a focus. It is in this latter evolution (muscle focus) that the blurring of boundaries between MET and PNF has emerged.
2. PNF identifies the restriction barrier at which the isometric contraction commences quite differently from the way it is identified in MET. In many descriptions of PNF the restriction barrier appears to involve moving the area to an end of range, *where the patient perceives mild discomfort*. For example, Azevedo et al. (2011) identify hamstring end of range as follows: '[The] examiner extended the subject's knee to the point of self-reported mild discomfort'. Note: This barrier definition appears similar to some descriptions of MET, as noted by Shoup (2006), and others, earlier in this chapter.
3. In MET, however, the restriction barrier is most commonly described as the very first perceived sign of tension, resistance, 'bind' (Stiles, 2009) or even short of that (Janda et al., 2006).
4. PNF frequently calls for a far longer and stronger isometric contraction, often employing all available strength, than is used in MET application, where 20% or less of available strength is requested (Greenman, 2003). For example, Glynn and Fiddler (2009) suggest the following in PNF application: 'During the technique the limb is taken to the end of available ROM and the patient is instructed to "hold" the position whilst the physiotherapist applies measured resistance to build up a maximal isometric contraction in the muscle group that requires lengthening'.
5. In this last example, we see the therapist 'applying measured resistance' while the patient 'holds the

position'. This is a reversal of the protocol used in MET where it is *always* the patient, and *not the therapist*, who introduces isometric effort.

It is suggested that the key to safe and clinically effective use of MET lies in understanding and employing 'easy end of range' barriers sometimes described in osteopathy as the 'feather-edge' of the barrier, as well as utilising mild, brief contractions initiated by the patient.

These elements, all of which contribute to MET being a more easily controlled sequence of actions than those described for PNF, as well as potentially being far less stressful for the patient than PNF methods, will be emphasised in those chapters dealing with the clinical use of MET (e.g. Chapters 5 to 7).

Different MET Approaches

How the various METs are applied has varied little since originally described by Dr Mitchell over 50 years ago. The process of application has been refined and nuanced but application foundations remain and have stood the test of time. The descriptions of MET variations listed below are summaries only, which are more detailed, step-by-step, protocols offered in the chapters (e.g. Chapters 5 to 7) where MET in treatment of soft tissue and joint dysfunction are explored.

Note: A series of exercises are described in Chapter 5 to assist with learning the basics of MET application.

A Note on Terminology

1. There is a need for clear and concise language to avoid ambiguity and misinterpretations, for example, when describing apparently simple terms such as 'contract'. Faulkner (2003) points out that the dictionary definition of the verb 'contract' specifically in relation to muscle, is 'to undergo an increase in tension, or force, and become shorter'. Faulkner further notes that an activated muscle always generates force, but that it does not always shorten, for example, when isometrically activated. This leads him to suggest that the term 'isometric contraction' is inaccurate since no external, overall shortening occurs.
2. In an absolute sense he is correct; however, for there to be a simultaneous contraction, and no overall length change, a combination of both shortening and lengthening needs to occur inside the muscle as it contracts. This feature of contraction is explored further below when we evaluate the mechanisms that may be operating in MET and PNF, particularly viscoelasticity.
3. Much of the supporting literature for these techniques derives from the fields of engineering, physiology and neuroscience, as well as physiotherapy and sports science. Searching the research databases such as PubMed reveals the variation in the language used across fields and professions to describe similar phenomena (e.g. interoceptive awareness has a host of synonyms that are not always accurate); methods (e.g. osteopathic manipulative treatment (OMT) as MET combined with other techniques; isometric eccentric contractions, discussed in Chapters 5, 7 and 10; and physiology (e.g. extracellular matrix used interchangeably with fascia). Inaccurate language leads to inaccurate understanding of what neighbouring fields do and hinders progress. Elementary efforts are in progress to streamline this confusing situation (see Chapter 3) but, until they mature, the distance in understanding between the manual therapy professions and other important fields with great potential for interdisciplinary work, remains significant.

The terminology used in the descriptions of MET variations in this book – the words *agonist*, as well as *antagonist*, *acute* and *chronic,* for example – also require definition.

- *Agonist* refers to the muscle or soft tissues that are dysfunctional and are the target for treatment, possibly requiring subsequent stretching.
- *Antagonist* refers to muscles that perform the opposite movement(s) to the agonist.
- *Acute* is defined as anything that is acutely painful, or recently injured (within the previous 3 weeks or so), and therefore still in the remodelling process. Acute tissues are never stretched; however, various forms of isometric or isotonic contraction may be employed in their treatment (see mechanotransduction discussion below). For the purpose of MET, treatment of joints falls into the acute model of care, even if chronically dysfunctional. That is to say, no increased force is used subsequent to isometric contraction in joint treatment, simply movement to a new, easy barrier ('it releases, or it doesn't' is the mantra for joints).
- *Chronic* refers to soft tissues that are not acutely painful, and which have recovered from the acute stages of trauma, possibly manifesting fibrosis.

A number of MET variations exist, including:

- The **basic MET protocol** in which the origin and insertion of the targeted muscle remains constant during the contraction. This approach is regularly used in clinical practice to treat shortened restricted muscles and joints, and in treatment of pain. It involves identification of a restriction barrier. Once the barrier is gently engaged ('first sign of resistance'; feather-edge of resistance' (Stiles, 2009), a light isometric contraction of the agonist, or the antagonist, is introduced by the patient, following instruction as to the direction and degree of force to employ for (usually) 5 to 7 seconds. This is followed by subsequent repositioning of the structures, possibly involving a degree of stretching of the agonist in chronic settings, or simply moving to a new easy end of range, if an acute soft tissue, or any joint restriction is being addressed. The degree of effort called for, as the patient attempts to isometrically move against the practitioner's resisting contact hand(s), should be light, usually less than 20% of available strength, and often far less. The rationale for these variations and choices will be explained fully in later chapters. Choice of the antagonist to contract would be obvious if contraction of the agonist proved painful. The antagonist might also be chosen for active participation for other reasons, for example, as a means of incorporating a variety of soft tissues into an attempt to improve function of a joint (Lewit, 1999; Greenman 2003). In relation to the length of an isometric contraction, Fred Mitchell Jr DO, son of the main developer of MET, and a leading authority on the modality, has observed:

> *The important thing in MET is getting the correct muscle to contract in the appropriate controlled circumstances – not how long you wait before you say 'stop!' The sensory (spinal) adaptive response in the … proprioceptor mechanism … probably takes no more than one tenth of second. Once that (sensory) adaptive response occurs, passive mobilization, during the post-isometric phase, can usually be accomplished without effort. For joints, more than two seconds of isometric contraction is a waste of energy. For muscle MET, treatment (i.e. the contraction) should take longer.*
>
> ***Mitchell (2009)***

- This is, of course, an opinion, albeit an authoritative one, and should be reflected on as such. This is in contrast to a study that evaluated the ideal duration of MET contractions, in which Fryer and Ruszkowski (2004) investigated the influence of contraction duration in MET applied to the atlanto-axial joint in the neck. The results failed to demonstrate a significant benefit in the use of a longer (20 seconds) isometric contraction, compared with a shorter one (5 seconds) when treating the upper neck with MET: 'The use of a 5-second isometric contraction appeared to be more effective than longer contraction durations for increasing cervical range with MET'.
- **Pulsed MET** (Ruddy's rapid resistive duction) calls for the patient to introduce minute repetitive contractions, usually involving the antagonist(s) to restricted soft tissue structures (the 'agonist'), thus facilitating and toning the antagonist, and possibly inhibiting the agonist, with possible additional circulatory and proprioceptive benefits. This method stems from the work of one of the earliest pioneers of MET, Thomas Ruddy, D.O. (Ruddy, 1962) (see Chapters 3 and 5).
- **Rapid eccentric isotonic stretch** is also known as an isolytic stretch because it induces controlled tissue damage, for example, to break down adhesions and fibrosis within the muscle tissue (Kuchera & Kuchera, 1992, Sharvari, 2020). This method contrasts with SEIS that does not damage tissue (Parmar et al., 2011). In application of this method, the practitioner's resistance is greater than the patient's effort, resulting in the *rapid elongation* of the treated muscle while it is contracting.
- **SEIS:** The clinical usefulness of *slowly* stretching a muscle or its antagonist during a contraction has been demonstrated (Jones, 2001; Parmar et al., 2011). The most widely used form of SEIS involves a slow, resisted stretch of the antagonist of shortened soft-tissue structures, a process that tones the antagonist isotonically, after which the agonist is stretched. NOTE: *Confusingly, the slow version of eccentric isotonic stretching is sometimes also termed 'isolytic' (Parmar et al., 2011), and is therefore likely to become common usage, even if inaccurate.*
- **Isokinetic MET** involves multidirectional resisted active movements, designed to tone and balance muscles of an injured joint during rehabilitation. The resistance that the practitioner applies is less than the patient's effort. Therefore, the muscle gradually becomes shorter or is working against resistance. This type of MET is used to build muscle strength, motor control and endurance (Weng et al., 2009).

For more detail of all these methods, including protocols for use of pulsed MET and SEIS see Chapters 5 to 7.

The Addition of Respiratory and Visual Synkinesis

Respiratory synkinesis refers to the suggestion that it is clinically useful to have the patient inhale during most contractions and exhale during release or stretching, albeit with some exceptions. Exceptions are discussed in later chapters (Lewit, 1986, 1999).

Visual synkinesis refers to the clinical value of having the patient look in the direction of contraction, and then the direction of release or stretch. Look up and extensors tone, look down and flexors prepare for activity (Lisberger et al., 1994; Lewit, 1999). Janda (1988) confirms that eye position modifies muscle tone (visual synkinesis), particularly involving the suboccipital muscles (Komendatov, 1945).

MUSCLE TYPES AND MET

Muscle function involves postural joint stabilisation, long-lasting and repetitive activities like respiration or walking, as well as fast and generally powerful actions such as jumping or kicking (Schiaffino & Reggiani, 2011). Muscles have been distinguished/categorised in a variety of ways, for example, based on their:

1. Functional abilities: postural (tonic)/phasic and/or stabiliser/mobiliser. See further explanations below (Liebenson, 2006).
2. Reaction capacity: tight/overactive/hypertonic or weak/inhibited (Bullock-Saxton et al., 1993; Arab et al., 2011; Schuermans et al., 2017).
3. Structural locality: local/global (Bergmark, 1989; Norris, 1999). Local muscles do not typically produce movement. Instead, they create a stable joint situation that allows movement, and are therefore usually located close to joints (Bogduk, 1997; Retchford et al., 2013; Mahato, 2019). Global muscles are larger, more superficial and are mainly responsible for motion and the transfer of load between somatic regions.
4. Multijoint or monoarticular muscles: Richardson et al. (1999, 2000) have argued for the use of the terms multijoint muscles and monoarticular muscles characterisation.
5. Fibre type distribution: slow twitch/type I or fast twitch/type II – and variations on these (Liebenson, 2006). Muscles that contract slowly ('slow twitch fibres' or 'slow white fibres') are classified as type I. These have very low stores of energy-supplying glycogen but carry high concentrations of myoglobulin and mitochondria. These fibres fatigue slowly and are mainly involved in postural and stabilising tasks (Engel, 1986; Woo, 1987). There are also several phasic/active type II fibre forms, notably:
   - Type IIa fibres ('fast twitch' or 'fast red' fibres), which contract more speedily than type I and are moderately resistant to fatigue, with relatively high concentrations of mitochondria and myoglobulin.
   - Type IIb fibres ('fast twitch/glycolytic fibres' or 'fast white fibres'), which are less fatigue-resistant and depend more on glycolytic sources of energy, with low levels of mitochondria and myoglobulin.
   - Type IIm ('superfast' fibres), found mainly in the jaw muscles, which depend on a unique myosin structure that, along with a high glycogen content, differentiates this from the other type II fibres (Rowlerson et al., 1981).

Change of Muscle Type

Fibre type is not totally fixed. Evidence has shown the potential for adaptability of muscles, so that committed muscle fibres can be transformed from slow-twitch to fast-twitch and vice versa (Lin et al., 1994; Mukund & Subramaniam, 2019).

Apparently, by changing the frequency of stimulation to a motor unit, the biochemical properties can change, that is, slow-twitch muscle fibre that is rapidly stimulated converts to fast-twitch fibre and vice versa (Clark, 2001). An example of this potential, of clinical significance, involves the scalene muscles. Lewit (1999) confirms the scalene group can be classified as either postural or phasic. If the largely phasic scalene muscles, which are dedicated to movement, have postural functions thrust upon them – as in an asthmatic condition in which they will attempt to maintain the upper ribs in elevation to enhance lung capacity – and if, owing to the laboured breathing of such an individual, they are thoroughly and regularly stressed, their fibre type will alter and they will become postural muscles, and will shorten (Lin et al., 1994; Lin & Nardocci, 2016). This type of response has also been noted in the transversus abdominis (Richardson et al., 1992; Lynders, 2019).

A list of postural (also known as 'tonic') and phasic muscles is given below.

Stress Implications for Different Muscle Types

For practical purposes the descriptors 'postural' and 'phasic' (Janda, 1996; Lewit, 1999; Liebenson, 2006) are used in this text, despite other categorisations being available when discussing muscles. The implications of the effects of prolonged stress on different muscle types/ categories cannot be emphasised too strongly. For example, long-term stress involving type I muscles results in shortening (also with global, and mobiliser muscles) (Szeto et al., 2009).

In contrast, type II fibres undergoing similar stress will weaken (as will local and stabiliser muscles), without shortening over their whole length (they may, however, develop shortened areas within the muscle) (Liebenson, 2006; Kozlovskaya et al., 2007).

It is important to emphasise that shortness or tightness of a postural (tonic) muscle does not imply strength. Such muscles may test as strong or weak; however, a weak phasic muscle will not shorten overall, and will always test as weak (Liebenson, 2006).

Which Muscles Belong in Which Groupings?

- According to Norris (2000), research has shown that muscles that are inhibited or weak may lengthen, adding to the instability of the region in which they operate. It is the 'stabiliser' muscles that have this tendency: if they are inhibited because of deconditioning they become unable to adequately perform the role of stabilising joints in their 'neutral posture'. They therefore, to a large extent, equate with '*phasic*' muscles in the descriptions used in this book. 'Stabiliser' muscles, which are deeply situated, slow-twitch and tend to weaken and lengthen if deconditioned, include: transversus abdominis, multifidus, internal obliques, medial fibres of external oblique, quadratus lumborum, deep neck flexors, serratus anterior, lower trapezius, gluteus maximus and medius. These muscles can be correlated to a large extent (apart from quadratus lumborum) with muscles designated by Lewit (1999) and Janda (1983) as 'phasic'.
- The more superficial, fast-twitch muscles which tend to shorten (i.e. 'mobilisers' in Norris's terminology) include: suboccipital group, sternocleidomastoid, upper trapezius, levator scapulae, iliopsoas and hamstrings. These fall into the category of 'postural' muscles as described by Lewit (1999) and Liebenson (2006). Norris calls these 'mobilisers' because they cross more than one joint. They are also described in numerous texts as 'tonic' (Schleip et al., 2006).

This redefining of 'postural' (or 'tonic') as 'mobiliser' can be confusing, and many clinicians therefore prefer to refer to those muscles to which this descriptor applies, as 'having a tendency to shorten' whatever label is applied (Liebenson, 1989). Examples of patterns of imbalance that emerge as some muscles weaken and lengthen as their synergists become overworked, while their antagonists shorten, are summarised in Table 2.1.

As stated previously: to minimise confusion, this book will follow the Janda/Lewit/Liebenson categorisations of *postural* and *phasic* muscles.

Postural and phasic muscle lists. Type I postural (tonic) muscles are prone to loss of endurance capabilities when disused or subject to pathological influences and become shortened or tighter, whereas type II phasic muscles, when abused or disused, become weak (Lewit, 1999; Liebenson, 2006).

Postural muscles that become hypertonic and shorten in response to dysfunction include:

- Trapezius (upper), sternocleidomastoid, levator scapulae and upper aspects of pectoralis major, in the upper trunk; and the flexors of the arms. Quadratus lumborum, erector spinae, oblique abdominals and iliopsoas, in the lower trunk. Tensor fascia lata, rectus femoris, biceps femoris, adductors (longus brevis and magnus) piriformis, hamstrings, semitendinosus.

Phasic muscles, which weaken (i.e. are inhibited), and may lengthen, in response to dysfunction, include:

- The paravertebral muscles (not erector spinae) and scaleni, the extensors of the upper extremity (flexors are primarily postural), the abdominal aspects of

TABLE 2.1 Patterns of Imbalance

Underactive Stabiliser	Overactive Synergist	Shortened Antagonist
Gluteus medius	Tensor fascia lata, quadratus lumborum, piriformis	Thigh adductors
Gluteus maximus	Iliocostalis lumborum, hamstrings	Iliopsoas, rectus femoris
Transversus abdominis	Rectus abdominis	Iliocostalis lumborum
Lower trapezius	Levator scapulae, upper trapezius	Pectoralis major
Deep neck flexors	Sternocleidomastoid	Suboccipitals
Serratus anterior	Pectoralis major/minor	Rhomboids
Diaphragm	Scalenes, pectoralis major	

pectoralis major; middle and inferior aspects of trapezius; the rhomboids, serratus anterior, rectus abdominis; the internal and external obliques, gluteals, the peroneal muscles and the extensors of the arms.

Muscle groups such as the scaleni are equivocal: they start out as phasic muscles but can end up as postural.

It has been suggested (Schleip et al., 2006) that differences in quantities of intramuscular connective tissue, particularly the perimysium, in relation to postural (tonic) muscles and phasic muscles has a bearing on degrees of stiffness and possible functional features of these muscles. This is discussed further in Box 2.2: *Why Fascia Matters*.

BOX 2.2 Why Fascia Matters

A state of structural and functional continuity exists between all of the body's hard and soft tissues, with fascia being the ubiquitous elastic–plastic, gluey and fluid component that invests, supports and separates, connects and divides, wraps and gives cohesion and shape to the rest of the body – the fascial, connective tissue network (Ingber, 2008; Myers, 2021). Various models for conceptualising this fascial network exist, including biotensegrity, fascintegrity and myofascial chains. Biotensegrity is a mechanical model focused on solid fascia; Fascintegrity includes both solid and the liquid fascia. Myofascial chains encompass movement and transmission of force in the soft tissue continuum (Wilke et al., 2018; Bordoni & Myers, 2020; Ajimsha et al., 2020a, 2020b).

Any tendency to think of a local dysfunction as existing in isolation should be discouraged as we try to visualise a complex, interrelated, symbiotically functioning assortment of tissues, comprising skin, muscles, ligaments, tendons and bone, as well as the neural structures, blood and lymph channels and vessels that bisect and invest these tissues – all given shape, form and functional ability by the fascia (Schleip et al., 2006; Ingber, 2008; Solomonow, 2009; Adstrum et al., 2017; Bordoni et al., 2018; Bordoni et al., 2019). Evaluation and clinical reasoning related to soft tissue dysfunction therefore needs to consider the role, features and interaction of the fascia (Chaitow, 2018).

Fascial continuity and connectivity as a multidimensional contiguous network can be supported by the structure and function of the interstitium. The interstitium's body-wide network of fluid-filled interstitial spaces is organised as a lattice or mesh across tissue layers. The fibre lattice creates the interconnected spaces that are filled with moving fluid. The interstitium expands the understanding of organisation of fascia as interconnect but also as layers with siding capacity. The interstitium may act as a body-wide communication network (Benias et al., 2018; Cenaj et al., 2021).

To understand the fascial network and function it is necessary to review the mechanical properties, especially the relationship of stiffness to loads and deformation related to the forces exerted on tissues and the resulting changes in their shape (Guimarães et al., 2020; Kozyrina et al., 2020). Fascia alters its stiffness (the resistance to external deformation) via two mechanisms: cellular contraction and the modification of the fluid characteristics. The connective tissue surrounding the muscles stretched (i.e. fascia) is the candidate component for explaining the increase in joint resistance to stretch after a stretching intervention (Freitas, 2018; Wilke et al., 2018).

When fascia is excessively mechanically stressed, inflamed or immobile, collagen and matrix deposition tends to become disorganised, potentially resulting in fibrosis, adhesions and fascial 'thickening' (Langevin, 2011) also described as 'densification', (Stecco & Stecco, 2009), involving distortion of myofascial relationships, altering muscle balance and proprioception feedback. Increased amount of myofibroblasts has been observed in pathological fascia that might create tissue contractures (Wall et al., 2017; Blottner et al., 2019; Weig, 2020).

Consequent binding among layers that should stretch, glide and/or shift on each other, potentially impairs motor function (Fourie, 2009), while chronic tissue loading may form 'global soft tissue holding patterns' (Myers, 2009; Freitas, 2018). Distribution of hyaluronan is necessary for ease of movement among structures. Viscoelastic deformation is possible due to the high concentration of Glycosaminoglycans (GAG) and hyaluronan (Fede et al., 2018).

During passive stretching, the fascia is the first tissue that limits the elongation and would be an element that contributes to bind and the region where MET contractions begin.

Epimysial fascia is a type of deep fascia that ensheaths muscles and helps to define their shape and structure. It is continuous with the tendon, allowing it to transmit forces (Stecco et al., 2013; Stecco, 2015; Stecco et al., 2021). There are three layers: internal, middle and external, each with distinct arrangements of collagen fibres. Each layer of the fascia is comprised of types I and III collagen and elastic fibres. Between each layer is areolar connective tissue rich in hyaluronan (HA) (Bhattacharya et al., 2010). HA is a polysaccharide in the extracellular matrix that provides

BOX 2.2 Why Fascia Matters—cont'd

both lubrication and resistance to compression. Under normal physiological conditions, HA is responsible for normal gliding motion between components of fascia, muscle, nerves, lymphatics and blood vessels (Dowthwaite et al., 1998; Alberts et al., 2002; Stecco et al., 2008). Fasciacytes are specialised fibroblast-like cells that secrete the HA-rich matrix in fascial tissue (Stecco et al., 2017).

Fibrotic changes in muscle may have a substantial impact on tissue dynamics and force generation capacity on other most important performance properties such as myofascial force transmission and changes of fascia properties (stiffness vs elasticity). Myofascial force transmission to neighbouring muscles represents a mechanism protecting the target muscle against overload. Stretching, so far, has been used primarily to alter the neurophysiological and biomechanical function of the lengthened muscle. However, due to the morphological connections, it might as well affect synergists and antagonists, thereby modifying sports performance (Schleip et al., 2006; Wilke et al., 2018; Schleip et al., 2019).

Mechanotransduction describes a multimodal cellular and molecular process of how cells can sense and respond to mechanical stimulation from outside, generate intracellular molecules that are eventually released into the extracellular matrix (ECM) by stimulated cells, targeted to variable receptors to regulate morphology and functions in a given tissue (Zügel et al., 2018; Ajimsha et al., 2020b).

The implications of these observations are that 'short' postural (tonic) muscles need to be considered from this fascial perspective, that is, that at least some of the stiffness/tightness relates to fascia and not muscle, and that treatment should therefore take account of this.

Treatment Options

Loose connective tissue responds to light tissue stretch, which 'may be key to the therapeutic mechanism of treatments using mechanical stimulation of connective tissue' (Langevin, 2005, 2010b).

Myers (2010) suggests that stretching can be applied not only to fascial 'length' problems, but also to 'stuck layer' problems, using shear stress to allow the restoration of increased relative movement between the adjacent planes of fascia (Schwind, 2006).

Fourie (2009) and Langevin (2009) both suggest that their animal and human studies indicate that the ideal degree of stretch required to lengthen *loose connective tissue* should not exceed 20% of the available elasticity, with 5%–6% being adequate in many instances. Light (significantly less than 20% of available elasticity), sustained stretching is more effective in affecting fascia than more vigorous approaches (Langevin, 2010a). In other words, strong stretching is not recommended where fascia is concerned, and this fits well with the protocols recommended for use of stretching during muscle energy technique (MET) usage (see Chapters 5 and 6 for more details on this). In addition, breathing retraining is likely to assist in reducing excessive contractility in myofibroblasts in fascia (Chaitow, 2007, 2018; Jensen et al., 2008).

As noted in the discussion of viscoelastic features of PNF/MET, intramuscular fascia (the series elastic component, for example) appear responsive to isometric contractions and stretching. Fryer and Fossum (2010) suggest that apart from the influence of mechanoreceptors on pain (via both ascending and descending pathways), MET induces in vivo mechanical stretching of fibroblasts that alters interstitial osmotic pressure and increases blood flow, thus reducing concentrations of pro-inflammatory cytokines and reducing sensitisation of peripheral nociceptors.

Franklyn-Miller has added a further consideration to the effects of stretching. He has evaluated the remarkable degree in which muscular effort depends on the multiple links that muscles have with each other and with connective tissue structures. These connections mean that, for example, a hamstring stretch will produce 240% of the resulting hamstring strain in the iliotibial tract and 145% in the ipsilateral lumbar fascia, compared with the strain imparted in the hamstrings. This process of strain transmission during stretching involves many other tissues beyond the muscle that is being targeted, largely due to fascial connections, making the use of the word 'isolated', together with 'stretching, difficult to justify (Franklyn-Miller et al., 2009).

Imbalances between postural and phasic muscles are features of many musculoskeletal dysfunctional patterns, amongst which some of the most obvious are the so-called 'crossed syndromes' (Janda et al., 2006; in Liebenson, 2006). For details of these see Box 6.2, Chapter 6.

Joints, Muscles and MET: Identifying Sources of Pain

Identification of the ideal target tissues for treatment can be confusing, although guidelines can help in providing answers (Kaltenborn, 1985; Kuchera & Kuchera, 1992; Clarkson, 2020).