This chapter explores and reflects upon the principles and applications of contemporary treatment interventions in clinical sports therapy. Specifically, it examines evidence-based practice (EBP), soft tissue therapy, manual therapy, cryotherapy, heat therapy, electrotherapy and taping and strapping. Sports therapists will recognize that treatment interventions are the most suitable techniques to be delivered once the athlete or patient has been appropriately assessed and therapeutic goals identified; such interventions must be employed in conjunction with progressive exercise rehabilitation. With the delivery of any therapeutic intervention, there must be full consideration of the following: therapeutic objectives; effective communication with the patient; the positioning of the patient; the therapist’s working posture and their handling of the patient; treatment technique applications (including location, intensity, frequency and duration); and patient re-assessment. Obviously, there are times when the intervention will simply be the delivery of expert advice, which may be in the form of referral for medical assessment. An essential part of the intervention process in sports therapy is to consider how to best address any apparent causative (aetiological) factors to the patient’s condition so as to reduce potential for re-occurrence. Interventions such as sports nutrition, sports psychology and exercise rehabilitation have not been included in this chapter.

Evidence-based practice

This chapter aims to explore the evidence-base to support sports therapy interventions, and additionally provide guidance for best practice. While the utilization of an evidence-base for all interventions is idealistic, it is the recommended approach in which health care professionals formulate clinical decisions, and is based upon the latest and best scientific evidence available for individual patients (Sackett et al., 1996). Effective consideration and employment of EBP is processual. It is founded on clinical questioning, critique and appraisal of available evidence, appropriate integration and evaluation of clinical outcomes. The expert practitioner will apply ‘evidence-informed practice’ (EIP). True EIP is triadic and incorporates the essential evidence-based guidelines, the autonomy of the individual practitioner’s experience and expertise (and their ‘craft knowledge’), and the individual ‘patient’s culture’. Sackett et al. (1996) defined EBP as ‘integration of the best research evidence with clinical expertise and patient values and circumstances to make clinical decisions’. The process is also encapsulated by the term ‘clinical reasoning’. According
to Haynes et al. (2002), EBP must always incorporate: clinical expertise; reliable research evidence; and, crucially, patient preferences and actions. Efficient EBP is a seamless combination of factors which play a role in achieving one goal – the best possible advice and treatment for the patient. For practitioners, the process for delivery of EBP must embrace the ability to both critically appraise and integrate the research into practice. Critical appraisal involves the efficient selection, analysis and synthesis of research information; it also involves the ability to evaluate the usefulness of any adaptations incorporated into practice. Scott et al. (2013) state that 'It is imperative that a concerted effort is undertaken to ensure that research is pertinent to, meaningful to, and feasible for easy uptake into the clinical setting.' Clinical experience alone does not substantiate up-to-date clinical research, and the sports therapist must strive, through reflection, to explicitly identify gaps in their knowledge and areas for development. Scott et al. (2013) present a selection of barriers to achieving EBP:

- insufficient time to search for evidence;
- too much evidence available (information overload);
- insufficient relevant and applicable evidence;
- lack of collation of related evidence;
- inadequate access to evidence;
- insufficient training in how to access evidence;
- poor presentation of evidence;
- limited confidence and competence in appraising the quality of evidence (epistemological issues);
- limited applicability of evidence for, or from, heterogeneous populations;
- bias in research (bias in publication; bias in population selection, allocation, performance or outcome);
- restrictions in practitioner autonomy;
- limitations in practitioner incentives or motivations;
- the influence of patient expectations.

Irrespective of the professional experience of a therapist, formulating a sound and critically reasoned rationale for the care of the patient is the underpinning reason for adopting EBP. Although operating within an EBP framework is a formal requirement for sports therapists, it must be acknowledged that all areas of contemporary sports therapy practice require ongoing development for optimizing the evidence-base; and this is the case for all areas of health care. Although anecdotally practitioners may find certain methods and techniques consistently effective, and patients may indeed request or expect them, the evidence-base may not be so strong as to be scientifically justifiable. Within the process of ongoing research, sports therapists, their organizations and educational institutions, must aim to advance their position via the generation of reliable and progressively valid practice-based evidence, which must especially be focused upon all specified areas of expertise currently being utilized effectively in clinical and sporting settings. Dinsdale (2012) presents a case for sports therapists in private practice to undertake their own clinical auditing (i.e. systematically monitoring and evaluating their own performance). Clinical auditing may incorporate the formal documentation of: patient assessment methodologies; baseline assessment findings and clinical indicators; intervention strategies, types and dosages; and outcome measures). A number of evidence-based outcome measures and disability indexes have been produced in recent years, including: DASH (Disability of Arm, Shoulder and Hand); SPADI (Shoulder Pain and Disability Index); MFPDI (Manchester Foot Pain and Disability Index); and ODI (Oswestry Disability Index – also known as the
Oswestry Low Back Pain Disability Questionnaire). Such disability indexes offer regionally focused baseline and outcome subjective assessments, which can support appraisal of therapeutic performance (Manske and Lehecka, 2012); they are also useful when conducting case study research.

Greenhalgh and colleagues (2014) have presented a fresh consideration for EBP as they describe its movement towards a renaissance and refocusing. EBP has, following its formal introduction over 20 years ago, established into a solid and energetic intellectual community of health researchers, educationalists and practitioners; but, as with any emergent approach, lessons must be learnt from its implementation, delivery, measured outcomes and analysis. Greenhalgh (2012), Greenhalgh et al. (2014) and Ioannidis (2005) have all highlighted issues associated with EBP, including: the misappropriation of the evidence-based 'quality mark'; the sheer volume of evidence (including clinical guidelines) and challenges associated with the implementation of such; the marginal statistical significance of benefits; the challenges associated with incorporating patient-centred care; and the challenges of mapping EBP to patients with multiple morbidity. In their appraisal, Greenhalgh et al. (2014) request a progressive shift towards ‘real evidence-based medicine’ (REBM) which:

- makes the ethical care of the patient its top priority;
- demands individualized evidence in a format that clinicians and patients can understand;
- is characterized by expert judgement rather than mechanical rule following;
- shares decisions with patients through meaningful conversations;
- builds on a strong clinician–patient relationship and the human aspects of care;
- applies these principles at community level for evidence-based public health.

Once qualified and in practice, mandatory continuous professional development (CPD) is the essential, ongoing process for practitioners. CPD should be multifaceted, formally organized, and designed to advance individual professional knowledge, understanding and practice. CPD is an absolute hallmark characteristic for all health care professionals. CPD aims to ensure that practitioners incorporate the most current and reliable approaches to their work. Straus et al. (2005), cited in Manske and Lehecka (2012), present questions that practitioners should ask of themselves:

- Am I asking any well-informed questions?
- Am I becoming more efficient in my searching?
- Am I critically appraising evidence?
- Am I integrating critical appraisals into my practice?
- Have I done any audits of my diagnostic, therapeutic or other performances, including measures of patient satisfaction?

Databases applicable to sports therapy

Contemporary research and information sources for best practice are readily available via ‘open-access’ or subscription-based online databases. One essential component for the successful employment of EBP is being able to critique the evidence for any particular strategy, methodology or technique for its validity or clinical usefulness. It is extremely important for all sports therapists to be able to develop their own appreciation of what constitutes ‘reliable and valid’ literature, and to be able to critique and appraise said literature – whether a paper discussing a multi-centre, double-blinded randomized control trial (RCT), a small-scale pilot study, or a case study or case...
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series; or whether it is a systematic review or meta-analysis of a specified body of literature. According to Law and MacDermid (2008), there is a corresponding relationship between the quality of a study and the confidence of a clinical decision. The potential for bias is something the sports therapist must be able to identify, and this is a key component in the appraisal of the quality of any evidence. Bias may be considered as the tendency or disposition of researchers, authors, publishers or clinicians to present information and findings which may in some way not be a true representation. The concept of ranking levels of evidence is based on the principle that certain study types have more rigour; and higher-quality study designs provide more confidence to associated clinical decision making (Belsey and Snell, 2009). The International Centre for Allied Health Evidence (ICAHE, 2014) clarify that while there is not one standard hierarchy of evidence, there is a recognizable consensus of hierarchy pertaining to different types of research. Reliably constructed systematic reviews and meta-analyses rank highest because, by definition, they rigorously analyse data from multiple primary studies. Well-constructed primary experimental studies rank above observational studies because these will attempt to control for bias in their design (the highest ranking studies of this type are RCTs). Lowest in the ranking of research hierarchy is evidence-based opinion, such as that seen in narrative reviews, sometimes in editorial commentaries and in some textbooks. Table 3.1 presents a summary of hierarchical levels of research evidence; Table 3.2 presents a summarized hierarchy of information sources; and Table 3.3 presents the American Academy of Family Physicians’ (AAFP) Strength of Recommendation Taxonomy (SORT).

Databases applicable to sports therapy

Below is a selection of online databases which are useful for accessing contemporary and archived research information relevant to sports therapy:

- AMED (Allied and Complementary Medicine)
- CINAHL (Cumulative Index to Nursing and Allied Health Literature)
- Cochrane Collaboration
- DARE (Database of Abstracts of Reviews of Effects)
- EMBASE
- HRC Academic (Health Reference Center Academic)

Table 3.1 Hierarchical levels of research evidence

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Relative ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic reviews and meta-analyses</td>
<td>1</td>
</tr>
<tr>
<td>Randomized control double-blind trials (RCT)</td>
<td>2</td>
</tr>
<tr>
<td>Cohort studies</td>
<td>3</td>
</tr>
<tr>
<td>Case controlled studies</td>
<td>4</td>
</tr>
<tr>
<td>Cross-sectional studies</td>
<td>5</td>
</tr>
<tr>
<td>Case reports</td>
<td>6</td>
</tr>
<tr>
<td>Expert opinion, commentaries, ideas, editorials</td>
<td>7</td>
</tr>
<tr>
<td>Anecdotal (experiential, unpublished) opinion</td>
<td>8</td>
</tr>
<tr>
<td>Animal research</td>
<td>9</td>
</tr>
<tr>
<td>In-vitro research</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: adapted from Cook, 2012; Dinsdale, 2008; Greenhalgh, 1997; Sackett et al., 1996.
Table 3.2 Hierarchy of information sources

<table>
<thead>
<tr>
<th>Information source</th>
<th>Relevance</th>
<th>Validity</th>
<th>Cost</th>
<th>Usefulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence-based textbook</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Systematic review</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><em>Journal of Family Practice</em> POEMs (patient-oriented evidence that matters)</td>
<td>High</td>
<td>High</td>
<td>Mod</td>
<td>High</td>
</tr>
<tr>
<td>Journal of Family Practice POEMs (patient-oriented evidence that matters)</td>
<td>High</td>
<td>High</td>
<td>Mod</td>
<td>High</td>
</tr>
<tr>
<td>Colleagues</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>High–moderate</td>
</tr>
<tr>
<td>Practice guidelines (evidence-based)</td>
<td>Mod</td>
<td>High</td>
<td>Low</td>
<td>High–moderate</td>
</tr>
<tr>
<td>Cochrane Database</td>
<td>Moderate–high</td>
<td>High</td>
<td>Low</td>
<td>High–moderate</td>
</tr>
<tr>
<td>Standard textbook</td>
<td>High</td>
<td>Low</td>
<td>Mod</td>
<td>Mod</td>
</tr>
<tr>
<td>Standard journal review</td>
<td>High</td>
<td>Mod</td>
<td>Low</td>
<td>Mod</td>
</tr>
<tr>
<td>Practice guidelines (consensus)</td>
<td>Mod</td>
<td>Mod</td>
<td>Low</td>
<td>Mod</td>
</tr>
<tr>
<td>Internet (general)</td>
<td>Low–moderate</td>
<td>Low–moderate</td>
<td>Low</td>
<td>Low–moderate</td>
</tr>
<tr>
<td>Mass media</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>


Table 3.3 Strength of recommendation taxonomy (SORT)

<table>
<thead>
<tr>
<th>Strength of recommendation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Recommendation based on consistent and good-quality patient-oriented evidence</td>
</tr>
<tr>
<td>B</td>
<td>Recommendation based on inconsistent or limited-quality patient-oriented evidence</td>
</tr>
<tr>
<td>C</td>
<td>Recommendation based on consensus, usual practice, opinion, disease-oriented evidence, or case series for studies of diagnosis, treatment, prevention or screening</td>
</tr>
</tbody>
</table>


- MEDLINE
- NHS Evidence
- NICE (National Institute for Health and Care Excellence)
- PEDro (Physiotherapy Evidence Database)
- PubMed
- SciVerse SCOPUS
- SPORTDiscus
- Trip
- Zetoc.

Obviously, when searching such databases, sports therapists should aim to appreciate the difference between peer-reviewed, evidence-based journal articles, edited textbooks and conference proceedings, and those which are not. Introductory (summary) abstracts on such databases are especially useful, and are usually freely available. The sports therapist should also aim to use search terms which are most likely to provide the most applicable results (i.e. ‘MeSH’
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terms: medical subject headings – which are a vocabulary of indexed terms used in some databases). Furthermore, such approaches as ‘Boolean logic’ may also be used. This is a simple method for specifically linking or separating two or more search terms for optimizing results, for example, using ‘and’ between terms retrieves articles containing both terms; using ‘or’ between terms retrieves articles containing either or all of the terms; and using ‘not’ between terms excludes the retrieval of articles which contain the terms preceded with ‘not’ in the search. Search term methodology may also employ use of truncation or ‘wildcards’ where, for example, a root word – plus a designated symbol (applicable to the database in question), such as * ? or @ – may be used to retrieve a wider range of results.

The sports therapist is advised to gain familiarity with the wide range of research that is undertaken in the field so that they can appreciate which methodology has been employed – or could be employed – and essentially, the reliability and validity of such. There are a number of simple, initial methods which may be used to either assist in the appraisal of study design (by identifying the key features of a study), or to help develop a viable literature review format (ICAHE, 2014; Sackett et al., 1996); these include:

- ‘PICO’ (Problem/sample Population/Patient; Intervention/exposure/test; Comparators/Controls; and Outcomes/results);
- ‘PIPOH’ (Population; Intervention; Profession; Outcome; and Healthcare setting);
- ‘PECOT’ (Population; Exposure; Comparator; Outcome; and Time period);
- ‘SPICE’ (Setting; Perspective; Intervention; Comparison; and Evaluation);
- ‘ECLIPSE’ (Expectations; Client group; Location; Impact; Profession; and Service).

The sports therapist must also aim to be critical in their reading of research. Ioannidis (2005) presented a stirring article suggesting that much of the published research is false, and stated that ‘claimed research findings may often be simply accurate measures of the prevailing bias’. Certainly it can be observed that newer evidence frequently refutes previous evidence. Hence, sports therapists must aim to identify and note the research question, the study design, the ethical issues, the specified inclusion and exclusion criteria of the study, the method of data gathering and analysis, the time frame, the significance of results, the conclusions, the recommendations and the possibility of methodological flaws, confounders or bias. A number of established and straightforward critical appraisal tools have been produced to assist practitioners in their assessment of published research, such as:

- The Physiotherapy Evidence Database ‘PEDro scale’ for measuring the methodological quality in clinical trials.
- The ‘QUADAS’ tool for assessing systematic reviews of diagnostic accuracy studies.
- The Critical Appraisal Skills Programme (CASP, 2014) tools for systematic reviews, randomised controlled trials, cohort studies, case control studies, economic evaluations, diagnostic studies, qualitative studies and clinical prediction rules.
- Organizations such as the UK-based Medical Research Council (MRC) and Centre for Evidence-Based Medicine (CEBM) provide comprehensive online resources for research educators, researchers, clinicians and students on areas such as critical appraisal, research design, research ethics, research funding and the implementation of EBP.
Practitioner Tip Box 3.1

Considerations in the critical evaluation of research

- Research title, aim and objectives
- Rationale
- Context
- Relevance
- Conceptual framework
- Theoretical framework
- Methodological design (e.g. primary; secondary; systematic approach)
- Research hierarchy (e.g. CEBM; SORT)
- Search and review strategies
- Critical appraisal tools (e.g. PEDro; QUADAS)
- Credibility
- Ethical issues
- Objectivity
- Precision of experimental delivery
- Cumulative weighting
- Outcome measure(s)
- Data collection
- Data analysis
- Confounding variables (uncontrolled factors)
- Interpretation
- Confirmability
- Statistical significance (e.g. the level of acceptable error ['alpha level']; the probability that the results are due to chance ['p value'])
- Correlation (measure of the relationship between variables)
- Triangulation (use of multiple data sources to confirm or refute findings)
- Trustworthiness
- Reliability
- Internal validity (e.g. historical issues; maturation or loss of participants; data issues)
- External validity (e.g. the ‘Hawthorne effect’, where participants’ performance alters simply because they are being observed; multiple treatment interference)
- Bias (e.g. selection bias; conflicts of interest)
- PICO (patient/population/problem; intervention/exposure/test; controls/comparators; outcomes)
- Inclusion–exclusion criteria
- Recognition of design or conclusion limitations
- Conclusions
- Epistemology (analysis of the justified knowledge)
- Directions for future research
- Transferability potential
- Replication potential (repeatability/reproducibility)
- Synthesis potential
- Implications for practice
- Applicability to practice
- Contribution to the field
Table 3.4 Types of research

- Literature reviews (e.g. systematic reviews; meta-analyses; narrative reviews; document analyses)
- Qualitative studies (examination and analysis of beliefs, attitude, behaviour and interactions, and generation of non-numerical data; e.g. passive observation studies; participant observation studies; questionnaires; interviews; focus groups)
- Quantitative studies (generation of numerical data; e.g. case cohort studies; randomized control trials [RCTs])
- Mixed methods research (studies involving collection of both numerical and non-numerical data)
- Descriptive (non-experimental) research (studies which aim to describe characteristics of an individual or population group, e.g. unobtrusive job analysis)
- Experimental interventional studies (e.g. prevention strategies; diagnostic testing; acute interventions; training interventions; educational strategies; case studies; crossover studies)
- Case study (descriptive research involving a single individual, group, intervention or setting)
- Longitudinal studies (following a population over a time period, e.g. experiential; passive observational; prospective; retrospective; cohort; case-control)
- Cross-sectional studies (descriptive analyses of population groups, commonly for prevalences at a specific point in time)
- Time series studies (analyses of defined data obtained through repeated measurements during a designated time period)
- Grounded theory studies (theory derived from the analysis of participant responses)
- Ethnographic studies (interpretation of the activity of sub-cultural populations)
- Phenomenological studies (interpretation of specific aspects of population groups’ perceptions of lived experiences)
- Epidemiological studies (quantitative analysis of prevalence and incidence of conditions and injuries)
- Questionnaires (e.g. Delphi survey method; Likert-coded; mixed methods)
- Interviews (e.g. structured; semi-structured)
- Focus groups (qualitative research involving small participant groups, assembled to engage in structured discussion)
- Translational research (e.g. where findings from animal studies are first tested in humans)
- In-vitro (‘in-glass’) studies (i.e. in a test-tube or petri-dish) and animal-based (a form of in-vivo – ‘in the live’) studies – both of these typically form early foundations to an area of investigation; they are relatively lower-level evidence due to the obvious limitations in relevance and transferability

Source: adapted from Andrade and Clifford, 2012; Cook, 2012; Gratton and Jones, 2010; Hall and Getchell, 2014; Thomas et al., 2005).

Therapeutic interventions

Obviously, prior to the delivery of any clinical intervention, the sports therapist must undertake an appropriate patient assessment. Aside from exploring all aspects of the patient’s background, health status and main complaint(s), the therapist must aim, as a priority, to identify any reasons for proceeding with caution. Contraindications can range from straightforward locally avoidable conditions, such as an open wound or fungal infection, to more suspicious and concerning presentations such as ‘clinical red flag’ signs warranting immediate referral for medical assessment. It is beyond the scope of this chapter to review all contraindications to clinical sports therapy interventions, and reasons for using caution in practice, but sports therapists must become extremely confident with this fundamental aspect. Additionally, it is a professional and legal requirement to gain the patient’s informed consent prior to delivery of any intervention and that all patient records are produced clearly and correctly, are completed and updated after each session and that they are stored in keeping with Data Protection legislations to ensure safety and confidentiality.
Soft tissue therapy

Manual techniques for affecting soft tissues have perhaps been more commonly recognized as being forms of massage therapy (including such variants as ‘therapeutic’, ‘sports’, ‘remedial’, ‘corrective’ and ‘orthopaedic’ massage); however, the authors of this text favour the use of the generic term ‘soft tissue therapy’ (STT), mainly to promote an appreciation of the technical components of the various approaches and applications to treating soft tissues, and to differentiate from any less professional forms. STT in general is an extremely popular component of sports and physical therapy, and is favoured by patients and therapists alike. Broadly, the field of STT incorporates a wide range of methodologies, approaches and techniques for an equally wide-ranging set of (purported) therapeutic objectives. Such objectives may include:

- generation of mental and physical relaxation;
- release of unwanted local muscular tension (mechanical or reflexive);
- promotion of local neuromuscular excitability (muscular stimulation);
- stretching of tight and shortened soft tissues (muscle and fascia);
- mobilization of restricted or painful joints;
- optimization of soft tissue adhesions, fibrosis or scar tissue formation;
- increase of circulatory flow (arterial, venous and lymphatic);
- enhancement of warm-up and preparation for physical activity (pre-event massage);
- improved recovery from training and competition (post-event massage; maintenance massage);
- recovery from fatigue;
- promotion and support of injury healing mechanisms;
- relief from pain;
- reduction of dyspnea and expulsion of unwanted secretions in respiratory conditions;
- support for the use of other therapeutic interventions;
- promotion of general health and well-being.

Clearly this is an extremely broad set of therapeutic objectives and the evidence to support the efficacy of STT in all of its forms and applications is limited, if not largely speculative; indeed, Weerapong et al. (2005) highlight how the widespread utility of massage in athletic settings is due more to coaches and athletes holding firm beliefs of its potential benefits, based on observation and experience, rather than because of a body of hard scientific, empirical data. Nevertheless, the therapy is consistently requested and offers the patient/athlete an extremely personalized and focused intervention. Among the most well-recognized STT techniques and approaches are: effleurage; petrissage; tapotement; vibrations and shaking; friction techniques; stretching techniques; soft tissue release techniques; myofascial release techniques; instrument-assisted soft tissue mobilization; manual lymphatic drainage; neuromuscular techniques; muscle energy techniques; and positional release techniques. It is usual for the sports therapist to use a combination of soft tissue techniques. Technique selection must be based upon a thorough patient assessment and identification of the intended therapeutic objectives, but also it is imperative that the sports therapist understands the likely mechanisms of effect and most reliable applications. STT for both athletic and general populations has been popular for decades, and there are a multitude of high-profile advocates. Evidence suggests that, when employed, STT may take up nearly half the total treatment time during physical therapy treatments (Hemmings, 2001; Weerapong et al., 2005). STT is considered to be relevant to sports performance through a range of physiological effects (Hemmings, 2001). The main claims for STT relate to its ability to:
Clinical interventions in sports therapy

- increase local blood circulation (Goats 1994a; 1994b; Rinder and Sutherland 1995);
- enhance elimination of metabolic waste, including lactate clearance (Hemmings, 2001; Rinder and Sutherland, 1995);
- decrease sympathetic nerve activity (Callaghan 1993; Goldberg et al., 1992; Sullivan et al., 1991; Tiidus 2000; Weerapong et al., 2005);
- contribute positively to the inflammatory process (Callaghan 1993; Goats 1994a; 1994b; Moraska 2005; Rinder and Sutherland 1995);
- reduce delayed-onset muscle soreness (DOMS) (Hilbert et al., 2003; Zainuddin et al., 2005);
- address restrictions, adhesions and fibrosis in soft tissues (Donaldson, 2012; Hunter, 2006; Myers and Frederick, 2012);
- inhibit muscle hypertonicity (Chaitow, 2007; Chaitow and DeLany, 2002);
- reduce perceived post-exercise fatigue (Robertson et al., 2004);
- offset the negative aspects of stress (Field et al., 2005; Moyer et al., 2011).

Despite its popularity, the evidence of the effectiveness of STT as a general intervention is limited. Hyde et al. (2011) suggest that any soft tissue technique will have local mechanical and cellular effects, as well as associated neurological (indirect or reflexive) responses, which is a key aspect for practitioners to recognize. With regard to the effects of specific soft tissue mobilization (SSTM), Hunter (2006) describes: the local effects regarding blood and lymphatic flow, peripheral neural reception and the mechanical structural changes; the central effects which influence the general interpretation and regulation of nociception and threshold for neural

Photo 3.1 Ideal working posture during delivery of soft tissue therapy.
firing, which in turn may facilitate improved scope for motor patterning in rehabilitation; and the cognitive effects, which may include the generation of positive emotional responses (such as the reduced sense of fear or frustration or the improved sense of pleasure, safety and comfort), which can lead to improvements in decision making and behaviours. Such effects, it must be considered, relate not just to the treatment itself, but also to the therapeutic relationship and the setting. Galloway et al. (2012) provide a contemporary review of evidence to support massage therapy for athletic populations, and importantly highlight the need for practitioners to engage more effectively with the development of the evidence-base. Similarly, Brummitt (2008) reviewed the evidence for massage in aiding sports performance and rehabilitation. While numerous positive outcomes with regard to physical, physiological and psychological effect were identified in the literature, issues of flaws in study design were highlighted. Notwithstanding the evidence, the art, skill and specificity of the delivery and application of tissue palpation, pressure, depth, movement, stretch and proprioception, together with the time frame, duration, repetition and the response to the patient’s reported levels of comfort or discomfort are each equally important to achieving the therapeutic objectives. The recognizable physical, physiological, psychological and cumulative effects of STT have certainly reasoned this modality to be suitable as a treatment within athletic and general populations, but developing the evidence-base to support the whole spectrum of applications and indications must be seen as a priority of the profession; in so doing, practitioners and researchers must look to find ways to reliably prepare studies, recruit participants, standardize interventions and measure outcomes. Future research in this area must appreciate the findings and recommendations of previous research and the critical analysis that it has faced. Provided below is an overview of the main methods and techniques utilized within the fields of STT.

**Effleurage**

Effleurage is a technique using rhythmic stroking movements. Effleurage is frequently used as a technique to commence, link and conclude STT sessions (Callaghan, 1993; Watt, 2008). When oil or lotion is being used, effleurage is the technique which is employed to apply it. The purported benefits of effleurage include promoting circulation, warming of tissue, the generation of relaxation, and through the effect of stretching muscle and fascia can help to ease painful and restricted areas (Briggs, 2001; Goats, 1994b; Watt, 2008). Deeper effleurage stroking techniques during treatment can be applied using a smaller and reinforced contact surface, and is applied in both longitudinal and transverse directions using the tip or pad of the thumb or fingers, the heel of the hand (hypothenar eminence), the knuckles, the flesh of the forearm, the ulnar border and more specifically the olecranon process. As a basic rule, whenever the practitioner is choosing to work more deeply they must work more carefully and slowly. There is a great advantage for deep transverse stroking over, for example, longitudinal stretching because it can target specific restrictions and work across the direction of the affected fibres (‘across the grain’). Longitudinal stretching lengthens tissue, but it is limited in the fact that it preferentially affects (lengthens) the most elastic components of tissues, and in so doing will also actually bring tissue fibres closer together.

**Petrissage**

Petrissage describes a variety of techniques that rhythmically lift, compress, stretch and knead soft tissues. Techniques include wringing, picking-up and rolling, and may be delivered with a lifting, gripping and grasping type approach, or more compressively via the use of the palms of the hand.
The technique may be delivered in an alternating manner using both hands, or simply with a single hand. Petrissage can be slow, rhythmic, and restful, but also energetic and invigorating. With a gentle, but firm grasp, the tissues are raised and stretched away from the underlying bone with alternate squeezing and relaxing of the tissues. Petrissage techniques collectively may promote reflex vasodilation and hyperaemia that can lead to a decrease in tissue swelling. Vigorous kneading may cause a decrease in muscle spasm and stretch tissues shortened by injury.

**Tapotement**

Tapotement consists of percussive movements which involve rhythmic tapping or controlled striking (Lewis and Johnson, 2006). Tapotement is purported to: cause erythema (reddening of the skin due to local hyperaemia); stimulate muscle fibres (potentially invoking the myotatic stretch reflex to raise tone); increase cellular activity; increase airway clearance and decrease dyspnea; mobilize respiratory secretions; cause systematic and sensory arousal and enhanced alertness; and cause pain reduction through counterirritant analgesia (Andrade and Clifford, 2008). Tapotement most commonly uses both hands alternatively and quickly. Techniques include: hacking; flicking; cupping (or clapping); pounding; tapping; beating; and pincement. Pincement is a technique performed at speed without aggressive pinching of the skin (Benjamin and Lamp, 2005); fingers and thumbs are used to lightly pluck and pick up superficial tissues.

**Vibrations and shaking**

Vibration and shaking techniques may be applied locally to specific soft tissues, or more generally to a muscle group. A brisk trembling type motion of the hands or fingers is employed. This technique is often used pre-competition with a view to ‘excite’ the muscles (Goats 1994a).

**Friction techniques**

The friction technique aims to separate tissue fibres and restore mobility where restriction, adhesions, fibrosis and degeneration are present (Cyriax and Coldham, 1984). Frictions provide localized movement to a specifically identified site (lesion) in the muscle, tendon, fascia or ligament, while also inducing hyperaemia. Donaldson (2012) explains that reparative cells (fibroblasts), which lay down collagen, are mechanosensitive; hence, friction massage may facilitate matrix production and are aimed to restore the tissues’ mechanical properties during repair. Transverse friction techniques typically use reinforced thumb or finger tips, or the olecranon process (Cyriax and Coldham, 1984; Goats, 1994b; Watt, 2008). The technique may be delivered in a small circular motion (Goats, 1994b), or longitudinally, or perpendicular (transversely) to the orientation of the affected tissue fibres; and the technique should only be performed at the exact site of lesion (Donaldson, 2012). When the therapist applies friction to tendons and ligaments, it has been recommended that these tissues should be in a stretched position. In contrast, it is suggested that friction to muscle tissue is performed in a relaxed, shortened position (Cyriax and Coldham, 1984; Goats, 1994b). Donaldson (2012) highlights that much of the published evidence to support friction techniques has involved small sample sizes.

**Therapeutic stretching**

Whether deemed to be active, passive, static, ballistic, dynamic, maintenance, developmental or corrective, stretching involves a force application to lengthen tissue. Lederman (2014) proposes
that ‘functional range of movement’ may be effectively maintained by forces generated during normal daily activity (or perhaps more explicitly, guided therapeutic daily activity) and that ‘overloading is a training condition for adaptation in which physical challenges are raised above functional levels … and forces below the overloading threshold will be ineffective at inducing long-term range of movement change’. Lederman (2014) also suggests that functional activities may be able to provide the required adaptations in restricted soft tissue movement, and that some manual stretching approaches may fail to provide this.

Indications for therapeutic stretching may include: mechanical lengthening for improving soft tissue and segmental length and alignment, and normalizing range of joint movement; improving circulatory flow to dehydrated connective tissues; reducing low-grade interstitial oedema; improving movement control; stimulation of tissue cells during repair (fibroblasts; myofibroblasts) via a process of mechanotransduction; and reducing nociceptive firing caused by structural compression, joint malalignment, low-grade oedema and restricted myofascia.

Mechanotransduction is simply the process whereby tissue cells respond to mechanical loads (Khan and Scott, 2009). Therapists will appreciate the difference between active and passive ranges of movement, and also how tension imbalances between antagonistic muscle groups can affect and restrict movement. Stretching techniques rely on neural, structural (musculoskeletal), elastic and potential plastic effects to alter the available ranges of motion. As Myers and Frederick (2012) explain, the effects of stretching will relate to the variable components of delivery (the ‘task parameters’) (i.e. force type, intensity, amplitude, duration, speed, direction, repetition and frequency). Lederman (2014) explains how any of these task parameters may be carefully ‘amplified’ during rehabilitation progressions. While mechanoreception is not limited to the following, neural effects of stretching rely on three main reflexes: stretch reflex (invoked via stimulation of the intrafusal muscle spindles); inverse stretch reflex (invoked via stimulation of golgi tendon organs); and the perception and control of pain via nociceptive and central mechanisms (Vujnovich and Dawson, 1994). The three neural reflexes together respond to and contribute to the regulation of muscular flexibility during stretching. Another important consideration is that it is never just muscle tissue which is being stretched. The non-contractile tissues may be more resistant to stretch compared to muscle tissue due to their different structural constituents and associated viscoelastic properties; it is also important to remember that scar tissue and fibrous adhesions also comprise connective tissue (Sapega et al., 1981). With passive (assisted) stretching delivered by the therapist, the patient is positioned appropriately and remains as relaxed as possible. For optimal effects, the therapist must work with an understanding of where the stretching is to be focused. Some applications will involve attempting to fix and stabilize body areas which should not be moving during the stretch so as to localize the effect to the target area; other applications will incorporate a more global approach. As Myers and Frederick (2012) ascertain, ‘the use of the word “isolated” in conjunction with the word “stretching” is difficult to justify when a straight leg lift test produces 240% of the strain in the iliotibial tract that it does in the hamstrings’. The fact that motor control and task-specific muscle recruitment (to retrain functional movement patterns) are not being utilized during passive stretching shows another limiting aspect to its usefulness (Lederman, 2014). However, as part of a comprehensive strategy, the sports therapist will clinically reason their optimal approach. Debate continues regarding the optimal duration of stretching techniques to achieve lasting adaptation in soft tissue. Many authors recommend a gradual lengthening into the desired stretch position (aiming to inhibit the myotatic stretch reflex), with the stretch position held for 15–30 seconds (McAtee, 2013). Where there are fascial restrictions, stretches will need to be held for longer, but practitioners must recognize the highly individualized variants in regional tissue structure and composition, which means that there is not one single recipe for stretching restricted tissue. Jelveus (2011) has
highlighted the plethora of evidence that indicates static stretching prior to athletic activity can reduce power output and speed, and moreover may even contribute to the potential for injury.

All stretching techniques must be performed within a physiological range, as overstretching causes damage (Alter, 2004). Such damage may occur in muscular, fascial, tendon, ligamentous, capsular or neural tissue. While peripheral nerves are able to withstand moderate stretching force, and indeed neural tensioning is a recognized therapeutic intervention, structural damage can occur when a nerve is stretched to 10 per cent of its physiological length, and tearing (neurotmesis) can occur at 30 per cent (Ylinen, 2008). Dynamic stretching has been part of the pre-event warm-up strategy which has been universally recommended in recent years due to its efficacy in aiding increased body temperature, joint mobility and neuromuscular firing, as well as offering some contribution to the increased strength, power, endurance, anaerobic capacity and agility which is promoted during thorough dynamic warm-up.

As discussed later in this section, soft tissues are anisotrophic, and there is an order-effect relating to the movements of joints; the therapist should keep these aspects in mind when attempting to perform passive tissue lengthening techniques (Hunter, 2006). It must also be recognized that soft tissue flexibility incorporates the tension (or ‘tone’) as held by the nervous system – which is why stretching in itself will not address such a component effectively – as well as the mechanical, elastic and plastic limitations to its end of range. Beyond this, there are other tissues which influence the range of movement available, not least all main peripheral nerves and all associated joint capsules. It is important to note that patients with hypermobility require special consideration so as not to develop further instability. Ylinen (2008) provides a comprehensive, practical guide to passive stretching techniques.
Soft tissue release

Soft tissue release (STR) requires the therapist to apply pressure into an area of restriction while it is being stretched. Basic STR strategies employ a procedure of first positioning the patient appropriately; shortening (slackening) the target tissues; applying a specific pressure into the area of soft tissue requiring release; and then, as the associated joint is slowly passively or actively mobilized, stretching of the tissues directly below the fixed point (Sanderson, 2012). The analogy of a ‘key into a lock’ has been used (Cash, 2012), where the therapist applies a ‘key’ (the pressure) into a ‘lock’ (the shortened restricted tissue) and then ‘opens the door’ (stretches the tissue); this may also be explained as ‘pin and stretch’. Active STR involves the patient having to perform the joint movement and does mean that the therapist may be able exert a stronger reinforced pressure as they will have two hands available; passive STR has the therapist moving the patient with one hand and applying the pressure with the other.

Myofascial release

Fascia is a thoroughly integrated membrane of connective, viscoelastic tissue which covers and invests all structures of the body; fascia provides support and protection, and creates a structural unit. Fascia both separates and connects layers of muscle, compartments and cavities, as well as forming sheaths for nerves. Fascia thickens ligaments and joint capsules, and creates a continuous matrix that interconnects all structures of the body. Fascia is akin to a web that covers and interacts within the entire body. In order to appreciate how myofascial release (MFR) (may) work, it is essential to appreciate the main functional characteristics of fascia; such terms as viscoelasticity, thixotropy, creep and hysteresis require brief explanation. According to Schleip

Photo 3.3  Soft tissue release for the hamstring group.
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(2003), much of the work in myofascial therapy has been influenced by Rolf (1977), who was an early advocate of the requirement to therapeutically affect the ground substance of fascia with mechanical or thermal energy, and hence attempt to convert the substance aggregates from a dense gel-like state to a more fluid state, a process known as thixotropy, which itself is said to be due to the hydrophilic (water attracting) and viscoelastic (fluid-based elastic) properties of the fascial connective tissues. The fluid component of the ground substance (generated by the hydrophilic glycosaminoglycans) is essential to facilitate lubrication and synthesis of the collagen fibres it separates; and numerous factors can transpire to cause reduction in this fluid constituency (Chaitow and DeLany, 2002). The response of fascia to mechanical (tensile, shear and torsion forces) and thermal energy, in terms of its resultant plasticity (and potential for long-lasting deformation) is apparently time and force-dependent (Schleip, 2003). As such, fascia has been traditionally described as having ‘creep’ properties, which implies a relationship between time and stress on this connective tissue; a potential gradual conversion from ‘gel’ to ‘sol’ (fluid) state; a potential resulting effect on tissue length and freedom of movement; and further, an influence or effect on all related areas of the body. Barnes (1990) suggested that the time frame for thixotropic effect is 90–120 seconds. Hysteresis is the gradual resumption of viscoelastic structures to a resting length following deformation; the difference between pre- and post-loading strain is termed the ‘set’ (Atkins et al., 2010; Bogduk and Twomey, 1987). Andrade and Clifford (2008) recommend that the best method for achieving longer-lasting plastic deformation of myofascial tissue, importantly without compromising its structural integrity, is to perform sustained, low-intensity forces. It is important to recognize that the purported effects of MFR are not universally accepted. Ingraham (2013) presents an eloquent analysis and argues against the inherent potential of fascia to ‘release’; even Schleip (2003) has stated that plastic adaptation to moderate loading is ‘impossible to conceive’. Although advocates enthuse about the benefits of MFR, convincing evidence is still required for what exactly may be occurring during and after such intervention. Kidd (2009) builds an argument that MFR technique cannot be effectively evidenced, simply because of the inherent involvement and unique nature of each therapist’s delivery. It is often implied that effective MFR is a therapeutic art relying on experience, skill and intuition; and while therapeutic outcomes can be readily evaluated, can the therapist be excluded from the process?

MFR consists of the focused releasing of both obvious and subtle restrictions evident within the myofascial network. Aside from the obvious limitations in soft tissue flexibility and ranges of movement, such restrictions can also cause entrapment of neural and vascular structures which are embedded within the tissue, potentially leading to neurological and ischaemic conditions (Fritz, 2005). Myofascial release technique involves either gross or local application, depending on the desired clinical outcome. Gross myofascial release concentrates on groups of muscles or sections of the body and is performed by a hand or one or two fingers fixing the affected tissue, while the other hand or finger(s) applies the stretch in parallel to the long axis of the tissues away from the fixing hand. Reinforced fingers or the elbow can be used to deliver slow and responsive techniques to fascia. The practitioner must hone their sense of how the fascia yields in response to the mechanical and thermal energy and the resulting thixotropic effect. Using the palms in a ‘crossed-hands’ technique allows gradual lengthening of fascial tissue in opposing directions following an initially static and sustained contact. Other foundational MFR techniques include arm and leg pulls, which offer subtle distraction as limbs are taken steadily through a range as the therapist senses yield. MFR is very much a process employing constant assessment and observation of effect and the patient must be encouraged to fully relax. Once tightness or restriction is identified and met, the tissue stretches are held until the therapist senses that tension has subsided, and are then progressed carefully (Andrade and Clifford, 2008; Manheim, 2008). Practitioners must aim to appreciate what effect the technique is having
Photo 3.4  Myofascial release ('cross hands’ technique) to thoracolumbar region.

Photo 3.5  Myofascial release ('leg pull’ technique).
during its application; constant palpatory monitoring is required. Furthermore, it is important to appreciate that, just as with joints and muscles, the presentation of fascia varies from patient to patient; it may be regular or irregular, dense or loose, bound or hypermobile (Earls and Myers, 2010). A systematic review of MFR interventions for a range of musculoskeletal conditions by McKenney et al. (2013) found that the majority of studies had positive outcomes, but due to the mixed quality (higher-quality experimental to lower-quality case studies), few conclusions could be drawn, and further randomized controlled trials are required.

Instrument-assisted soft tissue mobilization

Massage tools and instruments may offer the therapist assistance with corrective and deeper work, making remedial work more specific to areas of fibrosis, and may also reduce manual stress to thumbs, fingers, hands and the upper extremity (Hammer, 2012). Instruments to assist in the treatment of soft tissue dysfunction and other problems have been in use for many years in traditional Chinese Gua Sha therapy (Nielsen, 1995). Wooden, hard plastic, stone (such as jade) and high-grade stainless steel instruments (‘tools’) have become more commonplace in recent years to assist practitioners in the delivery of corrective soft tissue techniques, both for protecting thumbs and fingers and for facilitating increased precision. The concept of instrument-assisted soft tissue mobilization (IASTM) has been developed, and although evidence is in its infancy, Loghmani and Warden (2009) are among those who are demonstrating the potential for enhanced soft tissue therapy using stainless steel instruments. Looney et al. (2011), in a case series, presented evidence to support the use of ‘Graston’ instrument mobilization of the plantar fascia. Other recognized protagonists include Hammer (2008; 2012) and Hyde et al. (2011). It
is proposed that specialized stainless steel instruments can be used as part of the palpatory assessment of tissues, and will ‘amplify’ the tactile and auditory senses. Orton (2013), in his brief review, described the versatility of such instruments, where multifaceted edges (blades) on a tool can facilitate improved precision and provide access to a host of usually challenging anatomical structures. Hence, this method can be extremely useful for attending to specific soft tissue problems associated with muscles, tendons, fascia, ligaments and scar tissue. By appreciating the need to assess the locality of any soft tissue lesion, the sports therapist will also understand the potential for unnecessarily aggravating tissue (and causing undue pain) if delivering IASTM treatment without due care. An emollient salve, typically with a base of beeswax and petroleum jelly, is the preferred medium for allowing smooth movement on tissue. Recognized methodology for IASTM incorporates the following:

- Selecting the appropriate tool and blade for the targeted tissue.
- Applying an initial ‘scanning’ assessment technique using an angle of approximately 30° to the skin (scanning techniques allow for superficial fascial and deeper soft tissue restrictions to be identified using the tool).
- Treatment methods include localized, short cross-fibre and ‘J-stroke’ techniques.
- Increased angles of application with maintained or increased pressure will increase depth and specificity of application.
- Blade size and contact area may be reduced to increase depth and specificity of application.
- Depth and specificity can also be achieved by altering the positioning of the body region (i.e. placing tissues on stretch or into shortened relaxation; or by guiding the patient to perform movement – active or resisted – during treatment).
- Both applied heat and warm-up exercises have been recommended for tissue preparation.
- Ice applications have been recommended pre- and/or post-treatment.

Photo 3.7 The ‘i-assist’ (‘scanning’ technique).
Photo 3.8 The ‘i-assist’ (treatment technique).

**Manual lymphatic drainage**

Manual lymphatic drainage (MLD) is a gentle advanced soft tissue technique which uses low-intensity pressures, strokes and joint movements, with the aim of manipulating skin and associated connective tissues to assist the function of the lymphatic system (French, 2011). As a secondary circulatory system, the lymphatic system comprises lymphatic vessels, lymph nodes and lymphatic ducts, which eventually drain into the left and right subclavian veins and return their fluid constituents to the general circulation. There are two primary functions of the lymphatic system; first, the collection and transportation of interstitial fluid, as lymph; and second, the production, storage and distribution of lymphocytes (specialized leucocytes – white blood cells), which are essential components of the immune system. The sports therapist may utilize aspects of MLD technique in acute stages of injury when oedema is present. Knowledge of location and direction of the main lymphatic vessels and nodes is central to this application (Andrade and Clifford, 2008). Instructing deep breathing, passive joint movements, elevation of limbs, physically encouraging circulatory flow in proximal vessels and pathways (including alternating gentle compressions over the anterior upper chest and shoulder area) are all potentially useful approaches. The lymph nodes that are proximal to the injury can be lightly massaged using circular, ‘figure of eight’ or ‘J-shape’ motions (French, 2011). These movements can be performed in conjunction with light effleurage techniques which follow the lymphatic pathway from the affected region towards the nearest set of proximal nodes, and followed with light stokes proximally away from these.
Myofascial trigger point therapy

Within neuromuscular therapy (NMT) there are a range of approaches and techniques. As Dejung et al. (2013) explain: ‘In folk medicine it has always been known that finger pressure on a painful spot can reduce the pain’. While the true aetiology of trigger points is still to be determined, trigger point therapy is a recognized soft tissue approach incorporating pressures, which are applied by the thumb, fingers, elbow or an applicator tool (such as a 'Jacknobby') to tissues deemed to be containing myofascial trigger points (MTrPs); this may also be known as ischaemic compression, or simply neuromuscular technique. Longitudinal or local stretching of the affected tissues, muscle energy techniques, positional release and myofascial release techniques are all commonly integrated into therapy designed to ‘deactivate’ the MTrPs. Ultrasound, laser, heat and cold (including ‘spray and stretch’) therapy have also been historically advocated. Invasive procedures such as dry needling, local anaesthetic and combination corticosteroid injections, as well as botulinum toxin (‘botox’) injections have also been advocated by some practitioners in resistant cases, although evidence is lacking. A combined NMT approach aims to eliminate MTrP activity and produce modifications in dysfunctional tissue and encourage a restoration of functional normality (Chaitow and DeLany, 2002; 2008). Alvarez and Rockwell (2002) suggested that myofascial pain syndrome is one of the most common causes of pain resulting from soft tissue dysfunction, and in particular, MTrPs. Explanations for the apparent existence of MTrPs incorporate a multitude of reasons, including: myofascial, postural and biomechanical imbalances; joint dysfunctions; trauma; overtraining; psychological and emotional issues (as may be associated with central sensitization); metabolic disorders; nutritional deficiencies; and conditions such as fibromyalgia (Chaitow, 2006). Any of these commonly presenting factors can contribute to hyperirritability, which is the hallmark of MTrPs, and while the actual aetiology and pathophysiology of MTrPs remains uncertain, what is certain is the multifactorial development aspect. Traditionally, MTrPs have been associated with dysfunctional motor end-plates, an excessive release of acetycholine (ACh), local tissue hypoxia and low pH (Dommerholt, 2013). Quintner et al. (2014), however, in their review, suggest that the traditional theory for MTrP development is flawed and argue that there are two more plausible explanations for the development of localized muscle tenderness ‘in structurally and physiologically unimpaired’ muscles. They propose that deep peripheral neurogenic inflammation may result in ectopic, spontaneous axonal discharge which can lead to sensitization of the innervated muscle; the authors do not, however, explain the underlying reasoning for such deep neuronal inflammation. Their second hypothesis designates an MTrP as ‘a site of secondary allodynia reflecting altered central nociceptive mechanisms’. The pathogenesis of MTrPs remains uncertain.

MTrPs have been described as being active (those that cause spontaneous and characteristically referred pain); and latent (those which have similar clinical features but without being currently responsible for pain) (Travell and Simons, 1998). Trigger point therapy (NMT or ischaemic compression) is presented as a technique utilizing palpatory assessment throughout delivery, communication and feedback from the patient, and continued modification of pressure application (which is usually intermittent). Applied pressure into a sensitive MTrP, which may be simply described as an area of local neuromuscular facilitation and chemical imbalance within a taut band of muscle, will typically cause referred pain to a site away from the local point (Simons, 2004). On first pressure there may be a ‘twitch’ response of the affected muscle (localized involuntary contraction); this is because the muscle fibres are facilitated and therefore have a reduced threshold for firing with mechanical stimulation. Trigger point therapy is delivered to generate a change in neuromuscular behaviour. Fritz (2005) notes that MTrPs may...
be identified during palpation by the presence of skin changes (tension and resistance to gliding; moisture from perspiration due to autonomic sympathetic facilitation; temperature changes; oedema), alongside deeper palpation which may evoke tenderness, and identify muscular tension or fibrosis. Gautschi (2008) explains that ischaemic compression to MTrPs can cause a reactive hyperaemia, which leads to an increase in local metabolism and a reflective detensioning of the taut band housing the MTrP. During trigger point therapy, direct manipulation may involve pushing the muscle belly together (to affect muscle spindles), pushing tendons apart (to affect golgi tendon organs – GTOs) and direct intermittent pressure (or squeezing together) of the MTrP (to affect local mechanoreceptors, including muscle spindles, and additionally to cause a circulatory effect). Chaitow and DeLany (2002; 2008) suggest gradually increasing local pressure applications of around eight seconds duration (staying within a maximum 7/10 subjective pain range) for between 30 seconds and two minutes at a time. The technique is deemed successful when any referral pain fades and when local pain and relaxation occurs in the affected muscle fibres. The therapist will maintain palpatory assessment during delivery, and it is essential that they maintain good working posture and protect their digits during treatment. It is recommended to deliver some form of lengthening of the locally affected connective tissues as part of the trigger point therapy, and obviously, as with all interventions, causative factors must be addressed and functional re-education employed (Gautschi, 2013).

Muscle energy technique

Muscle energy techniques (METs) are osteopathic in origin, and incorporate a number of approaches. They may be applied to both acute and chronic conditions, and aim to increase joint range of motion and soft tissue flexibility, reduce pain and decrease muscle spasm (Burns and Wells, 2006; Chaitow and DeLany, 2002). The basic principle of MET takes advantage of the relationship which exists between the peripheral nervous system and the muscles that they innervate, and how this relationship can be manipulated for therapeutic effect. More specifically, practitioners of MET will appreciate the reciprocal innervation of antagonistic muscle groups, and the specialized mechanoreceptors (GTOs) located at musculotendinous junctions. While the neuromuscular theory of reflex relaxation is plausible, no studies as yet show a decrease in electromyographic (EMG) activity following MET (Fryer, 2011). As the MET process typically takes a few minutes to perform, the techniques are highly likely to alter the pliability and length of the targeted myofascia due to its viscoelastic properties. Clearly, there are limitations to the MET evidence-base, as Fryer (2011) explains:

like many manual therapeutic approaches, the efficacy and effectiveness of MET technique are under-researched, and there is little evidence to guide practitioners in the choice of the most useful technique variations (such as number of repetitions, strength of contraction or duration of stretch phase), causing frustration for those endeavouring to integrate relevant evidence into practice.

Hence, while being anecdotally useful, and objectively effective, further research is required to confirm effects and best applications. Post-isometric relaxation (PIR) and reciprocal inhibition (RI) are the most well-recognized examples of MET and may be used in combination with other soft tissue techniques (Chaitow, 2006).
Post-isometric relaxation

PIR MET follows the simple protocol that a gentle tensile stress (a stretch) is applied to muscle following a gentle isometric contraction. An isometric contraction is relatively static; tension is generated in the muscle, but the muscle length and joint angle does not alter. An isometric contraction is performed at a position of bind (the ‘restriction barrier’), which is the position where the therapist first senses slight tensioning in the target tissue. This, it has been hypothesized, stimulates the GTOs and may cause a short-term relaxation (inhibition) of the involved muscle(s) and may contribute to resetting of the resting length (Norris, 2011; Vujnovich and Dawson, 1994). A ‘window of opportunity’ has also been described, where, following a low-intensity isometric contraction of the target muscle, a gentle stretch can be applied as the patient relaxes (and is instructed to breathe) (Chaitow, 2006) to make a change in the muscle length.

Application of PIR

Although a range of protocols are evident, for a general PIR strategy the therapist moves the affected tissues to a point where ‘bind’ is felt. The therapist then maintains this position for approximately ten seconds while the patient actively contracts against the therapist’s resistance anywhere in the range 15–75 per cent of maximal contraction (Ballantyne et al., 2003; Chaitow and DeLany, 2002; Smith and Fryer, 2008), although a simple gentle contraction (around 20 per cent) should suffice. The muscle is then relaxed, the patient encouraged to relax and breathe in and then out, and as they breathe out the limb is moved passively to the new position of bind. The process is usually repeated 2–5 times until no further increases are found (Burns and Wells, 2006; Chaitow and DeLany, 2002). Gibbons (2011) recommends that the final position is held for around 30 seconds in order to facilitate improved neuromuscular functioning.

Reciprocal inhibition

RI MET involves contraction of the antagonist muscle group, and deals with the reciprocal effects (relative inhibition of the target group) of an isometric contraction in the muscle group opposite to the target muscle group. Just as in PIR, the delivery of RI must incorporate appreciation and continued assessment of the ‘bind’ point, but often in RI, the isometric contraction will need to be performed back from the ‘bind’ point, in a mid-range joint position, due to the potential for cramp occurring in a biomechanically disadvantaged position (which relates to the length–tension relationship and active insufficiency in the contracting muscles). RI may be most useful when in acute or sub-acute situations where a degree muscle spasm is present – to help inhibit the hypertonic situation; and also where the contraction of an affected target muscle group may be uncomfortable or aggravating. When spasm or pain on contraction is not a feature, PIR and RI may be used in conjunction.

Positional release technique

Patients should ideally be effectively assessed in functional, loaded positions, if possible, so as to ascertain specific restrictions and symptomatic responses – which may not present as clearly in non-functional positions. Positional release technique (PRT) strategy can include having the patient’s affected tissues relaxed, on stretch, contracted, in weight-bearing and during progressively loaded movement patterns, which are performed with the aim of producing and reducing, and therefore identifying, the symptomatic response. Once the restrictions or symptoms have been identified, the treatment strategy may incorporate PRT which may actually employ similar patient positioning. This approach is obviously used in conjunction
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with whatever else the sports therapist feels is appropriate. There are a number of techniques that involve placing the patient’s body into a position of ‘ease’. In a patient that presents with a distorted position caused by hypertonicity or spasm, the therapist may place the patient into a position that exaggerates the distortion (Chaitow, 2007). The hypothesis of PRT is that compensatory positions allow the resetting of physiological processes, which in turn can reduce the spasm and pain rather than antagonize the situation by causing the body to react with an increase in pain and resistance (Chaitow and DeLany, 2008). PRT aims to rectify somatic or musculoskeletal disturbances and may be effective in complex regional pain syndrome (Collins, 2007). It is postulated that its efficacy is due to causing a decrease in the commonly developed proprioceptive hyperactivity (Chaitow, 2007), coupled with a controlling influence on the neurophysiological propagation brought about by the overstimulation of muscle spindles and the related increase in neural discharge caused by mechanical strain (Collins, 2007). It has also been proposed that a ‘circulatory flush’ of previously ischaemic tissue will occur. PRT is an appropriate treatment when presented with a patient with either acute or chronic neuromuscular dysfunction (Chaitow and DeLany, 2002; Collins, 2007).

Application of PRT

The technique relies on precise palpatory and effective communication skill, so as to deliver a sensitive approach and to work with the patient to achieve a sense of ease. Hypersensitive tissue points may be relieved by working, one step at a time, to position the affected body part into its position of maximum relief (with full patient relaxation) for between 20 and 90 seconds (Chaitow and DeLany, 2008; Collins, 2007), while maintaining contact with the palpating finger. This typically involves very slight slackening of tissue, utilizing a sequential combination of subtle physiological and accessory movements (for example, at the glenohumeral joint, passive application of small degrees of abduction, lateral rotation, horizontal extension and cephalad movements) each time reassessing for change in sensitivity. Once in a position of ease, it is recommended that an integrated approach is utilized, and digital ischaemic compressions (NMT) are delivered. If the therapist has found a comfortable resting position, and if the tender point decreases by at least 70 per cent, the treatment is deemed a success (Chaitow, 2007; Collins, 2007).

Integrated neuromuscular inhibition technique

Using a combination sequence of NMT, PRT and MET in the form of integrated neuromuscular inhibition technique (INIT) has been advocated by Chaitow (2007), Hall (2014) and Nagrale et al. (2010). Such an approach may begin with NMT (using ischaemic compressions) to the affected points, then delivery of PRT; in the INIT approach, the therapist may continue delivery of ischaemic compression during the PRT. Following PRT, MET (PIR and/or RI) and MFR may be used to lengthen the (potentially desensitized) affected tissue.

Progressive soft tissue therapy approaches

Strategies and systematic approaches for delivery of STT, in terms of positions of application, intensity, repetition, duration and frequency have been generally presented as being technique specific and essentially with a large degree of operator (therapist) autonomy. There have been developments in recommendations for strategy in delivery of STT presented in recent years, yet as ever, more clinically reliable research is required. Progressive approaches for targeting soft tissue restrictions has been advocated and popularized by numerous authors; these include:
‘Anatomy Trains’ and ‘Structural Integration Therapy’ (Earls and Myers, 2010; Myers, 2008); ‘Functional and Kinetic Treatment with Rehabilitation, Provocation and Movement’ (FAKTR-PM) (Hyde et al., 2011); ‘Specific Soft Tissue Mobilization’ (SSTM) (Hunter, 1994; 1998); and ‘Therapeutic Stretching’ (Lederman, 2014). Additionally, the field of neuromuscular therapy (including NMT, MET and PRT), which is subtly different to the more direct, mechanical approaches, and based on inhibitory, indirect and reflexive responses, is well established, with such authors as Chaitow (2006; 2007), Chaitow and DeLany (2002; 2008), Fritz (2005), Fryer (2011), Sharkey (2007) and Travell and Simons (1998). The traditional hypothesis for MTrPs has, however, been challenged by several authors (Quintner et al., 2014). The INIT approach, combining digital ischaemic compression, positional release, MET (PIR and/or RI) and MFR, shows good evidence for achieving a reduction in MTrP sensitivity and increasing length in restricted soft tissue (Hall, 2014; Nagrale et al., 2010). The understanding of INIT must include the structural and physiological intricacies of connective tissue and fascia as much as that of the muscular and neurovascular systems. It must also appreciate the many and various causes of dysfunction and adaptation (local and central; postural; traumatic; psychological; and respiratory). In the light of such appreciation, the practitioner will understand why STT is so useful, how it can work to influence positive changes (physically, physiologically and psychologically) and how it may be best applied. The mindful practitioner will, however, recognize that for long-term patient benefit an active, rather than passive, hands-on, approach may be far more appropriate.

Patient treatment positions and active involvement have been identified as being influential to the overall therapeutic potential for optimal improvement in tissue structure and function. Sports therapists should aim to consider, in remedial soft tissue treatments, the placing of patients into positions of function or provocation (which may be with affected soft tissues on stretch or in loaded contraction, such as with the use of theraband or free-weights) so as to be specific in their remedial delivery (Hyde et al., 2011). Furthermore, the concept of SSTM recognizes the fact that soft tissues are anisotrophic, in that their properties alter according to the different directions of movement that are applied to them, and they are not loaded equally during any particular mechanical stress. Additionally, there is an ‘order effect’ in which joints may be moved by the practitioner in order to affect any targeted multi-articular muscle group (Hunter, 2006). The message here is that there are numerous ways of moving or affecting soft tissues, and that it is not always appropriate to use conventional or simply linear stretches to obtain the desired results. Even when a target muscle has been placed on a multi-directional stretch, employing the ‘order effect’ of a combination of joint movements, the practitioner still has the opportunity to perform what may be called ‘accessory movements’ of the already stretched fibres. Hence, there are a host of approaches to employ, and the therapist has to reason their way through their delivery while being sensitive to the response and feel of the tissues, the ranges of movement being employed at the involved joints, and the response of the patient themselves. Practitioners should aim to combine their soft tissue techniques into a seamless and comfortable STT session; they must also consider the best approach to integrating their soft tissue skills into the complete sports therapy session, which may also incorporate elements of manual therapy (joint mobilizations), possibly electrotherapy, taping, cryotherapy and especially exercise rehabilitation. Arguably, this is one of the main challenges that the sports therapist faces – how to optimize their therapeutic strategy; and practitioners should aim to recognize the notion of ‘therapeutic intent’ – having a clear vision in their own mind of what they are setting out to achieve. Andrade and Clifford (2008; 2012) have presented an ‘outcome-based massage’ (OBM) methodology, which incorporates a four-stage systematic decision-making process regarding: the identification of patient impairments associated with their condition or wellness.
goals; the specification of desired and relevant (client-centred) outcomes; the selection of most appropriate therapeutic techniques; and the application of selected techniques (incorporating psychomotor skills). Certainly, by ‘throwing everything at the patient’, the therapist is unable to be confident about which interventions are helping or hindering progress. Essentially, it is the combined employment of clinical reasoning strategy alongside the utilization of EBP which must be the dominant influences upon management planning. Being able to progress the patient/athlete from a purely passive approach to a more active and functionally relevant programme must be a priority in the majority of cases.

Table 3.5 General and local contraindications and precautions to soft tissue therapy

<table>
<thead>
<tr>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute injuries</td>
</tr>
<tr>
<td>Suspicion of complex injury</td>
</tr>
<tr>
<td>Inability to ascertain the nature of the complaint</td>
</tr>
<tr>
<td>General malaise and feeling unwell</td>
</tr>
<tr>
<td>Severe pain</td>
</tr>
<tr>
<td>Highly irritable conditions</td>
</tr>
<tr>
<td>Dizziness</td>
</tr>
<tr>
<td>‘Red flag’ signs</td>
</tr>
<tr>
<td>Significant ‘yellow flag’ signs (concerning biopsychosocial factors)</td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Febrile state (fever)</td>
</tr>
<tr>
<td>Congestive heart disease</td>
</tr>
<tr>
<td>Circulatory disorders</td>
</tr>
<tr>
<td>Hypertension</td>
</tr>
<tr>
<td>Recent surgery</td>
</tr>
<tr>
<td>Post-surgical pain</td>
</tr>
<tr>
<td>Recent inoculations (&lt;24 hours)</td>
</tr>
<tr>
<td>Hypothermia / hyperthermia</td>
</tr>
<tr>
<td>Myositis ossificans</td>
</tr>
<tr>
<td>Hernia</td>
</tr>
<tr>
<td>Skin disorders</td>
</tr>
<tr>
<td>Tumours or unrecognizable lumps</td>
</tr>
<tr>
<td>Suspicion of melanoma</td>
</tr>
<tr>
<td>Suspicion of aneurysm</td>
</tr>
<tr>
<td>Haemophilia</td>
</tr>
<tr>
<td>Severe diabetes</td>
</tr>
<tr>
<td>Unstable epilepsy</td>
</tr>
<tr>
<td>Dysfunctional nervous system</td>
</tr>
<tr>
<td>Severe osteoarthritis / rheumatoid arthritis / osteoporosis / gout / bursitis / ankylosing spondylitis / spondylosis / spondylolysis / spondylolisthesis</td>
</tr>
<tr>
<td>Metal pins and plates</td>
</tr>
<tr>
<td>Pacemaker</td>
</tr>
<tr>
<td>Pregnancy</td>
</tr>
<tr>
<td>First two or three days of menstruation</td>
</tr>
<tr>
<td>Heavy meal</td>
</tr>
<tr>
<td>Alcohol / recreational drugs</td>
</tr>
<tr>
<td>Conditions requiring specialized medical supervision</td>
</tr>
</tbody>
</table>

Note: This list is not exhaustive; if there is any doubt regarding the suitability of patients for soft tissue therapy, then medical opinion must be sought.
Manual therapy

Principles of manual therapy

According to Cook (2012), the purpose of orthopaedic manual therapy is to apply techniques which ‘reduce, centralize, or abolish the patient’s signs and symptoms’. While the fields of manual therapy are diverse and multifaceted, and potentially indicated for a range of health conditions, for the sports therapist the utility of manual therapy will be focused to support the management of the common neuromusculoskeletal injuries and conditions which present clinically. Due to the potential risk factors associated with this area of practice, it is essential that any manual therapy provided by a sports therapist must be within their scope of practice. Hence, the sports therapist must be qualified and insured: to be able to undertake effective neuromusculoskeletal assessment of their patients; to be able to make autonomous decisions regarding their patients’ suitability to receive manual therapy; to be able to recognize when referral for medical assessment or other intervention must be recommended; and to be able to safely and effectively provide manual therapy when indicated.

In a pure sense, manual therapy may be described as being the application of an accurately directed and selected set of ‘hands-on’, non-invasive physical therapy techniques, with minimal equipment, and which are generally considered as being passively delivered treatments, but which may also be possibly offered in conjunction with certain active movements when appropriate. The techniques of manual therapy may include graded physiological and accessory joint mobilizations and manipulations, and neural mobilizations, as well as a vast range of soft tissue friction, stretching and muscle energy techniques. Hengeveld and Banks (2005) explain that, within the Maitland concept of manual therapy, ‘mobilization’ techniques are passive movements which are ‘performed in such a manner and speed that at all times they are within the control of the patient’ and that ‘manipulation’ techniques are categorized as passive, high-velocity, short- or low-amplitude thrust techniques (HVLT) which are ‘within the joint’s anatomical limit performed at such a speed that renders the patient powerless to prevent it’. It is generally accepted that manipulative techniques (Maitland grade V; Cyriax grade C) are not within the realm of a sports therapist unless appropriate post-graduate training has been undertaken. Manual therapy is not the sole domain of any one physical therapy profession, but is a primary component of the health care that orthopaedists, physiotherapists, osteopaths, chiropractors, manipulative therapists and sports therapists provide. Beyond this, Cook (2012) and others have explored the differences in underpinning manual therapy philosophy which are clearly apparent in the different professions. As Cook (2012) surmised, ‘there is no direct evidence to determine which assessment philosophy reigns superiorly over another’. There are a considerable number of influential manual therapy pioneers – practitioners who have contributed over the past 50 years to the understanding and general acceptance of manual therapy in clinical practice; these include: Butler (1991); Cook (2012); Cyriax and Cyriax (1982); Greenman (1996); Grieve (1988); Hartman (1997); Hengeveld and Banks (2005); Kaltenborn (1970; 1999); Magee (2008); Maitland et al. (2005); Mennell (1960); Mulligan (1993; 2004); and Paris (2012). Sports therapists must be recommended to develop their appreciation of the work of these recognized practitioners, in conjunction with a developing knowledge of ever-evolving contemporary EIP in this field. Clearly it is beyond the scope of this text to provide more than a brief overview of manual therapy and a discussion of the principles which underpin it, and as such sports therapists are directed towards the key reference material as presented in text.
### Table 3.6 Terminology in manual therapy

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological movement</td>
<td>A gross active or passive functional movement of a joint, such as flexion and extension (Hengeveld and Banks, 2005)</td>
</tr>
<tr>
<td>Accessory movement</td>
<td>A small movement of a joint which cannot be performed actively, but can be performed passively by the therapist. Accessory movements include the roll, spin and slide which accompany each joint’s physiological movements (Magee, 2008). Also known as ‘joint play’ (Mennell, 1960)</td>
</tr>
<tr>
<td>Close-packed (synarthrodial) position</td>
<td>Where the associated articular joint surfaces are in maximal contact with each other; where primary static stabilizers may be on tension; and where a position of maximal congruency occurs (Magee, 2008). An unfavourable position for joint mobilization techniques</td>
</tr>
<tr>
<td>Loose-packed (resting) position</td>
<td>Where the associated articular joint surfaces are not in maximal contact with each other; where primary static stabilizers are not on full tension; and where the joint is less than maximally congruent (Magee, 2008). A favourable position for performing joint mobilization techniques</td>
</tr>
<tr>
<td>Mobilization techniques</td>
<td>Passive physiological, accessory or combination movements performed in such a manner and speed that at all times they are within the control of the patient. These are most commonly graded I–IV (Maitland et al., 2005)</td>
</tr>
<tr>
<td>Manipulation techniques</td>
<td>Passive movements consisting of accurately localized high-velocity, small-amplitude thrust manoeuvres within the joint’s anatomical limit. It may employ use of short or long leverages, and is performed at such a speed that it is beyond the control of the patient (Cook, 2012). In the Maitland system, these are grade 5 techniques (Maitland et al., 2005)</td>
</tr>
<tr>
<td>Grades of joint mobilization</td>
<td>Systematically assessed and delivered, graded physiological or accessory, vertebral or peripheral, joint mobilizations. Several acknowledged grading systems exist, the most common being: Maitland grades of mobilization on a five-point scale (I–V) (Maitland et al., 2005); Cyriax grades on a three-point scale (A–C) (Atkins et al., 2010); and Kaltenborn grades, also on a three-point scale (I – loosening; II – tightening; III – stretching) (Kaltenborn, 1970; 1999)</td>
</tr>
<tr>
<td>MWM</td>
<td>‘Mobilizations with movement’, as first presented by Mulligan (1993; 2004); these may be applied to both vertebral and peripheral joints</td>
</tr>
<tr>
<td>NAGS</td>
<td>‘Natural apophyseal glides’. Oscillatory spinal mobilizations performed with the patient in a seated, weight-bearing position (Mulligan, 2004). They are applied to facet joints antero-cranially in a pre-assessed mid- to end-range position</td>
</tr>
<tr>
<td>SNAGS</td>
<td>‘Sustained natural apophyseal glides’. Spinal mobilizations performed with the patient in a seated, weight-bearing position (Mulligan, 2004). The combination of a sustained facet joint glide with active movement</td>
</tr>
<tr>
<td>Osteokinematics</td>
<td>A term used to describe the gross movements of body parts (bones at joints), described in terms of anatomical planes (i.e. frontal, sagittal and transverse), and what is occurring at the joint during the movement (for example, flexion or rotation)</td>
</tr>
<tr>
<td>Arthrokinematics</td>
<td>A term used to describe the movements occurring within the joint and between articular surfaces, and can be described as accessory movements</td>
</tr>
</tbody>
</table>
Terminology | Definition
--- | ---
Convex–concave rule | A functional anatomical concept indicating that joint movements are guided by the presence of a convex–concave congruency in the associated articulating surfaces. The movement of initiation dictates the direction of movement (Cook, 2012). If the moving surface is concave, the associated glide will occur in the same direction as the moving bone. If the moving surface is convex, the glide will occur in the opposite direction. The universal application of this theory, however, has been challenged.

Glide (slide) | An accessory movement where the same area of one articular surface meets new areas on the opposing articular surface (for example, a PA glide).

Spin | An accessory rotational movement around a stationary axis.

Roll | An accessory movement where one articular surface rolls on another. New areas on one articular surface will meet new areas on the opposing articular surface.

Capsular pattern | A pattern of proportional joint movement limitation as described by Cyriax and Cyriax (1982), where the capsule of the joint is affected (Magee, 2008; Petty, 2011). The pattern, it is suggested, is a result of a total joint reaction to arthrosis, with muscle spasm, capsular contraction (the most common cause) and osteophyte formation being typical causative mechanisms. Although Cyriax and Cyriax (1982) suggest that all major joints have a particular common capsular pattern, the universality of the theory has been questioned.

End-feel classifications | The quality of a joint’s end-feel, which is sensed by the therapist as the joint is passively taken to the end of its available range of movement. Generic and normal end-feels include: bone to bone; soft tissue approximation; tissue stretch. Generic abnormal end-feels include: hard capsular; empty; early muscle spasm; springy block (Magee, 2008). Therapists must appreciate that each set of joint movements will have their own set of normal and abnormal end-feels.

Hypomobility | A reduction in normal and expected mobility. May be congenital, developmental, acquired, age-related, local or general. It must be assessed and compared against contralateral regions and against published norms. May relate to joint restriction or soft tissue restriction.

Hypermobility | An increase in normal and expected mobility.

Cavitation | The audible or palpable ‘popping’ or ‘cracking’ that is a high-frequency vibration that may occur at a specific joint during a mobilization or manipulation technique (or spontaneously during functional movement). Cavitation is due to a sudden distention of the synovial joint capsule, and its effect on the associated negative intra-articular, vacuum-like pressure. Physiological changes may take place during a mobilization or manipulation in the absence of cavitation.

PPIVM | Passive physiological intervertebral movements

PA | Posteroanterior

AP | Anteroposterior

MG | Medial glide

LG | Lateral glide

TG | Transverse glide
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<table>
<thead>
<tr>
<th>Terminology</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>PAIVM</td>
<td>Passive accessory intervertebral movements</td>
</tr>
<tr>
<td>Traction</td>
<td>Manual or mechanical tensile force which therapeutically is designed to produce a combination of distraction and gliding to relieve pain, increase joint range of movement and improve function. ‘The terms traction and distraction have the same meaning in describing a force applied to produce separation of joint surfaces and widening of the joint space. There is a convention that traction is applied to spinal joints and distraction to peripheral joints, but this is not a hard and fast rule’ (Atkins et al., 2010). The opposite of compression</td>
</tr>
<tr>
<td>Compression</td>
<td>Mobilization techniques delivered so as to cause reduction in space between articular surfaces. The opposite of traction</td>
</tr>
<tr>
<td>Cephalad</td>
<td>Mobilization directed towards the head (i.e. cranially or proximally)</td>
</tr>
<tr>
<td>Caudad</td>
<td>Mobilization directed away from the body, towards a distal end</td>
</tr>
<tr>
<td>Oscillations</td>
<td>The rhythmic repetitive movements performed during mobilization techniques. Start position, grade, velocity and amplitude may be varied</td>
</tr>
</tbody>
</table>

Effects of manual therapy

Manual therapy techniques used in sports therapy are employed variously to assist the management of soft tissue, joint and nerve-related pain and inflammation, to promote tissue repair, to improve soft tissue and joint range of motion and to promote improved functional biomechanics and the patient’s kinaesthetic sense. The effects of manual therapy are multitudinous and involve neurophysiological (local, spinal and supraspinal), nutritional and mechanical responses (Houglum, 2010; McCreesh and O’Connor, 2012). Pain reduction may result initially via gate-control mechanisms, as stimulated larger-diameter A-beta mechanoreceptors may inhibit nociceptive messaging at the levels of the spinal cord and brainstem; and muscle spasm may relax in response to reduced nociceptive inputs. Descending inhibitory pathways have been shown to be activated for the generation of pain relief during the process of manual therapy (Vicenzino et al., 1998). Particularly in early joint-related injury management, manual therapy can be used to help create an ‘ideal environment’ for optimal recovery, especially where patients may be reluctant to actively mobilize (Hengeveld and Banks, 2005). As a result, local synovial and circulatory increases may facilitate increased nutrient exchange and metabolic activity, which can contribute to improved healing processes. Carefully targeted mechanical forces can improve joint hypomobility; as Houglum (2010) highlights, hypomobile joints may lead to the development of collagenous adhesions in their associated soft tissues (capsule; capsular ligaments; fascia; tendons; and muscles) which may be stretched and loosened by manual therapy. McCrereesh and O’Connor (2012) review the mechanical forces and resulting microtrauma to periarticular soft tissues, which may cause the required permanent change in length so as to observe significant increases in range of movement. Mechanotransduction is the process of tissue cells’ response to mechanical loading (Khan and Scott, 2009); and in appreciating this, therapists can recognize the potential to positively stimulate structural adaptation. In manual therapy, the mechanotransduction process first involves ‘mechanocoupling’, where applied forces cause deformation and perturbation of cells; these forces are then transformed into chemical signalling by the affected cells. The second part of the process involves ‘cell to cell communication’, where same-region tissue cells, not necessarily nor
initially directly in receipt of the mechanical stimuli, also register the signal (Wall and Banes, 2005). The third component of the mechanotransduction process is termed the ‘effector cell response’; this occurs at the boundary between the tissue cells and their extracellular matrix (ECM) as mechanically induced protein expression from tissue cells leads to remodelling of the ECM (Khan and Scott, 2009). Other effects also obviously occur; at synovial joints, the intra-articular pressure influences their available range of movement; and the pressure itself depends upon fluid volume and joint position (Levick et al., 1999). As where there is joint effusion, range of movement is usually limited; McCruessh and O’Connor (2012) explain that in such conditions, sustained end of available range positioning, in conjunction with appropriately graded mobilizations, can encourage reabsorption of excess fluid.

Finally, with regard to the effects of manual therapy, the potential for placebo effects (where patient beliefs may influence outcomes) must also be recognized. Bialosky et al. (2011) define the placebo effect in context as ‘a mechanism likely accounting for some of the treatment effects of all interventions for pain, including manual therapy’. The placebo effect is synergistically related to the patient, the clinician, the clinical intervention and the clinical environment; it is also ‘beyond the specific mechanical parameters of the intervention’. Clearly, although the placebo effect is challenging to quantify, it is a factor to consider both psychologically and physiologically with regard to optimizing patient outcomes.

Physiological and accessory joint movements
Physiological (osteokinematic) motion is defined as the gross body movements which the patient can perform actively, or which the therapist can perform passively. Active physiological movement is the result of concentric or eccentric muscle contractions, and where bones at joints move through their available ranges (Palastanga et al., 2007). Depending on the joint concerned, physiological movements include: flexion, extension, lateral flexion, abstraction, adduction, medial and lateral rotation, pronation, supination, plantarflexion, dorsiflexion, inversion, eversion and combinations of these. Physiological mobilizations may be performed in conjunction with accessory movements. Accessory (arthrokinematic) movements are the gliding, rolling and spinning movements which are necessary for normal physiological joint range of motion, but which cannot be isolated or actively performed independently of physiological movements, unless produced under external passive force (i.e. by the therapist). The reason that accessory movements cannot be performed actively is because humans do not have the intricate musculature or fine motor control to be able to glide, spin or roll independently of a physiological movement. If any of the accessory movements associated with a particular joint are deemed to be restricted (hypomobile), then it follows that normal full-range physiological movements are likely to be adversely affected; but obviously, other factors contribute to the quality of movement (pain, hypermobility, arthrosis and restricted soft tissue mobility for example). With such conditions, dyskinesia (gross abnormal movement pattern) will be observed.

Application of manual therapy
Any delivery of manual therapy must be preceded by the undertaking of a thorough patient history and subjective and objective assessment, and be based upon a clinically reasoned set of short-term therapeutic goals. Some patients, from the outset, will not be suitable candidates for manual therapy (due to identified contraindications) and must be managed accordingly. Importantly, the delivery of manual therapy must incorporate appreciation of patient (and symptom) response, hence practitioners must be recommended to work with care to observe and palpate all changes occurring in the target tissues. Indeed, Maitland et al. (2005) state that
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Palpation is the most important and most difficult skill to learn. Sports therapists should also appreciate that there are issues of inter-rater reliability regarding palpation, particularly with regard to intervertebral segment movement (Schneider et al., 2008). Maitland et al. (2005), cited in Banks and Hengeveld (2010), have presented a simple classification system for vertebral segment palpation: ideal (‘perfect in every way, asymptomatic and devoid of any palpable signs of movement impairment’); average (‘disadvantaged, tolerable level of symptoms accepted by the person, accompanying signs of disadvantage or impairment are evident’); abnormal (‘disordered, symptoms are unacceptable and there are clear palpable signs of tissue impairment’). A sequence for palpation must also be considered to incorporate assessment of: local superficial skin temperature and conductance (sweating); local soft tissue changes; bony position and alignment; and symptom responses to passive movement. As the majority of manual therapy is passively performed, Cook (2012) describes this aspect of effective delivery as assessing for ‘within-session changes’, and refers to it as a ‘patient response-based method’. The therapist must aim to achieve a confident understanding of: what is normal or abnormal (with regard to the tissues and structures being treated); what is hypomobile or hypermobile (and the degree of such); what is symptomatic or relieving (i.e. pain producing, exacerbating or reducing, or the cause of other symptoms such as dysaesthesia); and what the continuing therapeutic objectives are. The use of ‘clinical indicators’ (objective markers) should be incorporated into this approach. Clinical indicators are movements that have been identified during assessment as being problematic or restricted; these movements should be re-tested ‘within-session’. For the sports therapist, manual therapy is an essential intervention, but it must be underpinned by a comprehensive anatomical and pathological understanding, together with a strong appreciation of the principles of manual therapy (indications; contraindications; safety considerations; and practical applications). One other essential component of manual therapy, as highlighted by the International Federation of Orthopedic Manipulative Physical Therapists (IFOMPT, 2010), is its requirement to be ‘patient-centred’ – the patient must be at the centre of all clinical decision-making, and their understandings, beliefs and feelings must influence any resulting intervention.

Following patient assessment, the therapist is then challenged to select the most applicable therapeutic intervention. This requires considerable clinical reasoning, in the moment, and with regard to manual therapy, numerous considerations must present to the sports therapist: the current severity of symptoms; the state of tissue irritability; the main symptom-generating tissues (the ‘genics’); the acuteness or chronicity of the condition; the pain mechanisms at play (i.e. nociceptive; peripheral neuropathic; centrally sensitized); the effect of pain and any inflammation on the muscles associated with the joint (i.e. inhibition; atrophy; spasm); the presence of hypomobility (stiffness); the presence of hypermobility (laxity); the presence of articular surface degeneration; the presence of structural anomalies (i.e. cartilage; capsule; bone; cysts; fragmentation); the relationships between related regions and joints; beyond inhibition or spasm, the state of myofascial balance on the joint; clinical indicators (most problematic re-testable movements); and the presence of any psychosocial factors (yellow flags). Once all such considerations have been thought through, a treatment strategy must be formulated. This must include a plan for dosage of treatment, which will include identifying: joints to be treated (this must go beyond simply, for example, the elbow, or the thoracic spine) as the therapist must be anatomically specific); mobilizations to be employed (i.e. physiological or accessory, or combinations), and which specific types (or vectors) of mobilizations (for example, physiological flexion; accessory posteroanterior [PA] glide); grades of mobilizations (i.e. Maitland I–IV; Cyriax A–B, depending upon system employed); frequency of delivery (this includes consideration of the rhythm or speed of oscillations – which may be slow and gentle with one oscillation every one to two seconds (most appropriate for grade II and III, larger amplitude mobilizations), or
sharp staccato – with two to three oscillations per second (most appropriate for grade I and IV, smaller amplitude mobilizations), or sustained without movement (Maitland et al., 2005); duration of delivery of mobilizations – although evidence is lacking, 20–60 seconds of repetitions have been suggested for decreased range of motion, and 1–2 minutes for pain (however, this could be until a sense of symptom relief or reduction in stiffness or spasm is achieved, or simply a short set time frame, prior to any repeat application or re-testing); repetitions of a set of mobilizations (for example, the therapist may elect to perform one, two or three sets based on tissue and symptom response). Beyond this, further considerations to the successful delivery of manual therapy include: patient positioning; therapist position; handling and contact points; communication and feedback during application (visual, verbal and tactile); and assessment of efficacy (i.e. symptom relief; re-testing of clinical indicators). Cook (2012) presents a range of other subtle factors influencing delivery of mobilization therapy, including the fine-tuning of technique (such as altering the magnitude of forces, and the rate of any increase of force). When one considers the innumerable symptom-generating conditions that patients present with, in tandem with the variety of treatment strategies and techniques available to the sports therapist, it can be easily appreciated how exacting the practitioner must be from the outset.

**Convex–concave rule**

The shape of the articulating joint surfaces and direction of movement is defined to some degree by the convex–concave rule, which describes the directions of movement associated with a joint as being dependent upon the shape of the moving articular surfaces (Kaltenborn, 1999; Schomacher, 2009). Kessler and Hertling (1983) distinguished that as a concave surface

<table>
<thead>
<tr>
<th>Grade</th>
<th>amplitude</th>
<th>Range of movement</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Small</td>
<td>Start of range</td>
<td>Pain</td>
</tr>
<tr>
<td>II</td>
<td>Large</td>
<td>Across middle of range</td>
<td>Pain, Stiffness</td>
</tr>
<tr>
<td>III</td>
<td>Large</td>
<td>Middle to end of range movement</td>
<td>Stiffness, Pain</td>
</tr>
<tr>
<td>IV</td>
<td>Small</td>
<td>End of available range</td>
<td>Stiffness, Momentary pain</td>
</tr>
<tr>
<td>V</td>
<td>Small, high velocity</td>
<td>A manipulation past end of presenting available range</td>
<td>Stiffness, Pain</td>
</tr>
<tr>
<td>A</td>
<td>Small/large</td>
<td>Within pain-free elastic range. In peripheral joints. In mid-range at spinal joints</td>
<td>Pain</td>
</tr>
<tr>
<td>B</td>
<td>Small</td>
<td>At end of available range of peripheral and spinal joints. A sustained stretching technique to affect plastic deformation of connective tissues</td>
<td>Pain, Stiffness</td>
</tr>
<tr>
<td>C</td>
<td>Small, high velocity</td>
<td>A manipulation past end of presenting available range</td>
<td>Stiffness, Pain</td>
</tr>
</tbody>
</table>

Source: adapted from Atkins et al., 2010; Maitland et al., 2005.
moves on a convex surface (where the convex surface is fixed), then accessory movement (roll and glide) will occur in the same direction to the angular physiological movement. In contrast, if the convex joint surface is moving on a fixed concave surface, then the accessory movement is in the opposite direction to the angular physiological movement. During flexion or extension of the knee in non-weight-bearing (seated or single-leg stance), the concave tibial condyles will glide in the same direction on the fixed convex femoral condyles. As explained, when a convex surface moves on a fixed concave surface, the accessory roll and glide occurs in the opposite direction to the physiological movement, such as with elevation of the glenohumeral joint through abduction; here, when the concave glenoid cavity is fixed, the convex surface of the humeral head translates inferiorly as the humerus physiologically travels superiorly. Some articulatory surfaces may be observed to be relatively flat, and have less obvious concavity and convexity, but where this is the case, the smaller, flatter joint surface will frequently present with intra-articular fibrocartilage contributing to form a degree of concavity. Recent literature has, however, questioned the universal clinical relevance of the convex–concave rule. Banks and Hengeveld (2010) place lesser credence on the model as an influence for planning manual therapy, particularly with regard to pain, and stipulate the use of the least painful accessory movement(s) as the starting point for joint mobilizations. Johnson et al. (2007) suggest that the direction of mobilization may be irrelevant in treatment where joint hypomobility is present.

Open- and close-packed positioning
Correct joint positioning will enhance the effectiveness of any mobilization technique. It is essential to be aware of the open- and close-packed positions of joints. In many cases, it is preferable to perform mobilizations with the target joint in an open (or loose)-packed position. The open-packed position indicates that the articulating surfaces are not maximally congruent, are separated, and the joint will exhibit a certain amount of joint play. This is the position in which the joint capsule and ligaments are less tense. In contrast, the close-packed position is where joint surfaces are most congruent and in maximal contact with each other, the main ligaments and joint capsule are in a taut state, and the joint is said to have maximum stability.
<table>
<thead>
<tr>
<th>Table 3.8 Considerations in manual therapy</th>
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<tr>
<td><strong>Clinical indicators in manual therapy</strong></td>
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<tr>
<td><strong>Indications for manual therapy</strong></td>
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<tr>
<td><strong>Contraindications to manual therapy</strong></td>
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<tr>
<td><strong>Special questions in manual therapy</strong></td>
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<tr>
<td><strong>Precautions to manual therapy</strong></td>
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<tr>
<td><strong>Vertebrobasilar insufficiency (VBI)</strong></td>
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<tr>
<td><strong>Red flags in manual therapy</strong></td>
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</tbody>
</table>
of a condition; history of violent trauma; constant non-mechanical pain (and which does not alter with position, movement or medication); night pain; thoracic pain; previous history of cancer; recent significant unexplained weight loss; systemically unwell; impaired bladder or bowel control, and dysesthesia in the perianal region (‘saddle anaesthesia’) (both associated with cauda equine syndrome); blood in sputum; structural deformity; progressive neural deficits; bilateral radiculopathy; ulcer-type wounds which do not heal; abnormally presenting moles; clonus signs; long-term corticosteroid use; suspicion of DVT (deep vein thrombosis). This list is not exhaustive.

**Yellow flags in manual therapy**

Warning signs to the biopsychosocial factors which may be predictors of chronicity. ‘Bio’ relates to the biological and pathological aspect of the presenting injury or condition; ‘psycho’ relates to the cognitive aspects, the patient’s attitude, beliefs, emotions and behaviours regarding their condition; and ‘social’ relates to the patient’s domestic, work, social and cultural environment and stressors thereof. By being vigilant and sensitive to any presenting yellow flag signs, the therapist is better able to support and advise the patient accordingly. Biopsychosocial factors can be the cause of stress, depression, work absenteeism, fear avoidance beliefs about activity and work and symptom exacerbation. Importantly, yellow flags may affect patient adherence to the therapeutic programme. There may also be additional considerations, such as compensation issues.

**Adverse effects of manual therapy**

Undesirable effects of treatment, which may be short term and mild adverse effects (such as symptom exacerbation, muscle soreness or headache); or extremely rare major adverse effects (including vascular insults, neurological incapacity or death) (Carnes *et al.*, 2010). Adverse effects can be the result of poor practice (in patient selection, assessment or treatment) or due to unforeseeable, unexpected patient responses to treatment.

**Patient-centred manual therapy**

In manual therapy clinical decisions must be patient-centred. This means that patients’ understandings, beliefs and feelings are considered and influence the resulting interventions. Patients must be encouraged to be active participants (IFOMPT, 2010).

**Patient values**

The recognition of the unique expectations, concerns and beliefs that each patient has in any clinical situation. The individualized aspect of any case must be considered and integrated into resulting clinical decisions (IFOMPT, 2010).

**Placebo effect**

The perceivable or expected after-effect of an intervention. It has been suggested that manual therapy may provide a powerful, short-term placebo effect (Cook, 2012).

**Equipment in manual therapy**

While the emphasis in manual therapy is the use of techniques delivered by hand, equipment to support such delivery may include: height-adjustable couch; bolsters; and mobilization belts.

**Manual therapy variables**

The various ways in which the therapist may elect to deliver their treatment, which must be based on identified objectives and any precautionary contraindications. Variables may include: the positioning of the patient; the positioning of the target joint(s); the directions of mobilization techniques; the type of mobilization techniques employed (i.e. physiological; accessory; combination; oscillatory; sustained); the grades of mobilization (i.e. I–IV; A–C); the duration of application; the number of repeat applications.

**Proposed beneficial effects of manual therapy**

Pain relief; improved specific mobility; increased local blood flow; break down of fibrous adhesions; elastic and/or plastic deformation of soft tissues; improved functional mobility; patient education.
Table 3.9 Precautions and contraindications to manual therapy

**Absolute contraindications**
- Contagious infection
- Severe cardiovascular disease
- Deep vein thrombosis
- Phlebitis
- Inflammatory arthritis
- Malignancy
- Bone disease
- Fracture
- Congenitally deformed bone
- Vertebral artery insufficiency
- Recent operative procedures
- High severity or irritability
- Unremitting night pain (preventing patient from falling asleep)
- Conditions involving neurology (i.e. UMNL; spinal cord injury; cauda equina syndrome)
- Significant neural symptoms (multi-level; worsening symptoms)
- Patient under influence of alcohol or recreational drugs
- Conditions requiring specialized medical supervision

**Precautions**
- Significant joint laxity/instability
- Pain exacerbated by lying down
- Five Ds (dizziness; drop attacks; diplopia; dysarthria; dysphagia) – cervical manual therapy contraindicated
- History of cardiovascular disease
- History of cancer
- Medication that alters pain perception or circulatory response
- Benign tumour
- Acute injury/wound
- Nerve root signs
- Long-term steroid use
- Systemically unwell
- Recent manual or manipulative therapy from another health professional

Source: adapted from Cook, 2012; Maitland et al., 2005; Prentice, 2011; Hengeveld and Banks, 2005; Greenhalgh and Selfe, 2007; Vizniak, 2012).

Note: This list is not exhaustive; if there is any doubt regarding the suitability of patients for manual therapy, then medical opinion must be sought.

(Mangus et al., 2002). Initial mobilization is performed in an open-packed position; however, in some cases the position is determined by that which is least painful and most comfortable for the patient.

**Safety, precautions, contraindications and adverse reactions in manual therapy**

As with all manual therapies, the sports therapist must be fully conversant with red flag signs and precautions to treatment. Numerous authors (including Cook, 2012; Maitland et al., 2005; Prentice, 2011; Hengeveld and Banks, 2005; Greenhalgh and Selfe, 2006; and Vizniak, 2012) have presented safety considerations and precautions and contraindications to manual therapy treatment.
Photo 3.10  Passive physiological mobilization of the hip (medial rotation in neutral).
Photo 3.11  Passive physiological mobilization of the knee (flexion).

Photo 3.12  Accessory mobilization of the subtalar joint (AP glide).

Photo 3.13  Accessory mobilization of the glenohumeral joint (caudad glide in 90° abduction).
Photo 3.14  Accessory mobilization of the radiohumeral joint (caudad glide in 30° elbow flexion).

Photo 3.15  Accessory mobilization of the radiocarpal joint (PA glide in neutral).
Adverse effects may result from poor practice (in patient selection, assessment or treatment) or may be due to unforeseeable, unexpected patient responses to treatment. Carnes et al. (2010) identified that the risk of major adverse events within manual therapy is low, but that the prevalence of minor to moderate adverse events after treatment is more significant. Major adverse events (which may include vascular insults, neurological incapacity or even death) have been described as medium- to long-term duration, moderate to severe, and are considered unacceptable. They will also by nature normally require further medical care. Moderate adverse events differ from major simply in that they are less severe, but still require careful patient monitoring, such as with a worsening of symptoms. Mild events are described as being short-term and of low severity, and symptoms are transient and reversible; these may include mild inflammatory reactions, tissue tenderness, slight worsening of symptoms and post-treatment fatigue. In order to offset the potential for adverse events, sports therapists must recognize the significance of undertaking a detailed patient history, appreciating the history of the main complaint and, importantly for manual therapy, the severity, irritability and nature (SIN) of symptoms.

**Neurodynamic mobilization**

Butler (1991), Butler and Nee (2006), Coppieters and Nee (2012), Learman and Cook (2012), Ridehalgh and Barnard (2012) and Shacklock (1995; 2005) all discuss at length the specialized aspect of manual therapy which focuses on managing symptoms involving peripheral nervous tissue. The term ‘neurodynamics’ implies functional movement of the nervous system, and more explicitly, neurodynamics is the interaction between physiological and mechanical functions of the nervous system (Shacklock, 1995). In the clinical environment, neurodynamics must incorporate physical assessment of the functioning of the peripheral nervous system (sensory and motor). This includes (in addition to any other appropriate assessment methods) dermatomal, myotomal and reflex testing, and assessment of the mobility and irritability of peripheral nerves (via neurodynamic tests and nerve palpation). While neurodynamic therapy is indicated for peripheral neuropathic pain states (Coppieters and Nee, 2012), the nervous system must be viewed very much as a continuum, and any movements of the body will transmit forces along the system (Shacklock, 2005). Indeed, just as cervical flexion has been shown to alter the position and tension of the lumbar spinal cord and nerve roots, the straight leg raise (SLR) can exert tensioning and altered positioning via the sciatic nerve, spinal cord and thecal sac, up to the brain and its meninges (Breig, 1978). The tissues and structures found in close association with peripheral nerves as they pass through the body from nerve root to distal periphery may be described as mechanical interfaces; these include the fibro-osseous tunnels, muscles, tendons, joint capsules, ligaments, fibrous discs and fascia. The mechanical interfaces associated with each peripheral nerve may be considered as ‘neighbouring’ and ‘container’ tissues (NOI, 2010). It is important to recognize that local pathological states (such as with soft tissue inflammation, fibrosis or arthritic degeneration), as well as joint instability, can easily contribute to the irritation of peripheral nerves at mechanical interfaces during certain movements – and even simply at rest. The structure of the peripheral nerves themselves is complex and also varies throughout their length, and this in itself influences function (consider the perineurium, the distribution of the myelin sheath, the nodes of Ranvier and distribution of ion channels, the essential blood supply to the nerve and the ‘nerve of the nerve’ – the nervi nervorum). Shacklock (2005) explains that the perineurium ‘is effectively the cabling in the peripheral nerve’ and ‘the primary guardian against excessive tension’. Formed from densely packed connective tissue, the perineurium contributes longitudinal strength and elasticity to the nerve, and has viscoelastic properties. Sunderland (1991) identified that peripheral nerves are able to withstand 18–22 per cent strain
before failure. Simply, peripheral nerves, in addition to being directly affected by demyelinating disorders (such as Guillain-Barre syndrome), and indirectly by systemic conditions such as chronic diabetes, are also extremely vulnerable (sensitive) to the prolonged restrictive and compressive stresses associated with their mechanical interfaces. Such presenting conditions as carpal tunnel syndrome (CTS) or tarsal tunnel syndrome (TTS) often have a multifaceted aetiology, and practitioners should consider the local factors at the mechanical interfaces, as well as the ‘double-crush’ situation (where nerves are adversely affected at more than one site) (Schmid and Coppieters, 2010). Prolonged compression and restriction of a peripheral nerve can lead to local neural ischaemia, hypoxia, oedema, fibrosis, impaired axonal transport and ion channel alterations (and the development of abnormal impulse-generating sites – AIGS) (Coppieters and Nee, 2012). Symptomatically, these conditions can lead to local and diffuse, radiating pain, allodynia, hyperalgesia, dysestheasias and, in resistant cases, muscle weakness and further limitations in functional ranges of movement.

Where positive signs and symptoms are present, specific neurodynamic therapy techniques may then be indicated and employed, obviously in conjunction with other treatment and advice. As Ridehalgh and Barnard (2012) emphasize ‘there is no pure treatment for nerves, that is, treatment cannot be isolated to nerve alone: it will always, to a greater or lesser extent, affect joint and/or muscle tissues’. Nerve mobilization is the passive (or active) delivery of movement to facilitate therapeutic effects in the nervous system. Techniques may involve gross movements which mobilize or tension the nervous system, or more localized movements employed to affect mechanical interfaces and neural connective tissue (Butler, 1991). Once a clinical impression of the patient has been ascertained, the sports therapist may elect to use neurodynamic techniques to reduce symptoms and improve function. It is obviously imperative that the therapist has a competent understanding of peripheral neural anatomy in order to both identify specific problems associated with it, and to also affect it safely, positively, locally and globally. Confident working knowledge of the peripheral nervous system is essential for this aspect of clinical therapy. Sports therapists must know the five peripheral nerve plexuses (cervical – C1–4; brachial – C5–T1; lumbar – L1–4; lumbosacral – L4–S3; and sacral – S3–5); the main peripheral nerves (and their segmental origins and peripheral distributions); and the more global interconnectedness of the nervous system, including the relationship of the peripheral nervous system to the central nervous system (spinal cord and brain) and to all other body tissues. The sports therapist must aim to know all of the main muscles supplied by each of the main peripheral nerves. In the upper limb, the main peripheral nerve routes to familiarize (from the brachial plexus) are the axillary, musculocutaneous, ulnar, median and radial nerves and their tributaries. In the lower limb, the obturator and femoral nerves originate from the lumbar plexus. The superior and inferior gluteal nerves, and the sciatic nerve and its branches (tibial, common, superficial and deep peroneal, medial and lateral plantar nerves), all originate from the lumbosacral plexus.

Following the clinical assessment, the therapist should have formulated a working hypothesis of the nature of the patient’s problem, and the type and cause of their injury or pain. However, it is important to recognize that clinical assessment, including neurodynamic testing, cannot always irrefutably locate the precise source of symptoms; furthermore, asymptomatic patients may also experience positive limitations or discomfort during testing (Learman and Cook, 2012). Whether musculoskeletal and nociceptive, neuropathic, systemically pathological, acute or chronic, there may still be a good rationale for utilizing peripheral neural mobilization therapy. Just as with manual therapy applied to joint restrictions or pain, neural mobilization must be carefully planned, graded, delivered and evaluated. Particularly important to the assessment and ultimate mobilization of peripheral neural tissue are the recognized neurodynamic
Table 3.10 Terminology in neurodynamic mobilization

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td>Neurodynamics</td>
<td>The interaction between physiological and mechanical functions of the nervous system (Shacklock, 1995)</td>
</tr>
<tr>
<td>Nerve mobilization</td>
<td>The active or passive delivery of movement to facilitate therapeutic effects in the nervous system. May involve gross movement techniques which mobilize or tension the nervous system, or more localized movements employed to affect mechanical interfaces and neural connective tissue (Butler, 1991)</td>
</tr>
<tr>
<td>Adverse neural tension</td>
<td>‘Any abnormal physiological or mechanical response from the nervous system that limits the nervous system’s range or stretch or results in neurological symptoms through available range’ (Cook, 2012)</td>
</tr>
<tr>
<td>Sensitizing and desensitizing manoeuvres</td>
<td>Sensitizing manoeuvres involve delivery of systematic (sequenced) multipositional joint movements so as to evoke a carefully increased tensioning in neural tissue. May be used as a procedure in the assessment of patients with suspected adverse neural tension; or as part of a neural tensioning mobilization strategy. Desensitizing manoeuvres, which slacken neural tension to a degree, may be performed so as to reduce symptoms of neural tension during assessment; or as part of a neural gliding mobilization strategy</td>
</tr>
<tr>
<td>Neural glides</td>
<td>Slow, methodical, active or passive movements designed to mobilize neural tissue through its available range. These techniques have also been described as ‘neurodynamic sliders’ or ‘nerve flossing’</td>
</tr>
<tr>
<td>Neural tensioners</td>
<td>Slow, methodical, active or passive movements designed to offer gentle tensile stress to neural tissue</td>
</tr>
<tr>
<td>Mechanical interfaces</td>
<td>The tissues and structures found in close association with peripheral nerve tissue (such as fibro-osseous tunnels, muscles, tendons, joint capsules, ligaments, fibrous discs and fascia). May be considered as ‘neighbouring’ ‘container’ tissues (NOI, 2010). It is important to recognize that pathological responses (inflammation; arthropathy) can contribute to irritation at mechanical interfaces</td>
</tr>
</tbody>
</table>

tests. While best approaches and methods used to assess the mobility and symptom response of neural tissue are under constant appraisal and development, the four main tests used to assess the main upper limb nerves are known simply as upper limb neurodynamic tests (ULNTs). These are sequential and individualized multipositional joint movements which are designed to carefully lengthen specific peripheral nerves to a point of gentle tension or very mild symptom response. ULNT1 predominantly affects the median nerve pathway; ULNT2a affects the median, musculocutaneous and axillary pathways; ULNT2b affects the radial pathway; and ULNT3 affects the ulnar pathway. In the lower limb, the most well-recognized tests are the: femoral nerve stretch (slump knee bend) test; slump test (which assesses for possible neural irritation at the level of the spinal cord or dura mater, or through the peripheral sciatic distribution); and the SLR test (for lumbar nerve root and sciatic irritation). All neurodynamic tests must be performed carefully (as by nature neural tissue is sensitive, responsive and irritable). Sensitizing manoeuvres individualize the assessment via systematic (sequenced) positioning of the patient so as to evoke an increased tensioning of neural tissue. Desensitizing manoeuvres are performed so as to reduce neural tension slightly and help to confirm assessment findings. Adverse neural tension may be considered as a symptomatic limitation in range of movement affected by the restrictions placed on neural pathways.
As well as being used to assess adverse neural tension, sensitizing manoeuvres may then be used as part of the neural mobilization strategy; such techniques have been described as ‘neural tensioners’ – which, although performed slowly and methodically and designed to offer gentle tensile stress to neural tissue, can be irritating to more acute or irritable conditions. In such cases, ‘neural glides’ (also known as ‘neurodynamic sliders’) are similarly slow and methodical movements, but are designed to mobilize neural tissue through a designated and non-provocative range. When performing tensioning neural mobilization, the approach utilizes sequential, individualized, multipositional, proximal and distal joint movements to move the targeted peripheral nerve to a point of gentle tension (essentially ‘sensitizing’ the tissue via nerve strain). Nee and Butler (2006) suggest that tensioning techniques are not nerve stretches, and that they ‘are performed in an oscillatory fashion so as to gently engage resistance to movement that is usually associated with protective muscle activity’. Coppieters and Nee (2012) have highlighted that many conditions are not amenable to such tensioning techniques. When glides are performed the target peripheral nerve pathway is mobilized (still using the sequential, multipositional, proximal and distal approach) through its available range, but importantly not to a point of potentially irritating tension – simply one end of the pathway (distal or proximal) is moved towards the other and vice versa in a series of repetitions. Coppieters and Nee (2012) explain that ‘sliding techniques result not only in a larger longitudinal excursion of the nerve relative to surrounding structures, but are also not associated with significant increases in strain’. The starting point for treatment is established via the assessment of where in the sequential range of joint positions the limitations, tensions or symptoms are apparent (via the neurodynamic tests). Neural mobilizations, therefore, move the target peripheral nerve, its nerve bed and all associated connective tissue, fascia, muscles, tendons, bones and joint surfaces through a range of movement, carefully, repetitively and non-provocatively, from a pre-assessed start position. It is important not to mentally separate neural mobilization from manual therapy as a whole; the method for mobilizing nerves may be enhanced locally via directed soft tissue techniques (such as myofascial release or frictions) to any restrictive connective tissues or muscles (using muscle energy, neuromuscular or STR techniques). Physiological and accessory spinal or peripheral joint mobilization techniques are also usually used in combination with neural mobilizations.

The most appropriate method and strategy to employ cannot be ascertained without an individualized clinical assessment. It may be that designated STT, followed by specified spinal and peripheral joint mobilizations, will pave the way for more effective neurodynamic mobilization, but this may not always be the case. Similarly, the sports therapist must also clinically reason their way through the actual delivery of the neural mobilizations – for a start position to mobilize the median nerve pathway, for example, the patient may be positioned in supine with shoulder depression, then shoulder abduction to 90° and lateral rotation to 85°, the elbow may be extended to perhaps 35° flexion, the forearm to 90° supination, the wrist to 70° extension and the cervical spine may remain in neutral. Some patients will not tolerate such positioning because of the symptom response (or because of comorbidities); for others this position will not provide sufficient tensioning to provide effective mobilization. However, as an example, from such a start position, to gently tension the tissues the sports therapist may then sensitize through cervical lateral flexion carefully to the contralateral side while at the same time increasing extension at the elbow or wrist (hence, tensioning at both ends of the chain). Potentially less provocatively, to glide through this range (without providing additional proximal and distal tension) from the previous starting position, the therapist may instead desensitize the neural pathway via cervical lateral flexion to the ipsilateral side, while at the same time further extending the elbow and/or wrist. This may sound complicated; but with practice these techniques can become easily employed. It is important to familiarize the ways in which each of the main peripheral nerve pathways may be mobilized.
Table 3.11 Delivering neurodynamic mobilizations

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Grade of movement</strong></td>
<td>Small-amplitude movement, short of resistance</td>
</tr>
<tr>
<td></td>
<td>Larger-amplitude movement, short of resistance</td>
</tr>
<tr>
<td></td>
<td>Large-amplitude movement into early resistance</td>
</tr>
<tr>
<td></td>
<td>Small-amplitude movement into resistance</td>
</tr>
<tr>
<td><strong>Direction of movement</strong></td>
<td>May be longitudinal or transverse, but most likely will be a combination</td>
</tr>
<tr>
<td><strong>Sequence of movement</strong></td>
<td>The therapist may elect to emphasize the mobilizations via use of any of the proximal, middle or distal joint positions within the chain of involved joints, depending upon where the treatment is to be focused</td>
</tr>
<tr>
<td><strong>Amplitude of oscillation</strong></td>
<td>Movements may utilize short, sustained positions (tensioners) or slow, oscillatory techniques (gliders). These movements may be graded (as above)</td>
</tr>
<tr>
<td><strong>Velocity and rhythm of movement</strong></td>
<td>With gliding techniques, to avoid irritation, the velocity is generally slow or slightly faster through the graded range. Further, the rhythm may be smooth and steady, or staccato. With tensioning techniques, if indicated, the recommendation is to move towards neural strain slowly</td>
</tr>
<tr>
<td><strong>Repetition of movement</strong></td>
<td>The therapist should aim to provide neurodynamic mobilizations with a vigilant awareness of how the techniques are affecting the patient and their symptoms. If the patient is easily irritated, then techniques may need to be adjusted (by reducing the grade and position) or abandoned. If little or no provocation is apparent, then just as with joint mobilizations, the neurodynamic mobilizations may be continued, typically for between 20–60 seconds (although evidence is lacking)</td>
</tr>
<tr>
<td><strong>Repeat applications</strong></td>
<td>The therapist may elect to perform one, two or three sets of repetitions based on tissue and symptom response, and on ongoing clinical assessment</td>
</tr>
<tr>
<td><strong>Progression methods</strong></td>
<td>Progression is dependent on tissue, symptom and patient response. If there is no provocation, progressions in treatment can be maintained by altering joint positions (moving towards ends of ranges), increasing the direction and magnitude of force, reducing the amplitude of oscillation, increasing the duration of application, and also potentially (carefully) allowing more symptoms to be provoked</td>
</tr>
<tr>
<td><strong>Regression methods</strong></td>
<td>Regression is required when symptomatic irritation is apparent. The therapist may employ alterations to the ranges of joint movements involved, reduced direction and magnitude of force, increased amplitude of oscillation or reduced duration of application, all generally aimed at allowing fewer symptoms to be provoked</td>
</tr>
</tbody>
</table>

Source: adapted from Ridehalgh and Barnard, 2012.

Just as with all other interventions, the sports therapist must consider the full clinical impression of the patient and any potential contraindications or precautions prior to delivery. They must then consider grades of movement, repetitions of movement, duration of repetitions, re-testing movements for symptom changes, repeat applications and home care advice. Ridehalgh and Barnard (2012) suggest that the magnitude of force applied by the therapist should be related to their perception of resistance, and graded I–V. Such grades are related to those put forward by...
Magarey (1986) and Maitland et al. (2005) for joint mobilizations. However, such a grading system for neural mobilizations has limitations; this is due in part to the fact that tensioning techniques are different to gliding techniques, and that there is also such a subtle flexibility in how neural mobilizations may be approached and performed. Probably the most important influence of the delivery of neurodynamic mobilizations is how irritable the patient’s symptoms are, and how easily their symptoms are provoked. The evidence-base to support best practice in patients presenting with nerve-related symptoms is still evolving. A number of authors (Coppieters and Nee, 2012; Learman and Cook, 2012) have explored the limited evidence to support nerve gliding, nerve tensioning and the long-term clinical effectiveness, but conclude that further randomized trials with long-term follow-up are required.

**Approaches to manual therapy delivery**

In summary, manual therapy requires great care and process in delivery, and therapists must consider the following:

- patient history and prioritized objective assessment;
- the problem list and set of short-/long-term therapeutic goals prior to treatment;
- awareness of precautions and contraindications;
- main indications including local pain, hypomobility, dyskinesia and low-grade nerve irritation;
- main clinical indicators;
- type, range and grade of mobilizations required;
- patient positioning, patient handling, repetitions, duration and sets;
- patient, tissue and symptom response during treatment (visual, verbal and tactile);
- re-assessment of clinical indicators;
- selective use of additional interventions (such as STT or taping);
- patient home exercise and other advice;
- documentation of all assessment findings and specific management provided.

**Cryotherapy**

*With Peter K. Thain*

Within sports medicine environments, cryotherapy – literally meaning cold therapy – is a widely used therapeutic modality for the treatment of acute injuries, in addition to facilitating rehabilitation (Bleakley et al., 2004; Knight, 1995; Knight et al., 2000; MacAuley, 2001). In order to administer the most appropriate treatment for the athlete, it is imperative that the therapist understands the physiological effects of cryotherapy. This section therefore will outline the physiological effects of cryotherapy, before recommending specific modalities for use, dependent upon the aims of treatment.

**Physiological effects of cold application**

*Analgesia*

The immediate application of ice aims to provide a cold-induced analgesic effect, thereby reducing the appreciation of pain (Algafl y and George, 2007; Bleakley and Hopkins, 2010; Saeki, 2002). Evidence suggests that cooling of peripheral nervous tissue prolongs the latency
Keith Ward et al.

and duration of sensory action potentials, resulting in decreased nerve transmission (de Jong et al., 1966). Additionally, a declining temperature suppresses nociceptive receptor sensitivity (Kunesch et al., 1987), and may also act as a possible counterirritant (Saeki, 2002). Previous work examining the effect of ice application on analgesia has identified targeted skin temperatures to be 10–13.6 °C in order to provide an analgesic effect (Algafl y and George, 2007; Bugaj, 1975). If these target temperatures are achieved, nerve conduction velocity can be reduced by 10–33 per cent (Algafl y and George, 2007; McMeeken et al., 1984). The rate at which the nerve conduction can be slowed, and thus how quickly analgesia will be experienced, is dependent entirely upon the modality’s ability to reduce tissue temperature (Knight, 1995).

Metabolism

While there is unequivocal evidence to support the use of cryotherapy to provide an analgesic effect (Algafl y and George, 2007; Bleakley et al., 2004; Grant, 1964; Hayden, 1964; Knight et al., 2000; Pincivero et al., 1993), there is currently no research involving human subjects which supports the ability of ice application to reduce swelling. Until recently it was thought that ice application was fundamental in limiting the formation of oedema – typically referred to as swelling. When an injury occurs and there is structural damage, the swelling at the site of injury results from direct haemorrhaging and oedema (Knight, 1995). The swelling that occurs immediately with soft tissue injury is the result of haemorrhaging. Haemostasis can take place within minutes and by the time the extent of the injury has been determined, the haemorrhaging has probably stopped. Therefore, it is the delayed swelling, termed oedema, that therapists will be concerned with. The original premise of ice application by Knight (1995) was not to stop the initial haemorrhaging, but to reduce the effects of secondary hypoxic injury which causes disruption to healthy cells. The premise was that ice application would reduce metabolism, which in turn would limit the demands for oxygen in the tissue on the periphery of the injury, reducing secondary ischaemia and enzymatic injury and consequently oedema (Bleakley and Hopkins, 2010; Knight, 1995; Merrick, 2002).

A target temperature to reduce the oxygen demands of the injured tissue and reduce metabolic activity by 50 per cent is reported to be 10–11 °C (Sapega et al., 1988). However, while these target temperatures are readily achievable at the level of the skin, such temperatures are yet to be reported at depths where the majority of musculoskeletal injuries occur – and where the reduction in temperature is typically required. Consequently, following the work of Bleakley and Hopkins (2010) and others, it is currently apparent that there is limited reliable evidence to support the notion that ice application plays an active role in reducing secondary hypoxic injury, and thus oedema. What does this mean for the future of ice and cryotherapy? First, ice is a fantastic, non-pharmacological modality for helping to reduce pain. Additionally, it may be argued that while it may not be possible to reduce deeper tissues to 10 °C, even if the temperature declines by 1 °C then perceivably this may still be of some benefit.

Skin temperature response to cold applications

When cryotherapeutic modalities are applied to the skin there is an immediate and rapid reduction in skin temperature (Dykstra et al., 2009; Enwemeka et al., 2002; Merrick et al., 2003). Numerous studies have evaluated the effects of cooling skin temperature with a variety of application durations. Ice-based modalities consisting of crushed or cubed ice have been shown to reduce localized skin temperature to the required target temperature of 10–13.6 °C for analgesia within five minutes (Ebrall et al., 1989; Ebrall et al., 1992; Janwantanakul, 2006) and ten minutes (Jutte et al., 2001; Kanlayanaphotporn and Janwantanakul, 2005; Merrick et al., 2003). After the immediate sharp reduction in skin temperature, the rate of decline steadily
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Figure 3.1 The effect of ice bag application on skin temperature (°C) throughout a 30-minute application to the anterior thigh (source: adapted from Merrick et al., 1993).

The rate of deep tissue cooling depends on the depth of the target tissue (Merrick et al., 2003; Myrer et al., 1998; 2001). The temperature decline in subcutaneous tissue (just beneath the surface) following ice application presents a similar temperature decline curve to that of the skin, although to a lesser magnitude (Knight, 1995; Myrer et al., 1998). At this level there is still an immediate rapid decline in temperature initially, followed by a more gradual decline throughout the remainder of the icing period (Enwemeka et al., 2002; Myrer et al., 1998). Likewise, the rewarming of superficial tissues replicates that of skin temperature (Myrer et al., 1998), with a sharp increase in temperature followed by a more gradual increase to pre-application temperatures at ten minutes after the removal of application (Enwemeka et al., 2002).

At increased depths, such as that of intramuscular tissue, a linear decline in temperature at a depth of 1 cm below the subcutaneous tissue is maintained throughout a 20- (Myrer et al., 1998; 2000; 2001) and 30-minute application period (Merrick et al., 1993; 2003). The decline is gradual and to a lesser magnitude than that of superficial tissues (see Figure 3.2), outlining that the deeper the target tissue, the slower the response and more limited the extent of cooling due to a diminishing thermal gradient (Enwemeka et al., 2002; Jutte et al., 2001; Merrick et al., 2003). Merrick et al. (2003) illustrate this well as surface temperature declined by 25 °C following a 30-minute ice bag application to the anterior thigh, while at depths of 1 cm and 2 cm beneath the subcutaneous tissue, intramuscular temperature reduced just 8 °C and 4.5 °C, respectively. It is for this reason that the ability of cryotherapy modalities to reduce metabolism and thus limit secondary hypoxia injury has been questioned (Bleakley and Hopkins, 2010).
The target tissue temperature for a reduction in metabolism, which would most likely be at the equivalent depth of 2 cm beneath the subcutaneous tissue in the human model, has been reported to be approximately 10 °C (Sapega et al., 1988). In the study by Merrick et al. (2003), the temperature at 2 cm sub-adipose tissue was 30.6 °C following 30 minutes of wet ice application. No study to date has achieved a muscle temperature below 20 °C in human tissue (Bleakley and Hopkins, 2010).

In contrast to superficial tissues, following the removal of ice bag application there is a continued decline in intramuscular temperature at subcutaneous depths of 1 cm (Merrick et al., 1993; Myrer et al., 1998; Zemke et al., 1998), 2 cm (Dykstra et al., 2009; Jutte et al., 2001; Merrick et al., 1993) and 3 cm (Myrer et al., 2001). It has been reported that the temperature continually declined for five minutes after removal of the application (Merrick et al., 1993), while Myrer et al. (1998) stated the decline was very minimal. Conversely, a decline in temperature for 15 minutes after the removal of ice application has been reported (Dykstra et al., 2009). Such variances in results for ice bag application can be attributed to the depth of the thermistor (the temperature-sensitive resistor), with measurements obtained at 2 cm beneath the subcutaneous tissue by Dykstra et al. (2009), in comparison to 1 cm beneath the subcutaneous tissue by Merrick et al. (1993) and Myrer et al. (1998). These findings collectively underpin the thermodynamic principle regarding the conduction of thermal energy that the sports therapist needs to understand. The skin temperature will begin to rise by conduction of heat from the atmosphere, with superficial tissues subsequently warming via the absorption of thermal energy from the overlying warmed skin (Merrick et al., 2003). This process continues, concluding that the deeper the tissue the greater the delay in heat absorption, thus resulting in prolonged temperature reductions.

**Cryotherapy modalities**

While cryotherapy is frequently used in sports environments, there is no consensus on the optimum modality (MacAuley, 2001; Merrick et al., 2003). As previously discussed, there is a decline in skin temperature with continued application, until a temperature plateau is eventually reached just above the temperature of the modality (Knight, 1995). This would imply that the

![Figure 3.2](source: adapted from Merrick et al., 1993)
coldest modality would produce the greatest reduction in skin temperature and would therefore be the best modality at extracting heat from the body; however, this is not the case. When ice is applied to the skin, a thermal gradient exists between the modality and the temperature of the body (Knight, 1995). Basic thermodynamic principles suggest that the heat energy from the tissues is conducted into the modality. Over a period of time the modality will rise in temperature and become less effective as the thermal gradient decreases. Consequently, studies investigating the efficacy of different cryotherapy modalities at reducing skin temperature often compare ice bag application to that of commercially available gel packs (Belitsky et al., 1987; Kanlayanaphotporn and Janwantanakul, 2005; Kennet et al., 2007; Merrick et al., 2003).

The temperature of an ice bag prior to application is often 0 °C, while a gel or cryogen pack may be as low as −14 °C, and therefore the packs tend to remain prevalent in sports clubs, with first aiders and therapists possibly believing that colder is better (Kennet et al., 2007). Despite these commonly held beliefs, the evidence conclusively shows that after 15 (Belitsky et al., 1987), 20 (Kanlayanaphotporn and Janwantanakul, 2005; Kennet et al., 2007) and 30 minutes of application (Merrick et al., 2003), there is a greater reduction in skin temperature when using an ice bag compared to a gel pack. This can be attributed to the greater heat capacity of ice (Knight, 1995), in addition to the need to overcome the latent heat of fusion (Merrick et al., 2003). In other words, it takes a considerable amount of thermal energy to change one unit mass of a substance from solid to liquid without any change of temperature (Ellse and Honeywill, 2004). As a gel pack does not undergo a change in state, its ability to extract heat from tissue is significantly reduced in comparison to an ice pack. This is illustrated by Kennet et al. (2007) as the temperature of an ice bag throughout a 20-minute application period increased only 0.2 °C, in comparison to an increase of 12.3 °C seen in the gel pack. Furthermore, Merrick et al. (2003) observed a progressive decline in skin temperature throughout a 30-minute ice bag application, in contrast to a gel pack which reached its lowest skin temperature after just 11 minutes. Consequently, evidence suggests that ice-based modalities cause a greater reduction in skin temperature as a result of undergoing a change in state, therefore increasing the ability to absorb heat.

With regard to ice bag applications, ice is often delivered in non-porous bags in the form of cubed ice (Dykstra et al., 2009; Hart et al., 2005; Jutte et al., 2001) or crushed ice (Dykstra et al.,

![Figure 3.3](source: adapted from Merrick et al., 2003)
2009; Hopkins et al., 2006). Such methods are referred to as dry ice due to the non-porous nature of the bag and the dry interface (Belitsky et al., 1987). Several studies have used wet ice, consisting of a fabric bag into which crushed ice is added (Belitsky et al., 1987; Ebrall et al., 1992; Kennet et al., 2007; Merrick et al., 2003). This porous material provides a wet interface to stop potential ice burn, while the water remains in contact with the skin. Based on the concept that cryotherapy modalities absorb heat through conduction and evaporation, wet ice exhibits a greater thermal conduction than that of its dry ice counterpart, and has therefore been shown to be superior at reducing skin temperatures (Belitsky et al., 1987). After 15 minutes of application, the wet ice modality has been shown to reduce skin temperature by 12 °C in comparison to a reduction of 9.9 °C following dry ice bag application (Belitsky et al., 1987). Additionally, in the literature reviewed, the lowest skin temperature reported after ten minutes of ice application was 3.6 °C, which utilized a wet ice method (Ebrall et al. 1992).

While recovery ice baths will be discussed later in this section, ice immersion techniques are also commonly used during early injury management (Kennet et al., 2007; Myrer et al., 1998) – mainly for peripheral extremities (ankle, foot, elbow, wrist and hand). The general consensus appears to be that the colder the water, the greater the reduction in tissue temperature (Knight et al., 1981). However, there is a lack of high-quality research directly comparing wet ice application and ice immersion techniques. Recently, it has been identified that wet ice produces lower skin temperatures compared to immersion after 20 minutes of application to the ankle; however, the temperature of the immersion was 10 °C, with the effects of a colder ice bath such as 1–4 °C unknown (Kennet et al., 2007). A comparison in temperature changes of the calf muscle following 20 minutes of either cold whirlpool immersion (10 °C), or crushed ice bag application identified that ice bag application reduced intramuscular (subcutaneous + 1 cm) temperature by a further 2 °C in comparison to the cold whirlpool immersion (Myrer et al., 1998). Despite this, the rewarming rate of the crushed ice bag was significantly faster than that of the immersion technique, which showed a continued decline in intramuscular temperature 25 minutes after the removal of application. The subcutaneous temperature rewarmed in both modalities directly after the removal of the application (Myrer et al., 1998). This ability of the intramuscular tissue to continue cooling long after the removal of cold whirlpool immersion, in contrast to the ice bag, can be accredited to the size of the contact area (Merrick et al., 2003). With the conduction of thermal energy between the tissues, an enhanced thermal gradient may have been maintained when immersion was administered as the water absorbed heat from the full circumference of the ankle as opposed to just a focal area. Sports therapists can be recommended to utilize ice water immersion techniques during rehabilitation when extended periods of analgesia are required.

Cryokinetics

The ability of cryotherapy to provide an analgesic effect is the fundamental basis behind cryokinetics; aimed to better facilitate rehabilitation by reducing pain spasm and neural inhibition, enabling rehabilitation exercises to be performed earlier than would normally be possible (Bleakley et al., 2004; Hopkins and Stencil, 2002; Knight et al., 2000). First coined by Hayden (1964), cryokinetics (literally meaning ‘cold’ and ‘motion’) was shown to give marked improvements in soldiers’ recovery time following injury (Grant, 1964; Hayden, 1964). Knight (1995) developed a sequence of exercises for the rehabilitation of a lateral ankle sprain using cryokinetics; Pincivero et al. (1993) identify that such protocols can enhance the return to activity.

Cryokinetic protocols generally involve an initial period of ten minutes of ice application to induce analgesia before exercise is performed (Hayden, 1964; Knight et al., 2000; Pincivero et
Exercise is then undertaken until the analgesic effect diminishes (Barnes, 1979), typically for just two to three minutes (Knight, 1995). Subsequent ice applications of between three to five minutes are then re-administered before exercise is performed again (Barnes, 1979; Knight et al., 2000). Cryotherapy does not remove all pain-sensing mechanisms, but may offset residual pain such as that caused by pressure from swelling on nerves and damaged tissue (Knight, 1995). Therapists may be concerned with cold water immersion (CWI) that the patient may not appreciate pain – a factor which could potentially contribute to further injury, yet this is not the case; such ice applications cause a degree of analgesia rather than complete anaesthesia. If an exercise becomes too advanced for the stage of rehabilitation, pain is still likely to be perceived, signalling the need to reduce the intensity (Knight 1995; Knight et al., 2000).

During prescription of cryokinetic protocols, CWI is the modality of choice as it provides an optimal period of analgesia, thus increasing the window of opportunity to perform exercise (Knight, 1995). Although wet ice applications reduce skin temperature more quickly than immersion (Kennet et al., 2007), it is the rate of re-warming which is paramount in cryokinetics, which is retarded following ice immersion (Myrer et al., 1998). Cryokinetics is a powerful tool for the therapist. Initiation in the early phase of rehabilitation allows muscles to contract and therefore the ability to actively pump the swelling out of the area via the lymphatic drainage system (Knight, 1995). In the instance of an ankle sprain, by administering ice immersion, simple range-of-motion exercises can be performed earlier than normally would be possible, thus reducing swelling more quickly. Cryokinetics can be initiated in the sub-acute phase of rehabilitation right through until the athlete is ready to return to activity (Knight, 1995). Bleakley et al. (2012) have recommended a new early management acronym and methodology – POLICE (protection, optimal loading, ice, compression and elevation). The concept of optimal loading encourages incremental rehabilitation, whereby early activity promotes recovery. The implementation of cryokinetics allows for this optimal loading to take place more readily.

**Ice massage**

When implementing cryokinetic protocols, ice immersion is not always possible due to the anatomical location of the target tissue, for example at the knee, hip or shoulder. In such situations sports therapists may utilize wet ice bag applications or ice massage techniques. Ice massage consists of cubed ice applied directly to the skin in a typically gentle, stroking pattern parallel to the underlying muscle fibres (Knight, 1995). To protect the therapist’s fingers, the ‘tear-away cup method’ can be utilized (characterized by water frozen in a polystyrene cup). Once frozen, the therapist tears away the lip of the cup to reveal the ice and then applies the massage directly to the target area. Alternatively, the ‘lolly-stick method’ may be preferred, characterized by a tongue-depressor placed into the polystyrene cup prior to freezing. This time, once frozen, the therapist removes the ice completely from the cup and applies the treatment by holding the tongue-depressor (acting as a handle). Duration of application should be between five and ten minutes to provide an analgesic effect (Grant, 1964; Halvorson, 1990; Hayden, 1964). The sports therapist should note that during the ice massage, the athlete will usually (obviously) experience a cold sensation, followed by a feeling of burning and aching (Grant, 1964). This period of discomfort should only present for a few minutes, yet is essential if analgesia is to ensue (Hayden, 1964). If ice massage is implemented for cryokinetic protocols, once the analgesia has been achieved the ice massage should be terminated and exercise should immediately follow. Subsequent two-minute applications are required every three minutes to maintain pain-free exercise (Bugaj, 1975). The ice massage modality is not only confined to use...
within cryokinetics, but is also recommended for pitch-side first aid when the athlete is to return to the field of play, and for quick analgesia where wet ice bags and ice machines may not be available. Ice massage is popular with sports therapists as it is inexpensive, immediately useful and can be administered by the athlete at home.

**Cryotherapy: modality selection**

The choice of cryotherapy modality should be made with reference to the physiological changes the sports therapist is trying to achieve. Following are three typical scenarios.

**Scenario one: acute setting – return to play**

When the athlete has received a trauma to the ankle/foot complex, but there is no obvious structural damage, the aim of the ice application is to provide quick pain relief before the athlete returns to activity. The best modality to use is an ice bag containing crushed ice, as it has been shown to reduce temperatures to critical levels required for analgesia within five minutes (Jutte *et al.*, 2001; Merrick *et al.*, 2003). Wet ice applications may be considered (where ice is applied through a fabric bag) as this method exhibits a greater thermal conduction than that of its dry ice counterpart. If wet ice is conceived as being messy or impractical in certain pitch-side situations, it is recommended that a mixture of cubed ice and water is put into a plastic bag and then applied (Dykstra *et al.*, 2009). However, during half-time, crushed ice can be placed into a thin wet cotton cloth and applied for fast pain relief for treating contusions following heavy tackles; such management may facilitate return to play.

**Scenario two: acute setting – removal from play**

When the athlete has received a significant trauma to the ankle – but where there is clear structural damage – the ice application will aim to provide pain relief, but more importantly, compression will need to be applied. In an effort to reduce oedema, compression will limit the available space for fluid to accumulate. As a result, wet ice application is of little use as the compression will not be consistent as the water escapes the porous bag. Instead, the dry ice method of crushed ice should be applied in a plastic bag and attached with a compression bandage. The ice is not the most important factor here, but rather the compression.

The ice may be applied intermittently – for ten minutes on, and then removed for ten minutes. In the rest period, the compression bandage should be reapplied. After the ten minutes of rest, the ice should be reapplied. Ideally, this cycle (ten minutes on, ten minutes off) will be continued for an appropriate period post-injury (over the following hours). Once icing is finished, before returning home, the injury should have the compression wrap reapplied.

The rationale for ten minutes on, ten minutes off, not only allows the skin a rest period from constant cold, but more importantly, the modality’s ability to absorb heat is at its maximal for at least ten minutes before the modality temperature may begin to rise. Additionally, a thermal gradient is created between the skin and the intramuscular tissues, which allows cold to be reached at depth. When the ice is reapplied for a second ten-minute period, the tissue temperature at depth has not risen to pre-treatment levels and therefore can reach a lower temperature still. So, rather than the traditionally 20 minutes of continuous ice application – where the modality may start to warm after 15 minutes – here the athlete still receives a combined total of 20 minutes of ice application, but the tissue is maintained at a lower temperature for over 30 minutes.

Intermittent applications of ten minutes are superior at reducing skin temperature at the ankle (Ebrall *et al.*, 1992). Repeated ice applications of ten minutes on, ten minutes off, ten
minutes on, not only have reduced skin temperature to below 3 °C following the second application, but have maintained temperatures below 15 °C for 33 minutes – 40 per cent longer than a 20-minute continuous application. Additionally, intermittent ice application significantly reduced pain on activity one week after a lateral ankle sprain injury (Bleakley et al., 2006).

Scenario three: rehabilitation
During the rehabilitation setting, cryokinetic protocols should be implemented (Knight et al., 2000; Pincivero et al., 1993). Ice immersion should be the chosen modality here rather than wet ice bag application as it provides a longer period of analgesia. The consideration is less about how quickly the pain relief occurs, but more about how long it lasts. The longer the period of analgesia, the larger the window of opportunity to perform exercise.

Effect of cryotherapy on functional performance
With such a widespread use of cryotherapy in the sports medicine environment, sports therapists may have concerns regarding the possible detrimental effects ice applications may have on functional performance (Costello and Donnelly, 2010; Jameson et al., 2001). Studies have examined the effects of cryotherapy on numerous functional tasks such as shuttle runs and vertical jump height (Cross et al., 1996; Evans et al., 1995; Richendollar et al., 2006). Cross et al. (1996) reported that single-leg vertical jump height decreased, and that agility shuttle run times were slower following 20 minutes of ice immersion (13 °C) of the lower leg. Moreover, similar results were obtained when an ice bag application was applied for 20 minutes to the anterior thigh prior to maximal functional performance (Richendollar et al., 2006). Furthermore, functional measures such as single-leg jumping have been shown to yield a decreased vertical impulse following full lower leg immersion (10 °C) for ten minutes (Kinzey et al., 2000). In the only study to date to incorporate bilateral immersion, Patterson et al. (2008) identified jump
height, peak power, agility T-test and a 40-yard dash were all impaired following immersion of the lower leg in a 10 °C cold whirlpool for 20 minutes. It was also reported that jump height and peak power remained significantly reduced for 32 minutes post application (Patterson et al., 2008). In contrast, 20 minutes of immersion (1 °C) of the ankle complex (Evans et al., 1995) and a ten-minute ice bag application to the lateral and medial aspects of the ankle (Attnip and McCrory, 2004) do not negatively affect functional performance. The contradictory results could be accredited to the surface area of tissue cooled. Whether unilateral (Cross et al., 1996) or bilateral (Patterson et al., 2008) immersion of the lower limb to the head of the fibula, the incorporation of muscle cooling was detrimental to functional performance. However, when ice application was focused specifically to a joint, no detriment in performance was apparent (Attnip and McCrory 2004; Evans et al., 1995). In studies utilizing focal joint cooling rather than applications directly to muscle, no detriments in postural stability have been identified (Hart et al., 2005; Jameson et al., 2001). Jameson et al. (2001) examined ground reaction force (GRF) during landing from a vertical jump after subjects received crushed ice to either the ankle or knee, or a combination of both for 20 minutes. However, no significant difference in vertical GRF was identified between the experimental and control groups. Likewise, Hart et al. (2005) concluded that a 20-minute ice bag application to the knee did not alter peak vertical GRF or muscle activity of the gastrocnemius, hamstrings, quadriceps or gluteus medius during a single-leg landing. In fact, cooling of a joint, independent of a muscle, may be advantageous with a greater facilitation of the soleus motor neurone pool evident (Hopkins and Stencil 2002; Krause et al., 2000). Whenever a detriment in functional performance has been identified, large muscle groups such as the quadriceps have been the target for cryotherapy. It is therefore prudent to suggest that cryotherapy to muscular tissue (Cross et al., 1996; Patterson et al., 2008; Richendollar et al., 2006) provides greater detriment to functional performance than that of cryotherapy to a joint, such as the ankle (Attnip and McCrory, 2004; Evans et al., 1995; Jameson et al., 2001) or knee (Hart et al., 2005; Jameson et al., 2001). Despite this, where detriments in performance have been identified, ice application has been longer than that typically applied in the sporting environment. While longer application times may be present for cryokinetic protocols, the location of ice application is typically to a joint where detriments in performance have not been elicited. Consequently, the therapist should not be concerned with sending athletes immediately back to activity following cryotherapy treatment to provide analgesia.

Recovery ice baths

After the athlete competes, the musculoskeletal, nervous and metabolic systems can become fatigued, potentially leading to a detriment in subsequent performance (Ingram et al., 2009). In an attempt to promote improved recovery, sports therapists may implement recovery cold water baths (also known as cold water immersion – CWI) up to the iliac crest or neck line (Bailey et al., 2007; Wilcock et al., 2006). Both water temperature and duration can vary from short bouts of 30 seconds (Mantoni et al., 2007) to longer periods of ten minutes (Bailey et al., 2007) in temperatures often below 15 °C (Bleakley and Davison, 2010). However, much of this modality’s popularity comes from anecdotal evidence (Wilcock et al., 2006), as the results from controlled laboratory experiments remain equivocal, with no consensus on an optimum treatment protocol (Bleakley and Davison, 2010; Cochrane, 2004). The sports therapist must understand that it is often challenging to get athletes to adhere to full immersion in cold water baths due to the intensity of the cold. Moreover, trying to implement extended periods of CWI immediately post-exercise can often be impossible in a team environment due to logistic constraints. However, when CWI is utilized, it is essential that athletes are monitored.
Practitioner Tip Box 3.2

Patient home-care advice

It is recommended, for all areas of specified home-care advice – whether exercise, cryotherapy, heat therapy or any other – that clearly presented written/printed instructions are provided for patients. Photographic or video instruction demonstrating or coaching exercise techniques may also be provided using the patient’s mobile phone. This will help to offset the potential for any harm or lack of progress due to misunderstanding of specific advice, and will also promote patient adherence.

throughout. With athletes who are unaccustomed to sudden entry into cold water, there is often a cold shock response – this consists of an inspiratory gasp, tachycardia and hyperventilation – which can quickly lead to unconsciousness (Lloyd, 1994; Tipton, 1989). Therefore it is recommended to implement habituation sessions for new athletes, where water temperatures are gradually lowered and the duration of applications are gradually increased.

Precautions and contraindications for cryotherapy

Patients with a fear or clear intolerance to ice applications should not be administered cryotherapy (Swenson et al., 1996). Such conditions include Raynaud’s phenomenon (where exposure to cold results in unduly reactive vasoconstriction of extremities, and most commonly affects fingers and toes [RSA, 2013]); and cryoglobulinaemia (where immune complexes precipitating at low temperatures are deposited onto vascular endothelial walls, and may cause a form of vasculitis [Patient Plus, 2011]). The risk of frostbite following cryotherapy is extremely rare but can be reduced by keeping application periods to less than 40 minutes (Knight, 1995). A barrier between the skin and the ice modality is advisable, such as with crushed ice placed in a plastic or fabric bag. Cryogen gel packs should be avoided as there are superior modalities to achieve the desired effects. Bleakley and Hopkins (2010) identified no cases of skin burns or untoward effects as a result of ice application in their review of over 35 laboratory-based cryotherapy studies.

Cryotherapy can be reliably administered to provide an analgesic effect, and therapists should consider the use of wet ice bag application to provide rapid pain relief. Cryokinetic protocols can be implemented in the sub-acute phase in order to provide optimal loading and aid the removal of swelling. Rest and ice application alone will not reduce swelling.

Heat therapy

Thermostimulation or heat therapy is the use of heat for therapeutic purposes, and may relate to any application of substance or device whose temperature is greater than body temperature. This allows the heat to pass from the device to the body. Heat is energy which is produced by the movement of atoms and molecules (Knight and Draper, 2008). The perception of heat is based primarily on subjective interpretation, and each individual will respond differently depending on the circumstances. The manner in which the body responds to the application of heat depends upon the type of heat therapy used, together with the duration and intensity of the application. It is also affected by the differing response of the tissues in different parts of the
body. For a positive reaction to heat therapy, heat needs to be absorbed into the area and spread to adjacent tissues. For therapeutic use, it is important to apply the correct amount of heat; if too little is used, then no significant changes will occur, too much and tissues may be damaged (Prentice, 2009). Within sports therapy, heat may be used to boost blood flow to the area, where increasing local circulation improves the delivery of nutrients to the area and assists the removal of metabolites from the area. Such activity is likely to improve the healing rate of injured tissue, although evidence is limited (Knight and Draper, 2008).

Heat therapy may aid relaxation and general soreness, and anecdotally is often appreciated by patients. Heat therapy can be useful when used as a pre-treatment prior to STT. Laboratory studies have identified that warming of the musculotendinous unit will aid extensibility, and may decrease muscle strain (Knight et al., 2001; Noonan et al., 1993; Strickler et al., 1990; Taylor et al., 1995). The perception of pain may be decreased via the stimulation of A-beta thermoreceptors, as per the gate control theory of pain (Melzack and Wall, 1965; Prentice, 2009). The physiological effects of heat (vasodilation and hyperaemia) cause an increase in circulation (Knight and Draper, 2008), and this is thought to remove chemical irritants such as bradykinin away from the area. Metabolism of the site is increased; this benefits healing but must not be used during the initial phases as this will exacerbate bleeding and inflammatory responses (Knight and Draper, 2008). Heat may decrease pain by promoting a general sedative effect. This aids relaxation and is effective for general aches and pains (Knight and Draper, 2008). Muscle spasms, which may develop as a protective response to injury, can cause local ischaemia; these may be eased through the thermally induced increase in circulation and effect on the muscle spindles (Prentice, 2009). Joint stiffness may be decreased due to the ‘gel to sol’ effect on connective tissues induced by the increased local temperature (Burke et al., 2001; Henricson et al., 1984; Taylor et al., 1995). Cross-linked fibres in collagen are also released to some degree. The combination of neural, vascular and mechanical effects allow connective tissues to become more elastic and enable more effective lengthening of soft tissues and mobilizing of joints to take place. Although heat is useful for relieving general aches and pains, it is not as effective as cold therapy when used with exercise in the early stages of sub-acute injury and may cause an exacerbation of pain (Knight and Draper, 2008). If pain becomes more dull and less sharp, heat may be better than cold in decreasing symptoms. Chronic injuries tend to respond well to heat therapy as it can be recommended for general pain relief, muscle soreness and tissue relaxation. Due to the gradual onset of chronic or overuse injuries, there is little effect on the circulation, therefore secondary metabolic injury is less of a concern. In such cases, pain may occur during activity and treatment may involve heat therapy prior to activity, and cold post-exercise (Knight and Draper, 2008).

**Transference of heat**

**Conduction**

Conduction is the transference of heat between two objects of uneven temperature, and requires direct contact between two objects. Hotter, faster-moving molecules interact with cooler atoms and molecules, transferring heat (energy) until the temperature becomes even (Knight and Draper, 2008). How quickly this occurs depends on the temperature of the modality and the exposure time. It is also affected by the quantity of blood flow in the area. Temperatures should not exceed 47 °C (116.6 °F), and great care should be taken with modalities above 45 °C (113 °F). These should not be used for longer than 30 minutes so that tissue damage can be prevented (Prentice, 2009). Conduction is the method of heat transfer most commonly used in sports and physical therapy, e.g. hot packs.
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Convection
Convection is the transfer of heat indirectly through fluid or air as it passes its surface. This is a faster process than conduction. Convection is affected by the temperature of the modality and how fast the air (or fluid) is moved away from the body once it has become warm. If the air is moving slowly, then it will act as an insulator and continue to keep the body warm. It is also affected by how quickly the body part conducts heat. Hydrotherapeutic whirlpools use both convection and conduction to transfer heat (Knight and Draper, 2008).

Radiation
This may also be called radiant energy and uses the form of electromagnetic waves or rays to transfer heat. It transfers heat from one object to another through space without physical contact. Diathermy, laser, infrared and ultraviolet lamps use radiation to transmit heat (Knight and Draper, 2008).

Conversion
Deeper tissues may be selectively heated by conversion, a form of energy used by ultrasound and diathermy to increase tissue temperature, and therefore stimulate metabolic processes. Conversion relates to the generation of heat through other forms of energy (Prentice, 2009).

Heat therapy modalities

Hot packs
These are commonly used in sports therapy and superficially heat the tissues to help prepare the area for treatment (Starkey, 2004). They come in a variety of forms: they may be a dry, electrically heated pack; a simple hot water bottle; a gel-pack, warmed in hot water; a moist-heat pack – such as a ‘wheat-bag’, warmed in a microwave oven; or a hydrocollator pack. Medical standard electrically heated packs are heated to a temperature of 40–42 °C and can be controlled via a thermostat to maintain a constant temperature (Kitchen and Bazin, 2004). Hydrocollator packs are a form of moist heat, and are most commonly used in hospital settings or larger clinical environments. The packs are immersed in hot water in specialized cabinets at a temperature of approximately 75 °C. Hydrocollator packs contain silicate gel inside a cotton wrapping. Once heated, the packs are wrapped inside a towelling cover and applied to the affected area (most commonly osteoarthritic joints) for 20–30 minutes at a working temperature of 40–42 °C (Kitchen and Bazin, 2004; Prentice, 2010). It is essential that patients are carefully selected and monitored during the delivery of any direct heat application; patients must be instructed to report if the heat is too hot.

Infra-red lamps
Infra-red (IR) waves sit between visible light and microwaves on the electromagnetic spectrum. Most contemporary IR heat lamps use luminous 350–450 nm wavelengths (i.e. in addition to IR, they incorporate additional visible red light) with a light source of tungsten or carbon filament (Vizniak, 2012). Practitioners must observe the manufacturer’s instructions regarding intensity output and recommended applications. Basic rules for delivery include appreciation of the inverse square law, which dictates the distance that the lamp should be positioned from the patient’s body (the intensity of IR radiation increases as the distance from the patient decreases, and vice versa), but the actual intensity relates to the output of the lamp (Ward, 2004). The minimum recommended distance from the body is typically 50 cm. For even distribution of heat, the lamp and patient should be positioned so as to allow the rays to strike the body near
to an angle of 90° (Vizniak, 2012). Radiant (luminous) IR can penetrate superficial skin layers to reach myofascial tissue. Treatment times are typically 10–20 minutes, and the patient should be free of any massage lotion or oil, have removed any jewellery and should avoid any eye exposure. Practitioners should always check equipment prior to use (i.e. the lamp, its stand, bulb, leads, plug and controls), and monitor patients’ response during treatment.

**Paraffin wax**

Paraffin wax is a traditional physical therapy modality. The wax is heated in a thermostatically controlled container, and is maintained at a temperature of 42–54 °C (Kitchen and Bazin, 2004). While it has been used to treat smaller areas of the body such as the hands and feet, typically again for easing pain and stiffness associated with osteoarthritis, its popularity has waned in recent years. Treatment lasts 20–30 minutes. Application may be in the form of direct and repeated immersion (hands and feet), or molten wax may be brush-layered onto the affected area of the body. Usually, a thick layer of wax is built onto the body area, and then covered with plastic sheeting and towels to retain the heat. Due to the insulation quality of the wax, heat is maintained in the area, and superficial warming occurs. The procedure is less time-efficient than other modalities. Paraffin wax should not be used on broken skin, and caution should be used if there are any sensory or circulation impairments.

**Hot water immersion**

Hot water immersion (HWI) can include spas, hot tubs, whirlpools, hot water baths and showers. They are effective methods of providing general whole-body warming, which can generate a range of physiological and psychological responses, including, general relaxation, muscular relaxation, improved joint mobility and pain relief. Water temperature is recommended to be 36–41 °C.

**Precautions with heat therapy**

With acute injuries heat therapy will not normally be applied within the first two or three days. The increased metabolism created by the application of heat can increase secondary metabolic injury and delay healing. General and peripheral vascular disorders affect the body’s ability to respond to increases in temperature and exacerbation of symptoms can occur. Sports therapists must take care also where the patient has impaired sensations. Overexposure or inability to sense changes in temperature can prevent the body’s natural response to heat (thermoregulation), and may cause overheating; the body can be easily overheated, causing symptomatic hypotension and faintness. Skin mottling, burns and scalds can occur if practitioners are not careful. Furthermore, excessive heat therapy can cause transient hypotension, fainting and headache. Sports therapists must be responsibly vigilant to how any heat therapy affects the patient, taking care to gain verbal, visual and tactile feedback during treatment.

**Electrotherapy**

*With Nick Gardiner*

**Principles of electrotherapy**

Conclusive scientific evidence for electrotherapeutic modalities (electro-physical agents – EPAs) is lacking. However, there is a body of evidence which demonstrates significant physiological effects that may be of use therapeutically (Alexander et al., 2010; Milne et al., 2001; Watson, 1996; 2000).
Therapeutic ultrasound

Watson (2013a) provides an expansive review of the history, equipment, applications and evidence underpinning ultrasound (US) therapy:

Ultrasound has been a part of clinical practice since the 1950s, and remains a popular and evidenced intervention for a range of clinical problems. Shah and Farrow (2012) provide an insight into its current clinical popularity as does the widely cited paper by Pope et al. (1995). General (textbook) reviews and explanations can be found in Watson and Young (2008) and Robertson et al. (2006), amongst others.

US machines use a piezoelectric transducer to produce mechanical vibrations, like sound waves but of a higher frequency; these are passed into the tissues via a coupling medium (gel or water) to avoid reflection of the waves. US absorption is greater for tissues with high protein content, so tendons, ligaments, fascia, joint capsules and scar tissue are the structures most commonly associated with US therapy (Vizniak, 2012), though a case for its use on muscle may still be made (Speed, 2001). US can be beneficial throughout the acute inflammatory, proliferative and maturation stages of healing, and the effects can be divided into non-thermal and thermal. US is proposed to accelerate the vascular and cellular events during the acute phase of healing (being pro-inflammatory); enhance fibroplasia and collagen synthesis during proliferation (being pro-proliferative); and improve the strength, elasticity and optimization of fibrous scar tissue during remodelling (Harr, 1999; Watson, 2013a).

The non-thermal benefits of US are utilized during the earlier stages of healing. Applications of US during the acute stage are proposed to enhance the inflammatory cascade (Watson, 2000). These effects occur by the ultrasonic mechanical vibrations interacting with specifically activated cells at the injury site (including platelets, mast cells, neutrophils and macrophages). It should be noted that there is conflicting evidence concerning this theory (Matsuzawa et al., 2004). Acoustic streaming, which is the unidirectional movement of a fluid affected by the US field, can stimulate cell activity if it occurs at the boundary of the cell membrane and the surrounding interstitial fluid. This can affect membrane permeability, diffusion rates and the membrane potential. US causes ‘cavitation’ – the formation and implosion of gas-filled voids within the tissues and interstitial fluids. When the cavitation is ‘stable’, acoustic streaming is likely to be enhanced, and has potential to be therapeutic. ‘Unstable cavitation’ may occur where inappropriate US frequencies or intensities are employed, or when the treatment (transducer) head remains stationary during application, and this can cause tissue irritation. During the proliferative stage of healing it is proposed that US may promote both fibroblastic and endothelial cell activity, maximizing early scar tissue production and its quality (Watson, 2000). During proliferation US has been shown to increase the process of angiogenesis (Hogan et al., 1982), along with an increase in protein synthesis. US has been shown to potentially stimulate cell division, fibroblast production and collagen synthesis during the active proliferative stage of ruptured rat tendons. This was hypothesized after the ultimate tensile strength was found to be greater compared to a control group (Ng et al., 2003). Benefits that are seen during the remodelling phase occur primarily as a result of the thermal effects of US, and the indications for this are general musculoskeletal disorders such as muscle spasm and soft tissue fibrosis. General thermal effects of US may include increased extensibility of collagen-rich tissues (i.e. fascia; scar tissue), increased blood flow, increased nerve conduction velocity, increased muscle relaxation and reduced muscle spasm, pain and myofascial trigger points.
US dosage for non-thermal treatments uses a pulsed delivery of the waves which reduces the heat in the tissue; this is known as the ‘duty cycle’. US machines will display this either as a ratio, such as 1:4 (one part US to four parts rest in each cycle), or as a percentage, i.e. 20 per cent. The ratio 1:4 is a relatively low dose of US, most commonly used in acute presentations. The other commonly pulsed ratios are 1:9 (extremely low dose), 1:2 (used more in the post-acute phase) and 1:1 (50 per cent). Thermal US treatments (for more chronic presentations) will use a continuous delivery, which may be displayed as CW (continuous wave) or as a percentage (100 per cent). A additional factor when prescribing US dosage is the target tissue depth. Most US machines will feature dual frequency options (1 MHz and 3 MHz). US energy decreases exponentially with depth. A frequency of 1 MHz is used for deeper tissues, and a half-value depth for this setting is approximately 4 cm. This means that half of the US energy will have been absorbed at 4 cm. Therefore, this is an essential factor when determining the intensity settings as this must allow for this absorption rate. As a general rule, a frequency of 3 MHz is used for more superficial structures, and its half-value depth is approximately 2.5 cm (Watson, 2000). The intensity of US application is measured in W cm⁻² (watts per centimetre squared) and relates to the power output to the surface area via the transducer head. Again, as a general rule, the more acute the injury, the less power will be needed to excite the tissue (and vice versa for more chronic injuries).

To calculate the timing of a US treatment a simple calculation can be used; the number of treatment heads that cover the affected area can be multiplied by the sum of the duty cycle as a ratio. For example, if the area to be treated was the equivalent to two treatment heads and the duty cycle was to be 1:4, then the sum required would be \(2 \times (1 + 4) = 10\) minutes. Another example may be that one treatment head was required for a duty cycle of 1:1; this sum would then be \(1 \times (1 + 1) = 2\) minutes (Watson, 2013b).

Bone has a high content of protein but as an injured structure has not historically been considered an indication for US. Specialized units that deliver very low intensities (0.01 W cm⁻²) have been shown to be most beneficial for fracture healing (LIPUS – low intensity pulsed ultrasound), but are expensive in comparison to conventional units (Warden et al., 2006). The shear forces applied to cellular membranes are thought to induce a cellular response and a 30–38 per cent acceleration rate for healing has been seen (Warden, 2003). There is research which suggests that lower intensity US may also be of benefit to soft tissue pathologies. It should also be noted that despite some comparisons between the results seen for the specialized units and standard LIPUS, it is thought that the accuracy of standard machines is not reliable enough to qualify their use for fracture healing. Another application of US is the use of phonophoresis, which is the driven migration of medication molecules from under the treatment head (as part of a coupling medium), offering superficial, non-invasive medication, and a potential synergistic relationship between US and medication (Wells, 1977). Phonophoresis has been most commonly used in clinical settings for the application of non-steroidal anti-inflammatory drugs (Hsieh, 2006; Sevier and Wilson, 1999).

### Table 3.12 Different parameters for therapeutic ultrasound intensity

<table>
<thead>
<tr>
<th>Stage of healing</th>
<th>Ultrasound intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute</td>
<td>0.1–0.3 W cm⁻²</td>
</tr>
<tr>
<td>Sub-acute</td>
<td>0.2–0.5 W cm⁻²</td>
</tr>
<tr>
<td>Chronic</td>
<td>0.3–0.8 W cm⁻²</td>
</tr>
</tbody>
</table>

Source: adapted from Watson, 2013b.
Table 3.13 Contraindications for ultrasound, interferential and TENS

<table>
<thead>
<tr>
<th>Contraindication</th>
<th>US (thermal)</th>
<th>US (Non-thermal)</th>
<th>IF and TENS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pregnancy</td>
<td>LC</td>
<td>LC</td>
<td>LC</td>
</tr>
<tr>
<td>Malignancy</td>
<td>C</td>
<td>C</td>
<td>LC</td>
</tr>
<tr>
<td>Electronic implants (pacemaker)</td>
<td>LC</td>
<td>LC</td>
<td>C</td>
</tr>
<tr>
<td>Active epiphysis (aged &lt;19)</td>
<td>LC</td>
<td>LC</td>
<td>LP</td>
</tr>
<tr>
<td>Metal implant</td>
<td>LC</td>
<td>LC</td>
<td>LP</td>
</tr>
<tr>
<td>Local circulatory insufficiency</td>
<td>LC</td>
<td>LC</td>
<td>LP</td>
</tr>
<tr>
<td>Devitalized tissue</td>
<td>LC</td>
<td>LC</td>
<td>LC</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>-</td>
<td>-</td>
<td>LC</td>
</tr>
<tr>
<td>Bacterial infections</td>
<td>LC</td>
<td>LC</td>
<td>LC</td>
</tr>
<tr>
<td>Tissue bleeding</td>
<td>LC</td>
<td>LC</td>
<td>LC</td>
</tr>
<tr>
<td>Specialized (organ) tissue</td>
<td>LC</td>
<td>LC</td>
<td>LC</td>
</tr>
</tbody>
</table>

Source: adapted from Robertson et al., 2006; Watson, 2011.
Note: LC, local contraindication; LP, local precaution; C, contraindication.

Contraindications to therapeutic ultrasound

Most US contraindications are related to its application for its thermal heat effect. In relation to soft tissue injuries, the main concerns include treatment over cancerous or infectious lesions, epiphyseal growth plates in children and adolescents, haemorrhagic regions, ischaemic peripheral regions, sensory disability, electronic (pacemaker) or metal implants and areas previously exposed to radiology (Belanger, 2002). As US has an effect on cellular activity and blood flow, it means that local circulatory issues and pregnancy and are also contraindications, along with bacterial infections.

Safety issues with therapeutic ultrasound

Transient, or unstable, cavitation is a potential risk of US treatment. This occurs due to inappropriate application and results in rapid changes in the volume of bubbles, leading to their implosion which can cause temperature changes and cell damage (Wells, 1977). It is important to keep the treatment head moving at all times to minimize the risk of transient unstable cavitation. Another common danger is the creation of standing waves which can occur when two interfacing tissues of differing acoustic properties reflect the ultrasonic waves, creating ‘hot spots’. This occurs when an incident wave meets a returning wave with the same amplitude, which results in a much stronger input than would be expected. This can cause endothelial damage through the release of free radicals. Endothelial cell metabolism and function is important for maintaining vascular integrity, thus rendering the micro-circulation a vulnerable component of soft tissue (Maxwell, 1992). For example, standing waves may be more likely to occur when US is applied to a tendon close to its attachment to a bony prominence. It is also important to perform a skin sensation test prior to the treatment in the form of a hot/cold test (typically using test tubes filled with water of different temperatures). Even though most potential benefits of US occur sometime after the treatment, it is still important to record an objective marker prior to treatment as this can be useful for recognizing if there has been any immediate negative impact from the treatment which may give reason to cease further treatments, or a justification to modify the treatment parameters.
Practitioner Tip Box 3.3

**Therapeutic ultrasound application**

1. Assess patient (suitability for ultrasound; therapeutic objectives; locality and size of treatment area)
2. Set machine up
3. Test machine (controls; leads; transducer head; function)
4. Work out application settings
5. Safety checks on patient (including all contraindications; hot/cold sensation)
6. Explain effects of treatment to patient
7. Position patient appropriately (for comfort; protect clothing)
8. Advise patient to mention any discomfort during treatment
9. Begin application (apply coupling gel, and apply transducer head to tissues prior to starting)
10. Keep transducer head slowly moving during application
11. Observe, monitor and communicate with patient

**Interferential therapy**

Interferential (IF) treatment is the application of alternating medium-frequency electrical currents which are then amplitude modulated to allow a mimicking of low-frequency currents to give therapeutic benefits. The amplitude modulated frequencies (AMFs) act as ‘carrier’ currents which deliver the low-frequency AMF to the affected area. The body then demodulates the AMF; the mechanisms for this are still to be fully established (De Domenico, 1982; Johnson and Tabasam, 2003). The reason this approach is used is because low-frequency stimulation of nerve and muscle fibres has been shown to have beneficial therapeutic effect on deep nerve tissue. Skin, however, has a naturally high resistance to the passage of low-frequency current so the delivery of two medium (IF) frequencies that summate means that a lower-frequency treatment can be delivered to provide potential pain relief (Kloth, 1991; Martin, 1994; Nelson, 1981). Most IF machines have a carrier frequency in the region of 4,000 Hz, and an adjustable frequency known as the interference frequency that ranges between 4,001 and 4,150 Hz. The resulting frequency is known as the AMF or the beat frequency, and is the low frequency that will be delivered to the tissues (Johnson and Tabasam, 2003). The main physiological (and psychological) benefit of applying IF is to address pain, reduce oedema, promote healing and improve neuromuscular activation (Johnson and Tabasam, 2003). Pain relief, in simple terms, may be explained and achieved through two main pathways; the pain gate mechanism (stimulating A-beta fibres), which is appropriate for acute symptoms, overriding A-delta and C fibres; and the stimulation of endogenous opioid mechanisms for more persistent presentation, which may influence C-fibre-generated nociception (De Domenico, 1982; Melzack and Wall, 1965). IF can also be used for muscle stimulation, which can be useful for inducing a pumping and flushing effect to increase blood flow to the area and reduce oedema, as well as neuromuscular re-education. This can be useful for reducing swelling and optimizing the healing process (Lamb and Mani, 1994; Noble et al., 2000).

Due to the summation of the two medium frequencies, IF can deliver low-frequency treatments with less discomfort than traditional methods. IF can also treat deeper and larger areas of tissues than other common electrotherapy modalities. Two-pole and four-pole IF can
Clinical interventions in sports therapy

Table 3.14 Recommended interferential therapy parameters

<table>
<thead>
<tr>
<th>Physiological effect</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain relief</td>
<td>90–150 Hz</td>
</tr>
<tr>
<td>Endogenous opioid mechanisms</td>
<td>1–5 Hz</td>
</tr>
<tr>
<td>Muscle stimulation</td>
<td>10–25 Hz</td>
</tr>
</tbody>
</table>

Source: adapted from De Domenico, 1982; Wadsworth and Chanmugam, 1980.

be used. Two-pole IF is 100 per cent amplitude modulated, which means it is efficient and produces perfectly formed beat frequencies. Four-pole, on the other hand, employs two circuits that are at right angles to each other, which produce a ‘clover leaf’ pattern where the interfering frequencies cross over (Kitchen and Bazin, 2004; Robertson et al., 2006). Four-pole is well indicated for intra-articular joint pain due to its ability to target deep tissues. The actual delivery of electrical stimulation is via either re-useable or disposable single-patient electrodes (pads). These are rubber-coated, and the re-usable pads require water-dampened sponge covers to allow conduction to the patient’s tissues. Re-useable electrodes need to be fixed in place using elasticated strapping. Disposable electrodes are slightly more costly, but much easier to apply, and arguably more hygienic. Suction pads are also available, which may also be easier to apply over irregular surfaces, and may aid the muscle pump action. Timings for treatments range from 10 to 20 minutes and the intensity of the machine should be set at the maximum within the patient’s comfort level (Savage, 1984; Goats, 1990; Wadsworth and Chanmugam, 1980). It is important to check with the patient that the level of intensity feels the same throughout the treatment as this may need to be turned up to account for accommodation to the level of
**Practitioner Tip Box 3.4**

**Interferential application**

1. Assess patient (suitability for IF; therapeutic objectives; locality and size of treatment area)
2. Set machine up
3. Test machine (controls; leads; electrodes; function)
4. Work out application settings
5. Safety checks on patient (including all contraindications; sharp/blunt sensation)
6. Explain effects of treatment to patient
7. Position patient appropriately (for comfort)
8. Advise patient to mention any discomfort during treatment
9. Begin application (start on minimum intensity and turn up to maximal comfortable intensity)
10. Observe, monitor and communicate with patient

stimulation. Most IF machines have a sweep setting available, and some are automatic. Sweep means that the AMFs that have been set will rise and fall between the two parameters over a number of seconds, for example, 90–150 Hz over a period of six seconds (Kitchen and Bazin, 2004). There is some research to suggest that applying a sweep may allow a greater stimulation of excitable tissues (Low and Reed, 2004; Savage, 1984).

**Contraindications to interferential therapy**

Most contra-indications for IF are nerve-related due to the type of stimulation IF delivers, so this includes conditions such as epilepsy, pacemakers and devitalized tissue. However, as IF also has the potential to stimulate blood flow, circulatory conditions must also be included.

**Safety issues with interferential therapy**

IF dangers include overstimulation of nerve fibres if intensity is set too high, and irritation to tissues if the athlete’s sensitivity is impaired. This is why it is important to carry out a skin sensation test in the form of a sharp/blunt test. Placement and positioning of the pads is important as poor electrode contact with the skin will lead to an ineffective treatment. It is also important to ensure that there are no short wave diathermy (SWD) machines in use within five metres at the same time (Goats, 1990). An appropriate objective marker should be recorded prior to the treatment for comparison afterwards.

**Transcutaneous electrical nerve stimulation**

Transcutaneous electrical nerve stimulation (TENS) is designed to provide pain relief by specifically exciting sensory nerves (Denegar, 2000). While there are some claims that TENS will aid management of inflammation and neuromuscular dysfunction, the most widely recognized indication is for the management of acute and chronic pain. This includes all manner of sports-related injuries such as low back pain, musculoskeletal pain, post-surgical pain and arthritic pain (Pengel et al., 2002; Topuz et al., 2004). The two main ways that TENS affects pain is via the pain gate mechanism, and through activation of the endogenous opioid system (i.e. stimulation
of endorphin release) (Melzack and Wall, 1965; Ignelzi and Nyquist, 1979; Sjölund et al., 1977; Andersson et al., 1977; Topuz et al., 2004). Conventional TENS activates the pain gate mechanism, and it does this using high-frequency (50–100 Hz), low-intensity (just above the patient’s sensation threshold) and short pulse width (50 us) parameters (Kitchen and Bazin, 2004; Walsh et al., 2000; Watson, 2011). Treatment times for conventional TENS range from 15–20 minutes to hours (Kitchen and Bazin, 2004; Robertson et al., 2006; Walsh et al., 2000). To activate the endogenous opioid system, an acupuncture-like setting is used (AL-TENS), which is effectively the opposite setting to that of conventional TENS. This uses a low-frequency (2–4 Hz), high-intensity (maximum for patient comfort) and long pulse width (200 us) (Walsh et al., 2000; Watson, 2011). AL-TENS produces a much more stimulatory treatment and feels like a rhythmical ‘thudding’. Consequently, the treatment times should be lower to reduce the risk of fatiguing muscle fibres, using an upper limit of 45 minutes to an hour (Robertson et al., 2006).

AL-TENS stimulates the release of endorphins and encephalins (Zadina et al., 1997). There are also modulated and burst settings (Kitchen and Bazin, 2004) that can be used if accommodation to the currents becomes an issue. Modulated TENS may be a viable option if the efficacy of conventional TENS is wearing off. It uses parameters of 40–150 Hz. Burst TENS is more of a ‘jack of all trades’, addressing pain through both pathways using a frequency of 50–100 Hz (Watson, 2011). It is the type of pain that is key when deciding what mode of TENS to apply. As a first treatment for sharp, localized pain, conventional TENS would be the most appropriate choice, and for deeper, more poorly localized aches AL-TENS would be the best choice. Dual-channel TENS can be applied if required, which means that two channels of current are delivered simultaneously through four electrodes. This is of use when treating a large area of tissue, or for addressing referred pain, for example, placing two electrodes paraspinally in the L4–S3 region, and two electrodes at the site of referred pain in the leg. TENS electrodes are normally self-adhesive and easy to apply. The most common approach to electrode placement is to apply them directly over the injured area, but it is possible to use peripheral nerves, spinal nerve roots, trigger points and acupuncture points (Robertson et al., 2006).

Contraindications to TENS

Due to the electrical stimulation that TENS delivers, patients with pacemakers and/or a history of epilepsy should not be treated. Inconclusive research means that the safest approach to treating pregnant patients is to consider pregnancy at least a local contraindication. Skin-related conditions such as bacterial infections should be avoided to reduce the chance of cross-infection.

Safety issues with TENS

The athlete must have normal skin sensation for the use of TENS to be safe, so a sharp/blunt test is required prior to all treatments. The small size, low cost and portable nature of the TENS units means they are especially good for home use. However, giving clear instructions for using the unit outside the clinic is essential. This includes dispensing advice such as not to use TENS while driving, operating machinery, sleeping or showering. It is also important to point out that prolonged use may result in irritation and a reddening of the skin beneath the electrodes. This will normally settle without complication. The athlete should be advised to adjust the exact positioning of the pads on a regular basis to avoid this. It is important to remember that TENS addresses more the symptoms of an injury rather than the cause. The patient should be made aware of this and understand that during TENS treatments, symptoms of pain may be masked which can increase the chance of worsening the injury through the performance of aggravating activities. Taking some form of objective marker and recording the patient’s pain VAS score will allow for a comparison of symptoms before and after the treatment.
Athletic taping and strapping

Principles of taping

Taping is a commonly utilized, temporary, adjunctive intervention (Birrer and Poole, 2004). It is used within all stages of the rehabilitation process for a host of therapeutic objectives, including: prophylactic or protective taping (to prevent injury); proprioceptive and joint positional sense taping (typically in repair stage recovery activities); compression taping to minimize swelling (such as in the presence of acute soft tissue injury); athletic taping to restrict specific movements during activity (such as restricting inversion in the presence of ankle instability); taping to improve motion control; taping to ‘offload’ irritable structures (such as with some reactive tendinopathies); taping to reduce biomechanical malalignment (such as with maltracking patella); taping to influence lymphatic drainage (such as with acute soft tissue injury); taping to stimulate muscle recruitment (facilitation) (such as with joint positional sense and postural re-education); taping to inhibit muscle recruitment; taping to relieve pain; taping to improve athletes’ confidence on returning to functional activities following injury; taping to hold splints, pads or packs in place (Abell, 2010; Anderson et al., 2009; Bahr and Engebretsen, 2009; Macdonald, 2004; Norris, 2011; Prentice, 2009; Vizniak, 2012).

Although taping in athletic and rehabilitation settings is widespread, evidence to support its use is somewhat limited, and particularly during sports, the desired effect of taping procedures can soon decrease as physically stressful activity takes place. Of the numerous published applications, the most common indications for athletic taping include: anterior glenohumeral instability; acromioclavicular sprain; elbow joint sprain; medial and lateral elbow epicondylalgia; wrist sprain; thumb medial ligament sprain; interphalangeal ligament sprain; adductor tears; quadriceps tears; hamstring tears; medial and lateral collateral ligament sprain; patellofemoral pain syndrome; patellar tendinopathy; medial tibial stress syndrome; calf tears; Achilles tendinopathy; medial and lateral ankle sprain; plantar fasciitis; turf toe (compressed and hyperextended first metatarsophalangeal joint); and a range of postural conditions (such as exaggerated thoracic kyphosis or lumbar lordosis, or ‘winging’ scapula). From an efficacy point of view, the sports therapist will be expected to consider the most appropriate taping application for the tissues involved, the severity and stage of healing, and the level of functional activity expected of the patient or athlete following the taping application. Beyond this, therapists must also consider when alternative methods of providing stability may be preferable. Purpose-designed products such as ankle and knee braces, lumbar and pelvic support belts, and epicondylalgia clasps are readily available and do have their place in early rehabilitation, and hence, the sports therapist will be expected to make informed decisions regarding their use. Braces, particularly when designed for the ankle, tend to fall into one of three categories: sleeves (provide compression and proprioception, but no stability); non-rigid (constructed from either elastic, nylon, canvas or neoprene with laces and/or elastic straps; these provide proprioception and minimal stability); and semi-rigid (similar to non-rigid, but with additional moulded medial and lateral support struts or air cushions; these may be used when greater stability is required) (Bahr and Engebretsen, 2009). By way of simple comparison, taping can be a cheaper short-term strategy, and can be more individualized. Bracing may be preferable when numerous repeat applications are required, and can also be re-tightened during activity (Abell, 2010). Bracing can be easily performed by the athlete, whereas taping is therapist-dependent. Certainly, athletes with a history of ankle sprains who regularly use either taping or bracing have been shown to have a lower incidence of re-injury (Quinn et al., 2000). The specific efficacy and indications for both, however, still require far more investigation.
Bandyopadhyay and Mahapatra (2012) provided an update and review of the use of tape in sports. They note that, as part of an injury-prevention strategy, athletic taping must be viewed as a major procedure. In contact and collision sports, tape may contribute to a reduction in extrinsic aetiology. Overuse injuries may be protected against and reduced. Taping is also commonly used to help return athletes earlier to their sports after injury, as taping provides the stability and support to injured structures. Butterwick et al. (2004) indicated that taping can reduce both incidence and intensity of injury in many sporting environments. Certainly, in clinical sports therapy practice, there is scope to explore the use of taping in the post-acute and early stages of rehabilitation, and also importantly as an intervention to reduce pain. McConnell (2000; 2002) has undertaken significant work in this area, particularly with regard to patellofemoral pain syndrome (PFPS). Of the possible disadvantages associated with taping, and not least the delivery of inappropriate, ineffective or, worse, harmful taping procedures, Birrer and Poole (2004) highlight the potential for the athlete developing a psychological dependency on the external support. Both Cordova et al. (2000) and Quirke and Harrison (2000) have identified the limited duration of effect from ankle taping applications in sports, suggesting that the effectiveness of tape may actually only last for 10–20 minutes. In a PEDro systematic review of ankle taping and bracing for proprioception Janssen and Kamper (2013) concluded, in light of the established evidence-base, that it should not be discouraged. This is clearly an area for further investigation, where both taping techniques and technologies must be evaluated.

Just as there are innumerable taping indications and applications, there are also a wide range of taping products and materials. While taping is generally seen as a useful adjunct to other therapeutic modalities, a strong understanding of anatomy, biomechanics, mechanisms of injury, pathology, progressive treatment and rehabilitation techniques, and individual sports, as well as the athlete or patient themselves, is required to guide the sports therapist in the choice of technique. Thorough clinical assessment should provide the therapist with necessary information to decide, for example, which structures need to be supported, which movements need to be restricted and what are the most suitable taping materials needed for the athlete and the sporting environment. Sports therapists will recognize that practice is the key to the delivery of proficient taping techniques. Although there are specific guidelines on correct taping techniques, practitioners must be open and flexible to experiment to adapt individual techniques to suit each situation and athlete. It is also important to bear in mind that taping applied incorrectly may aggravate an existing injury, or even cause a new one.

**Taping equipment**

There is a wide variety of taping equipment available, with products being developed for a range of uses. Birrer and Poole (2004) explain that athletic tape is graded on a number of technical characteristics, including: the number of vertical and horizontal threads per square inch; the tensile strength; whether the tape is cotton, synthetic or a combination; and its adhesive properties. Taping products can be expensive, and most are single-use and disposable, hence it is important to ensure that whichever products are selected, they must be the most appropriate for the therapeutic objectives and the environment. Taping materials should be stored hygienically in a dry, cool place. Some of the most common taping and strapping products are discussed below.
**Table 3.15 Athletic taping application terminology**

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor</td>
<td>A strip of adhesive rigid tape applied to provide a firm base to attach other tapes to</td>
</tr>
<tr>
<td>Basketweave</td>
<td>A series of alternate interweaving stirrup and spur strips applied in a half-overlapping pattern. Used at the ankle to restrict movement following sprain</td>
</tr>
<tr>
<td>Buddy tape</td>
<td>Circumferential adhesive non-elastic taping strips applied around two fingers proximal and distal to a sprained interphalangeal joint. May have a splint inserted between the two fingers</td>
</tr>
<tr>
<td>Butterfly</td>
<td>Strips of tape which fan out from a single anchor strip</td>
</tr>
<tr>
<td>Check-rein</td>
<td>One or more strips of tape which run between two anchor strips</td>
</tr>
<tr>
<td>Fan strip</td>
<td>Three or more strips of tape produced as an ‘X’ pattern. Applied between two anchor strips. The strips are then reinforced with additional locking anchor strips. Used to restrict joint movement</td>
</tr>
<tr>
<td>Figure of eight</td>
<td>Continuous loop of crepe, cohesive or elastic adhesive tape in a figure-of-eight pattern. Used to provide compression to control swelling, or to reinforce stability at a joint</td>
</tr>
<tr>
<td>Lock</td>
<td>A strip of rigid tape applied to provide final reinforcement and complete a tape application</td>
</tr>
<tr>
<td>McConnell technique</td>
<td>A specific application using strong, rigid tape (over hypoallergenic adhesive fleece tape) which aims to relieve pain and improve patellofemoral alignment and neuromuscular recruitment</td>
</tr>
<tr>
<td>Reinforcing strips</td>
<td>A series of overlapping strips which reinforce the underlying strips</td>
</tr>
<tr>
<td>Spica</td>
<td>A repeated figure of eight. Most commonly utilizes wide elastic tape, which may be applied over clothing. It is used mainly for restricting thumb, ankle, knee and hip movements. It may be reinforced by strips of adhesive rigid tape</td>
</tr>
<tr>
<td>Spiral</td>
<td>A winding, continuous elastic or cohesive strapping applied circumferentially around a limb to provide compression or restrict muscular movement. Each continued application overlaps the previous one by a half-width. May be reinforced by strips of rigid tape</td>
</tr>
<tr>
<td>Spur</td>
<td>Horizontal strips of tape which hold stirrups in place. May form part of a ‘basketweave’ pattern</td>
</tr>
<tr>
<td>Stirrup</td>
<td>A vertical U-shaped piece of tape supporting the lateral aspects of a joint. Stirrups run from one side of the joint and up the other</td>
</tr>
</tbody>
</table>

**Zinc oxide**

Zinc oxide (ZO) is adhesive, inelastic and hand-tearable, and is intended to provide certain rigid support to inert injured structures such as ligaments and joint capsules, and to also subtly reinforce other taping applications. ZO can be used as anchors at musculotendinous junctions, and is commonly indicated for prophylactic purposes. As it is inelastic, it should never be applied circumferentially. Depending on the anatomical area, ZO comes in a variety of sizes. To tear ZO, the sports therapist should pull the tape apart and perform a short, firm and quick twisting movement. ZO comes in a variety of widths (typically in rolls from 1.25 cm to 7.5 cm wide, and 5 m to 10 m long); and also a selection of densities and adhesive properties are available.
**Micropore**
A rigid, conformable, inelastic, non-woven viscose fabric which is coated with an acrylic adhesive (rather than, for example, a ZO adhesive). As it is micropolitan, it will withstand limited exposure to water without losing all of its adhesive properties, and also offers some protection against maceration.

**Elastic adhesive bandage**
Elastic adhesive bandaging (EAB) conforms to the contours of the body, and allows for normal tissue expansion, particularly involving musculature. It is adhesive and offers elasticity. EAB is usually non-tearable (requires cutting); however, there now are lighter-weight stretch tapes which can be torn by hand. EAB provides compression, and can also be used as an anchor around a muscle belly. If some give in the tape application is required, then EAB is indicated. It will not provide effective mechanical support to ligaments, but can be used in conjunction with ZO or other rigid tape. EAB is commonly available in a range of widths from 1.25 cm to 10 cm.

**Cohesive bandage**
Cohesive bandage has elastic properties and may be tearable or non-tearable. Cohesive is non-adhesive but sticks to itself. It is used to provide compression and support to tissues (particularly in acute situations), and can be easily removed and reapplied. Cohesive tapes tend to come in widths of between 5 cm and 10 cm.

**Hypoallergenic adhesive fleece mesh**
Hypoallergenic adhesive mesh (such as ‘hypafix’ or ‘mefix’) is a flexible, adhesive and breathable underwrap, which can provide skin protection when applied under other taping products, such as ZO. Because of the tape’s permeability, the skin is less vulnerable to maceration.

**Underwrap**
Underwrap is a light, non-adhesive, non-restricting polyurethane foam material which may be applied under EAB, ZO or micropore. It is also commonly used in conjunction with heel and lace pads, and essentially can help to reduce areas of skin contact with tape, which may otherwise cause skin irritation. When underwrap is applied, however, the actual tape application may loosen off more quickly with activity.

**Heel and lace pads**
Heel and lace pads are thin foam squares which are designed to help reduce friction around the ankle and foot. They are commonly used together with tape adhesive and lubrication (petroleum jelly).

**Padding and felt**
A foam, or rubberized, material must be cut to shape and used to pad out uneven regional contours or to apply specific compression to tissue. Examples include the use of a ‘horseshoe’ pad applied inferiorly to the medial or lateral malleoli for post-acute ankle support.

**Tape adhesive spray**
Adhesive spray (such as ‘Tuff skin’) may be applied directly to the skin prior to any tape application to reinforce the adhesion of tape. This can be useful when repetitive body movements or excessive sweating may cause loosening of the tape; also when the conditions are wet, or when the athlete has oily skin.
Keith Ward et al.

Tape remover
Tape remover (dehesive) works to dissolve the adhesive on EAB, ZO, micropore or fleece mesh. This is generally available in both lotion and spray form.

Tape scissors
Taping scissors are unique in that they are specifically designed with stubbed ends, for safety when attempting to remove tape. ‘Sharks’ are frequently used to take tape off, these specifically designed scissors minimize the chance of skin cuts, and are also easier to use for this purpose.

Practitioner Tip Box 3.5
Taping applications

- Assess patient/athlete (suitability for taping; therapeutic objectives; therapeutic technique)
- Consider all possible contraindications (including undetermined injury; compromised skin sensation or blood flow; allergy to taping materials)
- Do not tape acute injury (compression may be considered as a first aid measure)
- Do not apply tape to any area which has just received cryotherapy or heat therapy
- Tape will not stick to skin which has had massage lubricant applied
- Ensure all required material is at hand
- Clean (using antiseptic soap) and dry area to be taped
- Shave hair (in a downward direction) from any areas where tape will be applied directly to the skin (unless using underwrap or non-adhesive tape)
- Position the athlete appropriately and maintain this position throughout application
- Protect areas likely to experience friction
- Attend to and protect any skin lesions (blisters; grazes; cuts)
- Apply adhesive spray where increased adherence of tape is required
- Apply underwrap for sensitive skin
- Apply adhesive fleece tape under zinc oxide to protect skin in absence of underwrap
- Apply tape smoothly and firmly, avoiding wrinkles and gaps which could cause friction, blisters or skin breakdown
- Avoid using continuous taping tightly around a limb as this may cause a tourniquet effect
- Use strips of tape which are slightly angled to conform to the limb contours
- Always check that the taping is comfortable, avoiding undue pressure or tension. Remove if any discomfort arises
- Once tape has been applied, check that the technique has achieved its objective without limiting desired function
- Assess circulation, sensation and comfort local and distal to the area of application
- Alterations in skin colour, temperature or other sensory changes indicate that the tape is too tight and should be removed immediately
- Remember that gaps in tape applications can trap skin; creases can cause friction irritation
- Advise patient/athlete regarding how long to keep the taping application on, how to remove it and any follow-up treatment
Photo 3.19  Closed basketweave for the ankle (courtesy of Greg Littler and Lee Young).

Photo 3.20  Heel lock for the ankle (courtesy of Greg Littler and Lee Young).
Photo 3.21  Plantar fascia taping support (courtesy of Greg Littler and Lee Young).

Photo 3.22  Turf toe taping (courtesy of Greg Littler and Lee Young).

Photo 3.23  Achilles tendinopathy support (courtesy of Greg Littler and Lee Young).

Photo 3.24  Patella tendon off-load taping (courtesy of Greg Littler and Lee Young).
Photo 3.25 Medial collateral ligament taping (courtesy of Greg Littler and Lee Young).

Photo 3.26 Hip spica taping (courtesy of Greg Littler and Lee Young).
Photo 3.27  Acromioclavicular joint support (courtesy of Greg Littler and Lee Young).

Photo 3.28  Anterior glenohumeral instability support (courtesy of Greg Littler and Lee Young).

Photo 3.29  Elbow hyperextension restriction taping (courtesy of Greg Littler and Lee Young).
Precautions for taping and strapping

There are certain instances when the application of taping and strapping are not applicable. The main contraindications to taping and strapping include where: a complete assessment has not been performed; the therapist is unsure of the nature of the problem; serious injury is suspected; and urgent referral for medical assessment is required (first aid applications must still apply). Taping should never be used as a substitute for treatment. When the patient or athlete complains of discomfort, the therapist must use their professional judgement to determine the suitability of taping. It is considered a contraindication to tape (beyond first aid compression strapping) during acute stages of injury, where there are open wounds or where the joint is clearly unstable. Similarly, if the area is extremely swollen and irritable, shows signs of infection or there is a suspected fracture, poor circulation or known allergy to taping materials, or poor skin integrity, such as that which may follow local steroid therapy. Itching, blisters and other signs of allergy may present immediately following taping, or might be latent. Considerations must also be given regarding taping on or over areas where friction can occur during movement (particularly during exercise). Excessively tight taping applications or incorrectly taped areas may be identified by any circulatory changes such as oedema, changes in skin colour or failure of capillary refill (a pinch of the nail beds of fingers and toes can assess for this).

Tape should always be removed carefully using tape cutters or bandage scissors wherever necessary or possible. A lubricant may be applied to the tip of tape cutters to assist its gliding under the tape. The sports therapist must be careful to not nip the skin or any bony prominences. Tape may be more easily removed following a soak in the bath. Adhesive tape should be peeled back (preferably in line with hair growth) while supporting the adjacent skin; this will help reduce skin traction; a dehesive spray or lotion may be used and tape should never be ripped off. The sports therapist should always check the area after tape removal for any signs of allergy or irritation. All soiled taping materials must be disposed of hygienically, ideally into a clinical waste container. Tape should never be left on for too long, as this can lead to skin soreness and possible skin breakdown (maceration). Different taping products, applications and situations will determine how long a taping application should remain on the athlete or patient. As mentioned, athletic taping, where the athlete is taped prior to the game (whether for standard prophylactic purposes or for specific support to an existing injury) may only remain effective for a relatively short functional time frame, and re-application may be required at half-time. Athletic taping applications are usually removed immediately following the activity. Taping for other objectives may require tape to remain in-situ for 20 hours or so – any longer than this and there is potential for maceration and possible infection (particularly bacterial or fungal). Kinesiology applications, however, may in some circumstances be indicated to remain in place for two to three days.

Kinesiology taping

Kinesiology tape and its associated taping techniques were first developed in Japan in the 1970s, and have steadily gained popularity with athletes and practitioners over the past 20 years. While Dr Kenzo Kase first patented ‘Kinesio taping’ and ‘Kinesio Tex tape’ (Kinesio UK, 2013), there are now a number of established kinesiology-style taping methodologies in general usage. One of the original theories for the use of kinesiology tape was that the tape should mimic some of the movement, flexibility and function of human skin, hence the functional properties of kinesiology tape include an elasticity and thickness which resembles that of the epidermis (Kase et al., 2003). Kumbrink (2012) explains that kinesiology tapes are applied to follow the course
of tissues and may be applied to almost any region of the body. In addition, there are lymphatic applications designed to help improve local circulation; hence, kinesiology taping is proposed as a treatment method.

Although there are variant specifications, kinesiology tape is made predominantly from cotton, which surrounds its polymer elastic strands, and its porosity allows for evaporation of body moisture and quick drying. Most tapes are latex-free, hypoallergenic and water-resistant. They are backed by an acrylic adhesive, which is heat activated (by the gentle manual rubbing of the tape once in position). The adhesive is applied to the back of the tape in a wave-like pattern, similar to that of the fingerprint, and this, in combination with its elastic properties, is purported to facilitate the escape of moisture and to assist the tape’s ability to lift the skin. The tape is applied to a backing paper and supplied in rolls. Kinesiology tape’s elasticity allows for it to be stretched longitudinally by 100 per cent (or more) of its resting length, and most are applied to their backing paper in a state of slight tension (typically 10 per cent of available tension) (Kase et al., 2003; Kumbrink, 2012). This means that the tape ‘comes off the roll’ in slight tension. Traditional forms of kinesiology tape are only able to be stretched longitudinally, although there are now tapes which also provide for horizontal elasticity. Kinesiology tape is by definition ultra-flexible and mouldable to body contours (Gibbons, 2014). The tape is non-tearable and requires cutting prior to application; there are ‘pre-cut’ tapes available which are designed for specific applications, and these may save time, particularly in team settings or large departments. Original kinesiology tape came in four colours (cyan, magenta, beige and black), but there are now a host of different colours (and patterns) available. While there is no difference in the structure or properties of the traditional tapes, the four original colours were chosen to utilize potential additional benefits of ‘colour therapy’ (Gibbons, 2014; Kumbrink, 2012).

Just as with athletic taping, prior to any application the therapist must consider what the therapeutic objectives are, where the tape(s) will be applied and what degree of tension will be applicable. It is generally proposed that kinesiology tape may:

- aid the body’s natural healing processes;
- stimulate neurological and circulatory activity (thereby reducing pain and improving lymphatic drainage);
- facilitate either muscle activation or inhibition;
- provide support to injured muscles, tendons or ligaments;
- provide fascial, anatomical space or joint alignment correction (‘lift’ tapes).

The correction application techniques as described by Kase et al. (2003) have yet to be effectively evidenced. Kinesiology taping is not designed to provide rigid support for severe injury or to stabilize an unstable joint; the elastic properties will not efficiently facilitate this. However, it may be used to help prevent potentially harmful ranges of motion (Athletic Tape Info, 2013). Kinesiology tape is designed to provide support and stimulation to tissue while allowing the available range of motion; and the actual effect may be considered as offering a continuous and uninterrupted stimulation, which may then lead to favourable structural adaptation (Hyde et al., 2011). The four main applications for kinesiology taping are as follows (adapted from Kumbrink, 2012):

1. Muscle applications: stimulation and inhibition techniques – these typically use ‘I’ and ‘Y’ strips applied with the target muscle in an elongated position, and with the tape on around 10–20 per cent stretch.
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2. Support applications: applied to ligaments, tendons, muscle tears and spinal segments – these typically use an ‘I’ strip applied with between 70–90 per cent tape tension over the target tissue.

3. Correction (‘lift’) applications: applied to address myofascial tensions, localized pain points, myofascial trigger points, or bony misalignments. These typically use ‘I’ or ‘Y’ strips applied with tape tensions of 50–70 per cent.

4. Lymphatic applications: used to gently lift skin and thereby support lymphatic drainage – these may utilize ‘fan’ strips or ‘web’ patterns applied with the patient’s target region on stretch, and with typically around 25 per cent tape tension.

The general recommendation for muscle inhibition has been for the tape to be applied from insertion to origin; for muscle facilitation the tape may be applied from origin to insertion (both applications should have the target muscle on stretch) and with around 10–20 per cent tape tension. While athletes may perceive benefit, and clinicians anecdotally report positive outcomes, Gómez-Soriano and colleagues (2014) looked at applications of kinesiology tape applied to influence the gastrocnemius muscle in a double-blind, placebo-controlled crossover trial involving 19 healthy participants using a range of outcome measures (muscle tone, extensibility, electromyography and strength) and found ‘no effect on healthy muscle tone, extensibility nor strength’. They did identify a short-term increase of gastrocnemius EMG activity after taping, which ‘suggests the activation of central nervous system mechanisms, although without a therapeutic implication’. As ever, further research is require to substantiate the positive influence of kinesiology taping applications for muscle tone. Another of the aims (or claims) of kinesiology taping for injured ligaments and tendons is to increase stimulation of local mechanoreceptors to facilitate improved responsive proprioception (Kase et al., 2003). Typically, these tapes are applied with a high degree of tension (50–100 per cent). For localized areas of pain associated with muscular injury or MTrPs, a ‘lift’ or ‘star’ technique may be applied; this simply involves two or more short strips applied with high tension in a cross-type (X) pattern. In acute injury, kinesiology tape is purported to assist lymphatic circulation. As lymphatic applications are applied in a state of minimal tension (10–15 per cent), the tape’s elastic properties are designed to cause a lifting effect on the epidermis which may decrease pressure on superficial lymphatics and blood vessels. Applications to support this include the use of ‘fan’ strips or ‘web’ patterns. The base of the fan or web should be located in a direction towards the nearest proximal lymph nodes to which the therapist would like to encourage drainage. Bleakley (2013) interestingly identifies a challenge to the sports therapist’s clinical reasoning process in terms of how the oedema associated with many acute soft tissue injuries may be managed: ‘The revolutionary science of using kinesiotape to microscopically “lift” the skin to potentially enhance vascular and lymphatic function post-injury is tantamount to “anti-compression” and indicates the current ambiguity in this field of study.’

When kinesiology tape is applied with the skin and tissues in a position of stretch, and with the tape in a ‘resting tension’, ‘convolutions’ of the tape will appear as the patient returns to a neutral position following the tape application. It is the convolutions (resulting from the gentle elastic-recoil effect of the tape) which lift the skin. As the skin is ‘lifted’, and subcutaneous tissue pressure reduced, then any excessive interstitial fluid and channelling lymphatic fluid may be more effectively dispersed. Osmolarity gradients are altered and the direction of fluid flow runs from areas of high pressure to lower pressure (Hyde et al., 2011). This effect, it is proposed, can reduce fluid stasis, and therefore swelling and oedema, which in turn can assist the removal of chemical (locally noxious) irritants from the injured area and accelerate tissue healing. For its potential effect regarding pain relief, the consideration is that the tape can provide enhanced sensory (mechanical and innocuous) inputs, and as such will stimulate A-beta fibres, which may
then offset the previously stimulated nociceptive A-delta and C-fibre inputs. With taping applications that are aiming to affect neurosensory systems, the therapist will usually place the affected muscle onto a position of stretch, rather than the tape during the tape’s application.

Tapes are generally individually cut from standard 5 cm × 5 m tape rolls by the practitioner (although wider and longer tapes are available, as well as ‘pre-cut’ tapes). The patterns that may be employed include ‘I’, ‘X’, ‘Y’ and ‘fan’ strips. When applying the tape, the skin should be dry and free of oil, and excessively hairy areas may need to be trimmed or shaved; tape adhesive spray can also be used where effective adhesion may be compromised.

Prior to the application of kinesiology tape, the sports therapist must determine the appropriate tape size and shape, joint positioning and tape tension required. It is advisable to ‘round the edges’ of the tape (using scissors) so as to reduce the potential for the tape edges to start to peel off. Both the proximal base and distal ends should be applied without tension. Once tape has been applied, the patient/athlete should be observed performing functional activity.

When exploring the effects of kinesiology taping on scapular kinematics, muscle performance and shoulder impingement, Hsu et al. (2008) found positive changes in both scapular motion

Photo 3.30  Kinesiology ‘muscle’ technique.

Photo 3.31  Kinesiology ‘support’ technique.
Photo 3.32  Kinesiology ‘lift’ technique.

Photo 3.33  Kinesiology ‘star’ technique.

Photo 3.34  Kinesiology ‘lymphatic fan’ technique.
and muscle performance which supports its use as a treatment aid in managing shoulder impingement. In a randomized controlled study by Thelen and colleagues (2008), shoulder patients with rotator cuff conditions who were treated with kinesiology tape also demonstrated improved pain-free range of movement. Irrefutable evidence to support the use of all kinesiology taping applications is clearly lacking. Williams et al. (2012) concluded that, while there is significant case study and anecdotal support for the method, it is essential that more high-quality research is required, particularly regarding sports injuries.

The demand for and use of taping in sports therapy continues to grow; and while there are a wide range of taping techniques, applications, methodologies and technologies, it is essential now that the evidence-base for each of these interventions is expanded further so as to better guide practice and optimize therapeutic outcomes.

This chapter has attempted to present an introductory and informed discussion of the main contemporary clinical sports therapy interventions. In so doing, the authors have highlighted key principles and applications and essential safety issues, and provided evidence to support clinical decision making. It has been beyond the scope of this chapter to present a multitude of example treatment applications, but the sports therapist, as ever, is recommended to reflect on the information presented, and to review the main reference sources for each intervention. Finally, clinicians must be advised to think carefully and be very considerate in their use of modalities; as such, an educated internal dialogue (metacognitive reasoning) should always be employed (see Practitioner Tip Box 3.6).

**Practitioner Tip Box 3.6**

**Important questions to ask prior to delivery of any therapeutic modality**

- What specific goals am I attempting to achieve with this modality today?
- Am I using the best available modality (and correct application technique) to achieve these goals?
- What specific criteria must I consider to indicate that I should stop using this modality?
- What specific criteria must I consider to indicate that I have finished using this modality as part of this patient’s management plan?

Source: adapted from Merrick, 2012.

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