THE USE OF OBJECTIVE MARKERS AND OUTCOME MEASURES IN EQUINE PHYSIOTHERAPY AND REHABILITATION

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Abstract

Objective measures are used to determine the baseline function of a patient at the beginning of physiotherapy treatment, and at regular intervals, to monitor progress and treatment efficacy. The use of standardised and validated objective measures is an explicit requirement of human physiotherapy practice. Tools such as goniometers, to assess range of motion and pressure algometers, to measure mechanical nociceptive thresholds are single factor objective markers (ObjM) that have been tested for reliability and validity. However, these tools are limited in equine physiotherapy practice as they are unidimensional tests that may not measure the complex multi-faceted construct that relates to musculoskeletal performance and function in horses. Therefore, a composite outcome measure (OM), that includes a bank of ObjM, may provide a truer representative profile of a horse's status before, during or after rehabilitation.

The research aims of this thesis were to evaluate the current application of ObjM and OM in equine physiotherapy, as well as investigate and test the repeatability and validity of objective measures considered to be practical, simple and relatively inexpensive. The secondary aim was to progress the field of equine physiotherapy to fully meet the requirements of the physiotherapy professional standards; to undertake development of a composite OM that can be used to measure the quality of equine physiotherapy practice and therefore ensure effectiveness of physiotherapy interventions, improving the welfare of horses receiving treatment.

To evaluate the use of ObjM and OM used in equine physiotherapy practice a questionnaire was used to survey physiotherapists, with 76% reporting they used objective measures although these were mainly subjective assessment methods such as observation. Subsequently a literature review was undertaken to understand what OMs are available. Whilst single factor objective markers are reported in the evidence base, there is a lack of musculoskeletal function and performance measures. Understanding what should be included in a composite OM, specifically for equine musculoskeletal rehabilitation, is essential as the first stage in the development of a new OM. To achieve this, a Delphi

study was undertaken with a panel of experts working in equine rehabilitation and consensus on ten domains to be included was achieved: lameness, pain at rest, pain during exercise, behaviour during exercise, muscular symmetry, performance/functional capacity, behaviour at rest, palpation, balance and proprioception. Where a domain did not contain pre-tested, or clinically practical objective measures, studies were undertaken to test tools and techniques for inclusion.

The next stage in the development of a composite OM, for objective measurement of physiotherapy treatment and rehabilitation, is to confirm which reliable and valid ObjMs or OMs to include for each domain. Once formulated, the composite OM, named The Equine Musculoskeletal Rehabilitation Outcome Score (TEMROS), can then be taken forward for testing within specific equine musculoskeletal conditions

The research undertaken has contributed to the existing literature by adding new knowledge of OM use in horses and increasing understanding of the OM required by equine physiotherapists, as well as supporting clinical practice with reliability studies on ObjM not previously tested. This thesis and the papers included will aid equine physiotherapists with their clinical reasoning by providing clinically relevant critique of existing research, as well as clinically useful tools to use, when evaluating physiotherapy and rehabilitation interventions, in their own practice and in the wider equine musculoskeletal research community.

Abbreviations

ACPAT	Association of Chartered Physiotherapists in Animal Therapy
COSMIN	Consensus-based standards for the selection of health measurement instruments
CSP	Chartered Society of Physiotherapy
DEFRA	Department for Environment, Food and Rural Affairs
FINFUN	The Finnish neurological function testing battery for dogs
HCPC	Health and Care Professions Council
ICC	Intra-class correlation
IQR	Interquartile range
MCID	Minimal clinical important differences
MNT	Mechanical nociceptive threshold
NHS	National Health Service
ObjM	Objective marker
OM	Outcome measure
PA	Pressure algometry
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
PROM	Patient report outcome measure
SDFT	Superficial digital flexor tendon
SF-36	Short-form 36
T	Thoracic
TEMROS	The Equine Musculoskeletal Rehabilitation Outcome Score
VISA	Victorian Institute of Sport Assessment
WOMAC	Western Ontario and McMaster Universities osteoarthritis index

"Measure what is measurable, and make measurable what is not so"

Galileo Galilei (1564 – 1642)

Acknowledgements

Thirty years ago, a physiotherapist treated my pony. The next time I rode, I could feel the difference and I decided at that point I wanted to become an animal physiotherapist. My gratitude goes to my teachers, lecturers, human patients, owners and of course all the horses and ponies I've been lucky enough to meet on my journey to this point.

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CHAPTER 1

INTRODUCTION

Physiotherapy helps restore movement and function when an individual is affected by injury, illness or disability (Chartered Society of Physiotherapy [CSP], 2020a) with treatments structured around the goal of restoration of painless optimal function as well as prevention of loss of function (McGowan *et al*., 2007). Physiotherapy includes treatments such as manual therapy, use of electrophysical modalities and exercise prescription, as well as encompassing on-going rehabilitation. In the context of musculoskeletal conditions, rehabilitation focusses on building capacity in tissues, using gradual overload, progressing intensity and complexity of movement or physical activity (Cook and Purdam, 2015). Setting goals for physiotherapy treatment and rehabilitation requires the acknowledgement that the definition of performance and function varies dependent on the individual being treated and therefore goals should be based on priorities for the individual patient (Melin, 2018; Åsenlöf, Denison and Lindberg, 2004). For the equine physiotherapist, the desired outcome of treatment for an elite sports horse may be peak sporting performance or for an elderly retired horse, being able to perform natural behaviours whilst in a field. To determine the effectiveness of physiotherapy interventions, practitioners must be able to measure treatment effects and achievement of short- and long-term goals. To do this, reliable and valid outcome measures (OMs) and objective markers (ObjMs) must be used (Jette *et al*., 2009). Although both OMs and ObjMs are similarly objective, an OM is usually a composite score that contains sets of data, for example the Western Ontario and McMaster Universities osteoarthritis index (WOMAC) which scores pain, walking distance and fatigue levels in patients with osteoarthritis (Ackerman, 2009), whereas an ObjM is a marker of a single factor such as range of motion or muscle strength (Gaskell, 2008).

In human physiotherapy practice OMs and ObjMs are used to objectively determine the baseline function of a patient at the beginning of treatment and, once treatment has commenced, with the same measure being used to determine progress and treatment efficacy at regular intervals (Physiopaedia, 2020). For example, the use of the Victorian Institute of Sport assessment (VISA) OM for the common over-use injuries of patellar and Achilles tendinopathy, has allowed authors to review studies comparing two exercise approaches to their management (Malliaras *et al*., 2013). The VISA OMs score symptoms, simple tests of function and the ability to play sport using a visual analogue scale from 0-10 (Vinsentini *et al*., 1998; Robinson *et al*., 2001), and have been used successfully to show differences in exercise programmes with different loading dosages. An equine equivalent is tendon injury in racehorses which is also reported to be a common musculoskeletal condition (Thorpe, Clegg and Birch, 2010), with an incidence of 4.7 superficial digital flexor tendon (SDFT) injuries per 1000 horses (Johnston *et al*., 2019). Recovery from SDFT injuries in horses requires measuring of rehabilitation outcomes, similarly to patellar and Achilles tendinopathies in people. However, monitoring of recovery from SDFT injury in horses is commonly performed with repeated diagnostic ultrasound and lameness examinations (Kaneps, 2016) and no equine equivalent of the VISA symptom or functional scoring methods are reported to be in use, despite the frequency of these injuries and requirement for assessing rehabilitation.

1.1 Physiotherapy professional standards

The professional association of physiotherapists in the UK, the Chartered Society of Physiotherapy (CSP, 2020a) and the independent UK regulator, the Health and Care Professions Council (HCPC) state that registrant physiotherapists *'must be able to assure the quality of their practice. This includes gathering qualitative and quantitative data, participating in audit activity, using appropriate outcome measures and evaluating interventions to ensure they meet service users' needs and changes in health'* (HCPC, 2020). To protect horse welfare, it is critical that equine physiotherapists use OMs and ObjMs in their practice to demonstrate duty of care as well as measure the impact of the intervention. Moreover, the implementation of OMs and ObjMs can aid timeliness and cost-effectiveness of interventions (Jette *et al*., 2009).

Physiotherapy is listed as a treatment in the Veterinary Surgeons Act (Exemptions) Order 2015 (UK Government, 2020) and within the Code of Professional Conduct of Veterinary Surgeons (Royal College of Veterinary Surgeons, 2019). It is therefore imperative that physiotherapists follow the law, working under the direction of veterinary surgeons, who must ensure the health and welfare of animals committed to their care and to fulfil their professional responsibilities. These responsibilities are linked to five key areas: professional competence, honesty and integrity, independence and impartiality, client confidentiality and trust, as well as professional accountability. The use of ObjMs and OMs demonstrates, and accurately measures, professional competence, ensuring honesty and impartiality, therefore allowing a clinician to meet their professional code of conduct.

1.2 Use of outcome measures in physiotherapy practice

Measurement of individual musculoskeletal factors (e.g. joint range of motion with a goniometer; Biggs *et al*., 2009) and hip- and knee-strength with a hand-held dynamometer (Thorborg, Bandholm and Hölmich, 2013) can be used to monitor progress of treatment in human physiotherapy. These ObjMs are supplemented with patient reported OMs (PROM; Kyte, 2015; e.g. closed questions, given as a ranked or Likert score) that assess the actual or perceived ability of an individual to carry out activities. In human practice, PROM scores are used to assess activities such as moving in an environment or completing personal care tasks, and participation in life situations such as work or household management (Jette *et al*., 2009). PROM that measure states such as pain and function, in verbally communicative human patients, rely on answers to questions on pain levels or functional ability. When linking to OMs that can be used in the equine patient the method of collecting data is a key component to consider. There is a communication barrier when assessing outcomes from treatment of horses, due to the inability of the horse to verbalise symptoms (Williams and Tabor, 2017). It is plausible that this verbal boundary alters the capacity of OMs to track progress and treatment effectiveness of a given physiotherapy intervention and therefore it is an important factor considering the aforementioned duty of care that physiotherapists hold with their horse and human owner clients.

Whilst there are reliable ObjMs that could be used in equine physiotherapy, these consider a single factor and therefore only represent one element of the rehabilitation process. It is conceivable that a form of OM, made up of a composite of multiple ObjMs, could be designed so that those in contact with the horse report on their observations, or judgement of effectiveness of treatment holistically. Within this thesis, the veterinary physiotherapy industry requirements for an equine specific composite OM will be explored by gathering data from experienced professionals, and these will be taken forwards to underpin the formulation of an equine musculoskeletal rehabilitation OM. The impact of this research can then be disseminated to the equine physiotherapy and veterinary industries to impact clinical practice, especially in relation to horses undergoing medical or surgical intervention and rehabilitation. Not only would an increased use of OM support clinicians in meeting their required professional standards, the resultant effect would enhance the welfare of horses who require intervention for musculoskeletal conditions. If data from objective measurement are used to clinically reason treatments, there will be an increase in effectiveness and successful management of injury.

CHAPTER 2

AIMS AND OBJECTIVES

The aims of this thesis were to evaluate the current application of ObjM and OM in equine physiotherapy, as well as investigate and test the reliability and validity of ObjM and OM considered to be practical, simple and relatively inexpensive. A secondary aim was to progress the field of equine physiotherapy towards fully meeting the requirements of the physiotherapy professional standards. In addition, the overarching aim was to undertake development of a composite OM that could be used to measure the quality of equine physiotherapy practice and therefore ensure effectiveness of intervention, improving the welfare of horses receiving treatment.

The objectives of this thesis were:

1. To critically evaluate the understanding and use of ObjM and OM in equine physiotherapy.
2. To critically appraise the current research for ObjMs and OMs for use in equine physiotherapy.
3. To determine what ObjMs and OMs are required by practitioners (equine physiotherapists and veterinary surgeons) in the rehabilitation of horses.
4. To construct a framework for the development of a composite OM for use in equine physiotherapy and rehabilitation.
5. To develop and test ObjM for inclusion in a composite OM.

CHAPTER 3

PUBLICATIONS

This thesis is based on the following publications found in the final section of this document, from page 75, and that are referred to in the text by their Roman numerals. The relationship of these publications to the thesis objectives are outlined in Table 1.

I. **Tabor, G.** and Williams, J. (2018) The use of outcome measures in equine rehabilitation. *The Veterinary Nurse* 9 (9) 2-5.

II. **Tabor, G.** and Williams, J. (2020) Objective measurement in equine physiotherapy. *Comparative Exercise Physiology* 16 (1): 21-28.

III. **Tabor, G.,** Nankervis, K., Fernandes, J. and Williams, J. (2020) Generation of domains for the equine musculoskeletal rehabilitation outcome score: Development by expert consensus. *Animals* 10 (20): 203-217

IV. **Tabor, G.,** Elliott, A., Mann, N. and Williams, J., (2019) Equine Posture Analysis: Development of a Simple Tool to Record Equine Thoracolumbar Posture. *Journal of Equine Veterinary Science* 73: 81-83.

V. Taylor, F., **Tabor, G.** and Williams, J.M., (2019) Altered thoracolumbar position during application of craniocaudal spinal mobilisation in clinically sound leisure horses. *Comparative Exercise Physiology 15*(1): 49-53

VI. Merrifield-Jones, M., **Tabor, G.** and Williams, J. (2019) Inter and Intra-rater reliability of soft tissue palpation in the equine thoracic epaxial region. *Journal of Equine Veterinary Science* 83: 102812

VII. **Tabor, G.,** Mann, N. and Williams, J. (2018) Spinal posture in horses with and without back pain. The 10th International Symposium of The Association of Veterinary Rehabilitation and Physical Therapy. Knoxville; USA (Poster).

The author contributions can be found in Appendix 1.

Table 1: Relationship of thesis objectives and publications included within this thesis

Aims	**Objective**	**Paper I**	**Paper II**	**Paper III**	**Papers IV - VII**
1	To critically evaluate the understanding and use of objective markers and outcome measures in equine physiotherapy	X	X	X	X
2	To critically appraise the current research for objective markers and outcome measures for use in equine physiotherapy		X	X	
3	To determine what objective markers and outcome measures are required by practitioners (equine physiotherapists and veterinary surgeons) in the rehabilitation of horses	X		X	
4	To construct a framework for the development of a composite outcome measure for use in equine physiotherapy and rehabilitation		X	X	
5	Develop and test objective markers for inclusion in a composite outcome measure				X

A statement of credited learning requirements is provided in Appendix 2

CHAPTER 4

LITERATURE REVIEW

4.1 History of Physiotherapy in the United Kingdom

Physiotherapy has developed as a profession over the last century. Four nurses set up The Society of Trained Masseuses in 1894, to enhance their professionalism against reports of unscrupulous people offering massage as a euphemism for other services. The society incorporated remedial gymnasts in 1915 and to represent the scope of the work undertaken by members, the present name was adopted in 1944 (CSP, 2020b). The Chartered Society of Physiotherapy (CSP) promotes physiotherapy as being a science-based profession that takes a 'whole person' approach to health and wellbeing, which includes the patient's general lifestyle (CSP, 2020a).

4.2 Physiotherapy for animals

The introduction of physiotherapy for animals was first recorded in the early 19th Century when a physiotherapist called Charles Strong used faradic electrical currents to treat sporting injuries in people. One of his polo playing clients, Lord Mountbatten, asked Mr Strong to treat lame ponies, who apparently made amazing recoveries (Calatayud, 2019). One of Mr Strong's subsequent students became a co-founder of the Association of Chartered Physiotherapists in Animal Therapy (ACPAT), a professional network with the CSP, alongside Mary Bromiley MBE (1931 - 2019). From her own rehabilitation yard and via travelling to yards, Mrs Bromiley treated many of the successful racehorses at that time (Racing Post, 2019) and published books on massage techniques as well as equine injury, therapy and rehabilitation. However, her publications were mainly detailed instructions on techniques, drawn from clinical practice and experience. Improvements after treatment were assumed, without empirical data and not measured beyond subjective reporting.

Recognition of the importance of physiotherapy for equine athletes was furthered when ACPAT members were employed within the British Equestrian team in 1996. Chartered Physiotherapists, who are members of ACPAT, have accompanied the British Equestrian teams to all subsequent European, World and Olympic equestrian events (Sutton, 2020, personal communication).

Training to become a qualified ACPAT physiotherapist initially required candidates to complete an apprenticeship with a practicing ACPAT member until they were considered to have reached an appropriate standard and had obtained two veterinary references, making them eligible for membership. The first formal post-graduate course was launched in 1999 at the Royal Veterinary College and the first MSc Veterinary Physiotherapy graduates became full ACPAT members in 2001. As part of the MSc programmes, students are required to undertake research dissertations and this has contributed to the increase of published veterinary physiotherapy research. The introduction of this postgraduate programme and the subsequent output of students supports evidence informed practice tailored to the veterinary physiotherapy industry. There are two UK MSc programmes currently, for Chartered Physiotherapists who wish to translate their knowledge and skills developed on humans into practice with animals, one at The University of Liverpool and one at Hartpury University.

4.3 Animal Physiotherapy professional framework and legislation

The Veterinary Surgeons Act (Exemptions) Order 2015 (UK Government, 2020a) does not allow physiotherapists to make a clinical diagnosis, carry out tests for diagnostic purposes or provide medical or surgical treatment, as these are considered veterinary acts and therefore can only be carried out by a qualified veterinary surgeon. Physiotherapists working with horses work alongside veterinary surgeons who have made the diagnosis and prescribed treatment of the animal by physiotherapy. Animal physiotherapy training focuses on adapting assessment and treatment methods from human practice, applying these to the patient, based on an understanding of anatomical, physiological and biomechanical differences (Veenman, 2006). The physiotherapy emphasis is the assessment and management of a patient's function, based on the underlying pain and movement observed, rather than purely diagnosing a patho-anatomical condition (McGowan, Stubbs and Jull, 2007). Therefore when a horse is referred by a veterinarian for physiotherapy, the aim of the assessment is to reach a conclusion based on function that identifies impairment and limitations to physical activities (Goff, 2016) which complements the veterinary diagnosis, highlighting the synergy that exists between the two professions (McGowan, Stubbs and Jull, 2007).

There is more to animal physiotherapy than purely the application of one or more treatment modalities to a patient (McGowan, Stubbs and Jull, 2007). The practice of physiotherapy is a science-based profession which has been informed by the evidence-based medicine movement of the early 1990s, that has developed to focus on critical thinking, the importance of statistical reasoning and continuous evaluation of practice (Djulbegovic and Guyatt, 2017). When exploring the evidence base for equine physiotherapy, a review by Buchner and Schildboeck (2006) identified only a small number of reliable studies evidencing clinical efficacy. In response to Buchner and Schildboeck (2006), a second article by McGowan, Stubbs and Jull (2007), with two physiotherapists as co-authors, focussed on the science behind equine physiotherapy, extending the scope of the review into the wider physiotherapy literature. Whilst acknowledging that equine physiotherapy research is well behind that related to the human subject, McGowan, Stubbs and Jull (2007) support drawing data from the human physiotherapy profession, in contrast to Buchner and Schildboeck (2006). This is especially relevant in relation to neuromotor control and the stability model to solidify the evidence base for equine physiotherapy. Although suggestions for the direction of research are made in the later review paper's conclusion, it does not fit the criteria of evidence-based medicine in terms of being a systematic review or generating clinical practice guidelines which require a more substantial and higher level of evidence to draw from.

4.4 Physiotherapy interventions for equine rehabilitation

Research supporting the application of techniques commonly used by physiotherapists provide an evidence-base for a range of approaches. These studies develop evidence for clinicians to base their practice upon and are becoming more prevalent, often co-authored by biomechanical specialists, veterinary surgeons and physiotherapists. For example, Wakeling *et al*. (2006) demonstrated that reflex inhibition, a manual therapy technique specific to equine practice, had a positive effect on *longissimus dorsi* muscle tone. Similarly, exercises that positively alter swing phase kinematics in horses by use of trotting poles and devices fitted around the distal limb have been identified (Clayton, Stubbs and Lavagnino, 2015; Brown *et al*., 2015; Clayton *et al*., 2011). Neck exercises using food as a bait/lure to encourage dynamic mobilisation of the cervical spine have been shown to increase the cross-sectional area of the thoracolumbar spinal stabiliser muscle *multifidus* (Tabor, 2015; Stubbs *et al*., 2011) supporting their use as part of an exercise programme.

When considering the studies cited so far, they have small sample sizes (typically an n of < 10) and the exercises are yet to be tested on a representative population of horses with clinical pathology. In addition, limiting practical application, the methods of measuring the efficacy of the individual interventions are mostly laboratory based, such as motion analysis or electromyography. Nonetheless, this accumulation of research, which tests human exercise principles in horses, is starting to build the evidence base to assist physiotherapists in selecting exercises to be used in rehabilitation. With twenty years of Chartered Physiotherapists training at post graduate level to become recognised as a veterinary physiotherapist, there is now the emergence of a profession that is working hard to enhance the evidence base in alignment with the key principles of physiotherapy practice being at its core.

4.5 Physiotherapy assessment and outcome measures

An evidence-based approach is essential when considering the implications of treatment on animal welfare, especially if treatments are used that have no effect or a negative effect. There is an obligation to collect evidence to support animal physiotherapy practice and the methods used to collect data for this purpose need to be objective, reliable and valid (CSP, 2020c).

Objective measurement of biological variables that are not based on personal judgement can be used to measure single factors with unidimensional characteristics, but many musculoskeletal conditions are multifaceted (de Vet *et al*., 2011). Therefore, multidimensional measures or composite OM, are needed for more complex situations. Key to the success of composite OM is agreement on the terminology and definitions of measurement properties of PROMs (Mokkink *et al*., 2010a). A Delphi study was undertaken as part of the consensus-based standards for the selection of health measurement instruments (COSMIN) initiative to agree terms to increase uniformity of OM design, as well as improving the ability to compare outcomes due to the standardisation of OMs (Boers *et al*., 2014; Chiarotto at al., 2014; Mokkink *et al*., 2010a). A consensus on terminology and definitions of the domains of 'reliability', 'validity' and 'responsiveness' has been reported (Table 2; Mokkink *et al*., 2010a), with the hope that a more uniform use of these terms, based on the following definitions will be used in the literature on measurement properties. The domain definitions do not vary from those previously stated in educational articles (Elasy and Gaddy, 1998), but the importance of the COSMIN initiative and the setting of these definitions is demonstrated by frequent citation within the literature. The COSMIN guidelines have been followed by research groups evaluating outcome measurement conditions ranging from the quality of life in those caring for patients with dementia (Horton *et al*., 2019), to teenagers with cerebral palsy (McPhee *et al*., 2019) and to patients with low back pain (Jakobsson *et al*., 2019).

Table 2: Definitions agreed by consensus within Mokkink *et al*. (2010a).

Domain	**Definition**
Reliability	The degree to which the measurement is free from measurement error and the extent to which the score for patients who have not changed are the same for repeated measurement under several conditions. Measurement error is the systematic and random error of a patient's score that is not attributed to true changes in the construct to be measured
Validity	The degree to which a health-related patient-reported outcome instrument measures the construct it purports to measure
Responsiveness	The ability of a health-related patient-reported outcome instrument to detect change over time in a construct to be measured.

4.6 Outcome measure validity

The domain of validity has sub-elements that relate to the design of an OM which are key to the process by which an OM is taken from an idea, to an OM instrument available for use in practice. Mokkink *et al*. (2010a) achieved consensus on content, face and construct validity. When developing an OM, de Vet *et al*. (2011; pp 37) suggest referring to the literature and cooperation with clinicians who have treated large numbers of patients with the target conditions. This will assist in confirming *face validity*: the degree to which the items chosen to measure within the instrument look as though they are an adequate reflection of the construct to be measured (Mokkink *et al*. 2010a). Face and content validity (Mokkink *et al*. 2010a), were assessed in the development of a functional OM score for dogs with neurological pathology (Boström *et al*., 2018). The OM was considered to meet the criteria of face and content validity based on consensus that it measured motor function relevant for dogs with neurological disease, although only seven clinicians were included in this analysis which is a small sample of the population that may be involved in canine neurological rehabilitation. Being a condition specific measure (Boström *et al*., 2018), the Finnish neurological function testing battery for dogs (FINFUN) may be more responsive to subtle changes in the patient's condition than a more generalised OM (Kyte at al., 2015). It is important to highlight that the FINFUN assesses functional activities that may be also be measured in orthopaedic pathologies, however the design process of the FINFUN only related to dogs with a neurological paraparesis or paraplegia. This canine score is not intended for use to assess function in dogs with other pathologies that may affect the same functional movements but potentially in a different way. Therefore, when selecting an OM, the user should refer to the literature surrounding the development process to ensure that basic qualities such as face and content validity relate to the construct to be measured (Mokkink *et al*., 2010aa). For a more systematic review of measurement properties the COSMIN initiative developed a checklist that could be used to assess the consistency, validity and responsiveness of OMs (Mokkink *et al*., 2010b). Using these guidelines should ensure that measurement tools selected for a specific purpose meet those criteria and are, as in the example above, correctly applied to the condition being measured.

Development of OM in human medicine has leant in the direction of PROM use to support clinical decision making and quality improvement in patient care, with Kyte *el al.* (2015) noting their importance in patient-centred care. This approach goes beyond the perspective of a single patient and looks to use PROM to influence policy. However, Kyte *et al.*'s (2015) recommendation to adopt PROM was within the context of the National Health Service (NHS) in the United Kingdom which is working towards a performance model based on health outcomes (Porter, 2016). PROMs used for this purpose, in addition to evaluating functional capacity of the patient, include questions on mental and social factors to evaluate overall quality of life (Kyte *et al*., 2015). For example, the EQ-5D PROM is a generic quality of life measure and the CSP (CSP, 2020c) encourage physiotherapists to engage with its use to establish the benefits of physiotherapy for patients with musculoskeletal conditions in a more coordinated and standardised way. Use of the EQ-5D assists providers in demonstrating their activity and its value to patients, providing a basis for benchmarking, clinical audit and future research, and supports a more consistent evidence-based approach to commissioning. Despite its widespread use in a range of physiotherapy services (Caplan *et al*., 2017), the areas measured within the EQ-5D do not translate well to animal physiotherapy due to the areas assessed being self-reported outcomes which include psycho-social domains (mobility, self-care, usual activities, pain/discomfort and anxiety/depression; Rabin and Charro, 2001). Therefore, to gather meaningful data for animal physiotherapy, OM need to be selected based on the content and conceptual model they relate to (de Vet *et al*., 2011: pp 8). Table 3 lists a summary of the strengths and weaknesses of PROMs, ObjMs and of a composite OM.

Table 3: Summary of strengths and weakness of patient reported outcome measures (PROM), objective markers (ObjM) and composite outcome measures (OM), proposed by the author.

Measure	**Strengths**	**Weakness**
PROM	In human patients, reported on by the person Inexpensive and quick Facilitates goal setting in relation to patient valued outcomes	Need to be completed by a proxy for equine use
ObjM	Reliability and validity more easily tested Quick to apply Goniometry, pressure algometry and Posture assessment tested for equine use Potential low cost	Only captures a single element of data Potential high cost
Composite OM (mixed patient-report and ObjM)	Capture objective data from specific tests and patient centred responses	None designed or tested in equine use

4.7 Measurement of clinical significance

The value of an OM to establish a baseline in pain and dysfunction levels, and to monitor change during rehabilitation may support future research assessing the efficacy of treatment interventions. In studies with homogenous samples with low subject numbers there is high internal validity (efficacy), but less external validity (effectiveness) to place these effects into a wider population (Sackett and Haynes, 2002). Where effects are placed into the context of the population they are intended for, the measured effect shown (e.g. increased range of motion [ROM]) should be a change in clinical status of that patient. In human medicine ‘minimal clinically important differences’ (MCID) refer to the *“smallest difference in score in the domain of interest which* patients’ *perceive as beneficial and which would mandate, in the absence of troublesome side effects and excessive cost, a change in the patient's* management*”* (Jæschke, Singer and Guyatt, 1989; pp. 408). The MCID are considered an important parameter to enable a proper interpretation of change scores (Van Dulmen *et al*., 2017). Gaining data to measure MCID could be more difficult in horses due to the ability to evaluate the patient’s perception of improvement. However, future studies could use OM alongside traditional measurement, such as tendon healing with ultrasound imaging (Kaneps, 2016) thus reporting on meaningful and functional change, evaluated longitudinally and linked to performance markers.

A further step to provide support for treatments could be correlation of data from *in vitro* studies with outcomes measured by a valid OM tool. Kinser and Robins (2013) recommend that in research for mind-body interventions (practices that promote heath by facilitating interactions among the brain, mind, body and behaviour e.g. yoga and tai-chi) mixed methodologies are adopted, in which both qualitative and quantitative approaches are integrated into the study design to determine clinical effectiveness. Translating this suggestion to physiotherapy research, in the future a methodology using an OM tool could be combined with owner interviews. Knowledge of clinical significance would also assist physiotherapists’ clinical reasoning to apply selected techniques to their practice

4.8 Outcome measurement in the context of equine physiotherapy

The application of OM in the context of specific equine pathologies treated by physiotherapy, would allow physiotherapists to demonstrate their value to the horse’s rehabilitation and welfare, as well as allow data capture for future research as per the CSP’s guidance (CSP 2020c). However, the challenge in measuring equine outcomes is the potential for an observer to be influenced by the behaviour of the horse that may not be related to musculoskeletal dysfunction or pain (McGreevy and McLean, 2007). Although selective breeding has reduced the hyper-reactive tendencies of the horse, conflict behaviours (e.g. bucking, shying, rearing, swerving, leaping, and bolting) (McGreevy and McLean, 2007) overlap with those that manifest as either pain or distress during riding (Coomer *et al*., 2012). Therefore, the success of an intervention should be judged by an objective observer who is experienced in discriminating between ethological or pathology causes of behaviour. Indeed, when scoring behaviour in the presence or absence of musculoskeletal pain, Dyson and Van Dijk (2018) reported greater agreement between a very experienced Veterinary Surgeon's scores and a five year qualified Veterinary Surgeon, compared with the same experienced Veterinary Surgeon and Veterinary interns, technicians and nurses. This study identified key areas for training to improve interpretation of the ethogram which could also apply to OMs for musculoskeletal parameters. Future studies, where there is potentially an overlap between learned behaviour and behaviour due to pain, could follow the methods of Mullard *et al.* (2017) in which assessors were trained for an hour and given a training manual of the scoring system being tested.

Whilst not fulfilling the true definition of PROM, a reliable and valid composite OM specifically designed for equine musculoskeletal conditions could meet the criteria set by the CSP in terms of professional standards, as well as the COSMIN checklist criteria for measurement instruments. Using OM in equine physiotherapy would allow the evaluation of rehabilitation methods that have been tested in non-clinical populations. OMs could be used to judge effectiveness of dynamic mobilisation exercises, raised poles or manipulative techniques when assessing the physical Quality of life life characteristics of a horse, in terms of pain/discomfort, usual activities and functional capacity.

The development of a reliable and valid PROM for equine use, tested with a person reporting as a proxy for the horse's voice, could be beneficial for physiotherapists. To establish which person would be more appropriate for reporting on specific factors to be measured would need studying further, as a rider would be able to assess ridden function but a physiotherapist would be able to assess musculoskeletal function independent of the rider's evaluation. In addition to professional assessment, those with a duty of care to the horse could be asked to report on factors such as behaviour both during day-to-day handling and when ridden, which may be altered if the horse is in pain (Dyson *et al*. 2018; Dalla Costa *et al*., 2014) and therefore affecting performance. If the score was easy to use, time efficient, was cost effective and was able to be used away from the veterinary hospital setting, it could provide a useful method to gather data. Reflecting on clinical findings, in addition to imaging, is essential as it has been shown that pathology seen on scans does not always relate to pain and subsequent functional limitation. In the tibiofemoral joints of 712 patients aged over 50 years, the prevalence of an abnormality seen on magnetic resonance imaging was high in those reporting pain (90-97%) as well as those with painless knees (86-88%) (Guermazi *et al*., 2012). Similarly, in subjects without any symptoms in their shoulders, abnormalities were found in 96% for the same sample, therefore suggesting that scan findings should be interpreted closely with clinical findings to determine the cause of symptoms (Girish *et al*., 2011). In horses, imaging has been used to establish that abnormal radiological findings of the thoracolumbar spinous processes are present in clinically normal horses (Erichsen *et al* 2004; Zimmerman, Dyson and Murray, 2012) suggesting that over-reliance on imaging is not advised and supports a combined approach including detailed objective assessment and measure of clinical signs.

An OM can include self-reported ObjMs within the assessment tests, which then provides a total score that is composite from a range of different ObjMs, for example range of motion or pain scores. An example is WOMAC index which is used to evaluate the condition of patients with osteoarthritis of the knee and hip, which includes questions on pain, stiffness, and physical functioning of the joints (Bellamy *et al*., 2005). Physical functioning questions cover everyday activities such as stair use, standing up from a sitting or lying position, standing, bending, walking, getting in and out of a car, shopping, putting on or taking off socks, lying in bed, getting in or out of a bath, sitting, and heavy and light household duties. As in the WOMAC index, combining scores from a range of ObjM can be used for evaluation of physiotherapy interventions, as well as drug therapies (McConnell, Kolopack and Davis, 2001).

Alternatively, ObjMs can be used as individual measures, referred to as a comparable sign in physiotherapy assessment and can measure a range of variables such as range of motion, muscle strength or fitness. These scores can be taken forward through the intervention phase to monitor progress and then report on the outcome of treatment (Stokes and O'Neill, 2008; Abrams *et al*., 2006). Therefore, if ObjMs can demonstrate the effectiveness of a given treatment, the chosen intervention is supported as suitable, whereas if the opposite is true the intervention for that condition should be avoided. Thus, if a treatment used with the goal of increasing range of motion results in no change or a reduction of range, then this treatment should not be applied in that specific context. The use of such information collectively gathered from multiple instances, should go forward to underpin evidence-based practice.

ObjMs can be obtained using systems that can be considered 'gold standard' methods. In veterinary medical practice and research laboratory settings, diagnostic tools such as ultrasound imaging or radiography may be used but commonly these techniques are inaccessible to physiotherapists (Liljebrink and Bergh, 2010). Within research that could be applied to physiotherapeutic interventions, ultrasonographic measurement of muscle size (Stubbs *et al* 2011; de Oliveira *et al*., 2015; Tabor *et al*., 2015) has been used to measure the cross-sectional area of the *m*. *multifidus* and 3-dimensional kinematic analysis has been used to measure the effect of head and neck position on intervertebral motion (Clayton *et al.*, 2012 and 2010; Rhodin *et al*., 2009; Weishaupt at al., 2006). However, ultrasonography equipment is expensive, requires specialist training and time to set up/use. Less expensive and more accessible methods of gaining ObjM include pressure algometry and goniometry. For instance, pressure algometry (PA) has been used to test intra and inter-rater repeatability of muscle palpation (de Heus *et al*., 2010; Haussler and Erb, 2003) and measurement of dimensions and posture from photographs has been shown to be repeatable (Tabor and Randle, 2013). Range of motion assessed by goniometry has also been shown to be reliable in horses (Liljebrink and Bergh, 2010; Adair *et al*., 2016). However, it is not known how frequently ObjM are used in equine physiotherapy practice.

4.9 Industry stakeholders' involvement in outcome measurement

It is suggested that the owner of the horse is the primary stakeholders in the lives of horses and that equine welfare is ultimately determined by those responsible for their day-to-day care (Horseman *et al*., 2017; Williams and Tabor, 2017). Welfare is a construct that encompasses interrelated components of basic health and functioning, affective state, and natural living (Fraser *et al*., 1997) with reference to nutrition, environment, health, behaviour and mental state (Mellor, 2017), and as such any musculoskeletal pain condition or dysfunction would affect welfare in the horse. Indeed, the UK Department for Environment, Food and Rural Affairs (DEFRA) provides a code of practice for the welfare of horses, based on the Animal Welfare Act of 2006, which states that owners must ensure their animal is protected from pain, suffering, injury and disease (UK Government, 2020b). Therefore, the owner's opinion could form part of the evaluation of the outcome of treatment and be considered during the rehabilitation process, although confidence in the owner's ability to evaluate their horse's welfare must be pre-determined.

The challenge of including owner opinion when assessing outcome is how much weighting it would have on the measurement of progress and whether this could ever be truly objective. An educated owner with specific knowledge of the factors that underpin measurement would be needed to provide objective assessment. A concern is that a lack of fundamental knowledge, relating to equine health and welfare has been identified in horse owners who answered a 40-question survey, with over half incorrectly answering questions regarding basic nutrition and management of horses (Marlin *et al*., 2018). Another factor when considering the horse owner's view is bias, due to risks of overcompensation as a result of expectation of outcome and so the advice is for the assessor to be blinded (Hróbjartsson *et al*., 2013). Unfortunately, it would not be possible to have a blinded owner if they were participating in the rehabilitation and therefore the risk of bias would be high. In addition, it would be challenging to understand the impact of pre-existing bias or lack of knowledge. However, including the horse's owner in decision making and goal setting, based on their evaluation, may assist in building client engagement with rehabilitation and support client-physiotherapist relation (therapeutic alliance) which is key to ensuring the therapy recommendations are followed (Miciak *et al.*, 2018; Baker *et al.*, 2001).

An obvious difference exists between human and animal subjects in relation to expectation of outcomes, due to the ability of the human to understand the intention of the treatment, however this can give rise to positive outcomes due to the placebo effect. The placebo response is a poorly understood phenomenon that involves non-specific psychological or physiological therapeutic effects of a medical intervention (Mills and Cracknell, 2013; McMillan, 1999). Within animals undergoing treatment it is likely that there are expectations of treatment effect, especially if the owner is responsible for the administration of treatment and outcome measures (Muñana, Zhang, and Patterson, 2010). For example, owners reporting frequency of their dog's epileptic seizures when given a placebo was positively biased (Muñana, Zhang, and Patterson, 2010). Interestingly, both pet owners and veterinary surgeons' evaluation of outcomes, in a trial giving non-steroidal anti-inflammatories for osteo-arthritis, also demonstrated a caregiver placebo effect (Conzemius and Evans, 2012). In this study the caregiver was defined as the owner and the Veterinary Surgeon, but this status could equally apply to a physiotherapist or an owner reporting on outcomes from an equine rehabilitation intervention. Likewise Jæger, Larsen and Moe (2005) studied the effects of a treatment for pain arising from canine hip dysplasia and found that owners reported a significantly greater improvement in pain signs if they believed that their dog was receiving the active treatment, compared with those who believed their dog was receiving the placebo. Similar caregiver placebo responses were found within a randomised control trial for a treatment for headshaking in horses in which owners reported significant improvement during all activities for both placebo and treatment groups (Talbot *et al*., 2013). The effects of the treatment were assessed in a blinded, randomised manner by two veterinary surgeons, resulting in no significant differences between treatment and placebo group, and the authors conclude that the subjective assessment by the owner was biased due to the expectation of a positive response. Overlooking a caregiver placebo response could potentially lead to increased patient morbidity, increased financial and time burden on the caregiver, and divert resources away from treatments that may benefit the patient (Conzemius and Evans, 2012). To test effectiveness and efficacy of interventions caretaker bias can be avoided by performing double blind trials, in which neither owner, physiotherapist or veterinary surgeon are aware of which treatment the patient or animal is receiving (Jæger, Larsen and Moe, 2005) although practically this can create ethical issues if treatment is withheld or the treatment is challenging to design a sham version. To ensure duty of care to the patient is maintained *in vivo,* treatment inventions should not be withheld, but to ensure a robust methodology, the assessors should be blinded to the stratification of the subjects. This would ensure the ability to assess the sensitivity and specificity of the measure for certain conditions undergoing rehabilitation, and to determine if a placebo effect occurs within key stakeholders involved.

4.10 Literature review conclusions

The paucity of literature discussing OM use specifically in equine physiotherapy does not seem to match the requirement for use of OM in physiotherapy practice as per professional standards, however the available evidence may not reflect contemporary practice. There is a need to understand the current use of OMs in equine physiotherapy practice and link this to the current evidence base. Prospectively this will direct further research to support clinicians in practice, to ensure they can measure the quality of their equine physiotherapy practice and therefore ensure effectiveness of intervention. In addition to aiding physiotherapists with their clinical reasoning, selecting effective treatment and rehabilitation strategies will benefit horses by optimising recovery from injury and increasing capacity. The overarching argument supporting the need for this research is one that effective treatment and objective measurement of the treatment effect is essential to improving the welfare of horses requiring physiotherapy to restore painless optimal function.

CHAPTER 5

Methodology and Methods

The research included within this thesis is conducted from the viewpoint of positivism (Whaley and Krane, 2011) with acknowledgement that the range of methods used fits with the post-positivist epistemological paradigm (Krane and Baird, 2005). The studies have a bias towards a quantitative approach, with Papers I and III taking on a mixed-methods research design (Sparkes, 2015). In their review of debate surrounding epistemology, Whaley and Krane (2011) state that the choice of methods is secondary to the question of paradigm, thus methods should be chosen that are best suited to the purpose rather than fixed to a single paradigm. The aim of the methods included in this thesis was to obtain objective, empirical and verifiable knowledge that could be subject to hypothesis testing (Krane and Baird, 2005) and which therefore can be evaluated against the objectives regarding outcome measurement, to produce valid and generalisable research that would be of value to the equine physiotherapy industry.

5.1 Papers I and III

To gather information from physiotherapists to evaluate use of OMs (Paper I) and to collate opinion from the expert panel to generate domains for a composite OM (Paper III), an inductive research strategy was used, applied through a mixed methods approach. This method fits within both the positivist and interpretivist epistemological paradigm. However, these two studies (Paper I & III) would be associated with an inductive, positivist approach due to the study exploring reality and the aim to discover the 'truth' (Sutrisna, 2009). An inductive methodology aims to gather data and then reviews those data to develop a theory. By contrast a deductive process would use existing knowledge to generate hypotheses, which are then tested (Blackstone, 2018). Indeed, Sparkes (2015) suggests that a mixed-methods approach including open questions is commonly used in sport and exercise psychology research. Although not directly concerning physiotherapy, this approach can be used to develop hypotheses that can then be tested by quantitative methods. The inductive methodology used in Papers I and III was the starting point for the generation of the research questions that were taken forward to the subsequent papers (II and IV to VII) thus enabling a deductive approach thereafter.

To gather data, from the two groups of physiotherapists and panel members questioned in Paper I and III, online surveys were used. The questionnaire used in Paper I is included in Appendix 3. This method has, as a strength, the ability to conveniently collect data from participants who are spread over many geographical regions in a timely manner, using technology freely available to those being surveyed. The disadvantages of tools such as online surveys are the potential skewing of the sample and bias from those that elect to complete the questionnaires (Evans and Mathur, 2005). Nonetheless, this method remains the optimum choice for gathering data on attitudes, impressions or opinions via polling a section of the population (Evan and Mathur, 2018). Online surveys have been used successfully to gather data from physiotherapists treating patients with patellofemoral pain (Smith *et al*, 2017) and shoulder rotator cuff disorders (Littlewood, Lowe and Moore, 2017), suggesting this method as a valid approach to gain data from physiotherapists. The use of an online survey proved successful in enabling ACPAT physiotherapists and expert panel members to participate in these two studies.

When selecting sample populations of equine physiotherapists, the membership body of ACPAT were chosen to represent the UK practitioners trained to treat horses. Although lack of online experience and expertise is considered a limitation to using online surveys, their use does reduce data collection timeframes and remove the cost of traditional mail or telephone surveys (Evans and Mathur, 2005). Consequently, the online tool Survey Monkey™ (SurveyMonkey, San Mateo, CA, USA) was used to collate data. A large proportion of ACPAT members have access to a closed ACPAT group discussion page on the social media platform, Facebook™ (Facebook™, Menlo Park, CA, USA) and this was chosen as a suitable location to share the questionnaire. The ACPAT group had 332 members at the time of launching the survey and it was considered that, due to evidence of their engagement with social media, these members would be comfortable using an online survey tool. The questionnaire was also shared within the public group ‘Animal/Veterinary Physiotherapists and Other Professions’ (970 members) and ‘Equine Research Collaborations’ (2379 members). It was acknowledged that many ACPAT members are within these last two groups, and not all members of these groups are physiotherapists. However, to capture information from physiotherapists who treat horses but do not have prior training to treat humans, as opposed to ACPAT members who can treat animals in addition to humans, these two groups were selected.

To ensure that the data were collected from physiotherapists, only the first section of the online survey asked for professional registration information. Whilst the name of the professional body was confirmed as a legitimate organisation, as the participant was anonymous, the individual could not be cross-checked against the list of physiotherapists within that organisation. It could have been possible that erroneous people were answering the survey, although understanding a motive for this would be difficult. It is also possible that the sample used in this questionnaire did not give a fair representation of physiotherapists working with horses but in the guidance prior to opening the questionnaire participants were instructed to continue if they fitted these criteria. A sample size calculation was not undertaken as the total size of the equine physiotherapist population is unknown. Littlewood, Lowe and Moore (2017) and Smith *et al.* (2017) accepted samples size of 110 and 99 physiotherapists respectively, from the UK physiotherapy population. Both Littlewood, Lowe and Moore (2017) and Smith *et al.* (2017) do note that approximately 100 participants represented small sample sizes and a limitation but question whether a larger sample size would have altered the generalisability of the results when they were representative respondents from a range of clinical sittings and with a range of experience. When surveying equine physiotherapists, who are from a smaller overall population than physiotherapists treating people, 50-60 participants was considered a representative sample population.

To gather data to determine which domains were considered important for inclusion in an equine rehabilitation specific OM an online questionnaire tool was also used (Paper III). However, rather than an open survey with a link posted online, a list of experts to be surveyed for their opinion was generated. The experts were selected via purposive sampling (Devaney and Henchion, 2018) based on their published research and industry expertise. Purposive sampling could be a source of bias from those that compiled the list and it is likely that there were suitably qualified experts not known to the authors and therefore not invited to be involved. According to Donohoe and Needham (2009), experts can be defined based on their closeness to a problem or issue which is the lack of knowledge regarding the areas that should in measured in the context of OMs for equine physiotherapy. Closeness can be defined as those with deep experiential knowledge or 'hands-on' experience; as those individuals that possess professional and/or legal responsibility and as individuals that explore and inquire without perceived bias. Therefore, the invited participants have direct knowledge and experience which is of value to the process being undertaken via the Delphi method (Powell, 2003). The subject matter experts based in Europe and the United States were invited to participate and the Delphi method of gathering data was used to gain a convergence of opinion from the invited selection of veterinarians, physiotherapists and equine researchers. The methodology for Paper III was guided by international best practice guidelines for the development of patient reported outcome measures (Klassen *et al*., 2015). The Delphi method, which is an accepted method for achieving convergence of opinion, was selected as a technique using group communication from a panel of experts (Hsu and Sandford, 2007). Using the Delphi method, the panel members are able to review and revise their responses in the stages of the process (Murray *et al*., 2017) and the controlled feedback process provides anonymity to the respondents, which may be a factor in group based discussions (Hsu and Sandford, 2007). In this way, experts can interact anonymously, reflect on each others' responses and agree with or refute other participants' claims (Devaney and Henchion, 2018). The process contained four rounds of survey, with the list of domains that met the agreement criteria shared for feedback from the experts in the final stage.

5.2 Paper II

The aim of Paper II was to conduct a systematic review and meta-analysis of the research undertaken into outcome measures used in equine physiotherapy and rehabilitation. The purpose of conducting a literature review is to explore the work already undertaken and so to reduce and refine large quantities of information, to enable clinicians to keep abreast of primary literature as well a remain literate in broader aspects of work (Mulrow, 1994). A step further is for authors to conduct a systematic review which summarises results of controlled healthcare studies to provide evidence on the effectiveness of interventions. In terms of OM suitable for use by a physiotherapist treating horses, a literature review could serve to educate the clinician on what OMs are available to use, the relative value of the individual OM and how reliable they are. Notably the value of a review paper is dependent on factors such as what was done, what was found, and the clarity of reporting (Moher *et al*., 2009) as well as the outcome measures that were used (Cochrane, 2020). Mulrow (1994) advocated pooling data from results to increase power, thus creating a greater sample size which can then be used to determine consistency or conflicts. Using more complex statistical procedures from a larger number of other studies, a meta-analysis, provides a coherent statement of a general finding (Rozas and Klein, 2010). Cochrane is an international organisation with overarching goals to produce high quality, relevant up-to-date systematic reviews and other synthesized research evidence to inform health decision making (Cochrane, 2020). Although it is important to note that there are some areas of critique within the Cochrane review process (Trinh and Phillips, 2006), there are now over 7,500 Cochrane Systematic Reviews (Cochrane, 2020). To assist authors in improving the reporting of systematic reviews and meta-analyses, a group of researchers, clinicians and consumers created a document called the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to be used on randomised trials (Moher *et al*., 2009). According to the PRISMA website (PRISMA, 2020) several editorial organisations and several hundred journals publishing systematic reviews endorse the PRISMA Statement. The checklist provides key requirements for authors, for example three of 27 items on the list are to: describe the rationale for the review in the context of what is already known; describe the methods of handling data and combining results of studies, if done, including measures of consistency for each meta-analysis and summarise the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers) (Moher *et al*., 2009).

If the volume of literature within a specific topic area is limited and therefore sufficient data to meet the assumptions, required to conduct a meta-analysis are not available, a more traditional literature review can be undertaken. Rozas and Klein (2010) suggest these have the purpose of generally describing the extant research including methods, population and findings and that they are an important component of doctoral dissertations, published article and empirical reports. These authors argue in support of literature reviews, namely narrative reviews, to report on primary research and synthesise findings into one coherent document.

Due to the amount of available evidence on the topic of equine OM, a systematic review or meta-analysis could not be undertaken. Therefore, using the definition from Rozas and Klein (2010), a narrative review was conducted (Paper II) which was considered to meet the aim of this element of the thesis and the primary objective to review the available evidence. A literature search was performed in Science Direct, Wiley Online databases and Google Scholar, in addition to referring to a core Animal Physiotherapy textbook by McGowan and Goff (2016). Keywords in various combinations were used (equine, horse, physiotherapy, rehabilitation, measure, objective, outcome) within the date range 1990 – 2019. The title and abstracts of the retrieved studies were reviewed for suitability, for inclusion based on content related to the topic, and those not relevant were discarded and the reference lists of the selected articles were searched for additional papers to be included. The search strategy may not have identified all relevant papers, introducing bias to the review however the articles found were categorised into sections relating to equine physiotherapy assessment (Goff, 2016) to ensure assessment areas were not overlooked. These categories were pain assessment in horses, gait assessment, spinal posture and range of movement, goniometry, palpation and muscle size. Although the journal targeted for submission did not require the PRISMA format to be used, the

PRISMA checklist (Moher *et al*., 2009) was followed for Paper II and items on the checklist would have been satisfactorily achieved if evidence was required.

5.3 Papers IV, V and VII

A lack of objective assessment and measurement of equine posture along with limited methods to do this was a consistent theme emerging from Papers I, II and III. Paper IV assessed the posture i.e. position of the limbs or the carriage of the body as a whole and relates to the relative position of parts of the body (Dictionary.com, 2020) in horses. Posture is a key consideration in physiotherapy assessment as an increase in thoracolumbar extension and spinal stiffness is associated with back pain in horses (Wennerstrand *et al*., 2009 and 2004). Increased extension closes the space between the spinous processes and this occurs when the head and neck are held high (Berner *et al*., 2012). Vertebral problems have also been associated with changes in neck posture (Lesimple *et al.*, 2010). This perceived increase in extension could be due to osseous pathology or due to increase tension (spasm) in the epaxial muscle *longissimus dorsi* (Clayton, 2012), which does further suggest that the adaption to the position of the equine spine due to pain is reflected in a change in posture. The relationship between posture and pain formed the basis of the research question addressed within Papers IV, V and VII.

Subjective assessment of posture is discussed as part of a physiotherapy assessment (Goff, 2016) although there are no studies discussing methods to objectively record posture as part of assessment, in relation to pain in the thoracolumbar region. However, the concept of the morphological form of the horse, known as conformation, has been studied and this has been reported to relate to performance and soundness in horses (Druml, Dobretsberger and Brem, 2016; Holmström, Magnusson and Philipsson, 1990). Height, length of body segments and joint angles have been reported in groups of Swedish Warmbloods (Holmström, Magnusson and Philipsson, 1990), Thoroughbreds (Anderson and McIlwraith, 2004) and Lipizzaners (Druml, Dobretsberger and Brem, 2016). From this, identified variables such as flexor angle of the shoulder joint and hip (coxal) angle positively associated with performance and an increased metacarpophalangeal joint angle were related to an increased risk of superficial digital flexor tendon injury (Weller *et al*., 2006a). Measurement of body segments lengths and resultant angles requires a system of identification of reference points marked on the horse and subsequent measurement of these distances, either by hand, from photographs or alternatively via computerised analysis (Weller *et al*., 2006b; Anderson and McIlwraith, 2004; Holmström, Magnusson and Philipsson, 1990). Similar to methods that could be used to record posture, the approach relies on accurate placement of the markers and stance of the horse, which could be sources of error in measurement. Weller *et al*. (2006b) tested the accuracy of marker placement and found low variation with both inter-operator and intra-operator repeats although the biggest source of error was markers placed on proximal skeletal landmarks. These authors advocate that training regarding accurate marker placement would reduce this variation. An additional source of error in studies such as Holmström *et al*. (1990) and Anderson and McIlwraith (2004) is the variance in the technique used to take the measurements from the photographs, therefore Weller *et al*. (2006a & b) used a computerised 3-dimensional motion analysis system which reduced this source of error.

To investigate the relationship between conformation and dynamic movement of the equine back Johnston *et al*. (2002) used a 3-dimensional motion analysis similar to the system used by Weller *et al*. (2006a & b). Spinal markers were placed at eight locations along the back, from the highest point of the withers to the sacrum, and morphometric variables were correlated with motion at these markers. During the walk and trot a longer thoracic back resulted in greater lumbar lateral bending and an increased curvature of the mid-thoracic back was negatively correlated with angles at the 10th and 13th thoracic level (Johnston *et al*., 2002). A consideration is that equipment used i.e. a 4- or 6-camera system, does increase the demand for space and requires either sunlight or bright lighting, which may prove difficult in environments such as a racing yard (Weller *et al*., 2006b), therefore using a method of measurement that is reliable but does not require these aspects would be beneficial in practice.

To measure posture in physiotherapy practice, rather than within a research laboratory setting, an objective measurement method is required, and a technique used in practice that could be validated is to compare photographs pre- and post-treatment or rehabilitation phase. The use of software to measure distance and angle (i.e. depth and/or angle of lordosis) can provide objectivity that judgement by eye (see paper I) cannot. This method had not been subjected to either intra- or inter-repeatability testing but, as a potential measurement tool, was considered to have face validity by physiotherapists (personal communication with ACPAT members) as an OM and therefore was justified in assessing further.

To determine the method used to test the reliability of the proposed technique, a review of the processes used in the research identified in Paper II for intra- and inter-observer testing of objective measurement tools was undertaken (Tables 4 and 5). Taking this information forward to Paper IV, a repeated measures method with a single observer was used, as this was the consensus from related studies (Bergh, Svernhage and Connysson, 2018; Adair, Marcellin-Little and Levine, 2016; Menke *et al*., 2016; Greve and Dyson, 2013; Abe, Kearns and Rogers, 2012; Stubbs *et al*., 2011; de Heus *et al*., 2010; Liljebrink and Bergh, 2010; Stubbs *et al*., 2010; Varcoe-cocks *et al*., 2006; Haussler and Erb, 2006 and 2003). The same method of adapting good practice from previous studies to Paper IV was repeated by multiple observers (n = 3) to assess inter-rater reliability (Bergh, Svernhage and Connysson, 2018; Halsberghe, Gordon-Ross and Peterson, 2017; Adair, Marcellin-Little and Levine, 2016; Menke *et al*., 2016; Walker *et al*., 2016; Alrtib *et al*., 2015; de Heus *et al*., 2010; Liljebrink and Bergh, 2010; Lindner *et al*., 2010). This quantitative methodology was used to assess repeatability of a simple tool to record equine thoracolumbar posture (Paper IV) and was subsequently used to measure changes in spinal posture during a physiotherapy treatment technique (Paper V). In a small study, that was presented as a conference poster (Paper VII), the same method was used to determine if there were any differences in spinal posture between horses with and without back pain.

The purposeful simplicity of the technique evaluated in Paper IV means that, although measuring whole thoracolumbar lordosis, it is not able to identify which portion of the spinal region any postural change occurs within. When the technique was used to assess the effect of a physiotherapy intervention, in Paper V, the depth of the lordosis was measured at more than one location. This allowed differentiation between the change in posture, due to the intervention technique, at specific spinal levels and not only of the whole region. Increasing the number of levels measured, increased the time required to complete the data collection and in practice a measurement of spinal regions within the thoracolumbar region may be a limitation to uptake of the OM in clinical practice.

Table 4: Summary of intra-reliability testing of objective measures (ObjM) research for tools relevant to equine rehabilitation (ICC = Intraclass correlation; PA = pressure algometer; MNT = mechanical nociceptive threshold; CSA = cross-sectional area; CV = coefficient of variation; US = ultrasound imaging; SEM = standard error of measurement; FCR = flexible curve ruler; sig = significant; diff = difference).

ObjM ASSESSED	INTRA-RELIABILTY TESTING	NUMBER OF REPEATED MEASURES	SAMPLE SIZE	STATISTICAL TEST	RESULTS
GONIOMETRY (LILJEBRINK AND BERGH, 2010)	Flexion of 3 limb joints in standing riding horses plus standing and anaesthetised standardbred trotters	3 repeats	30	ICC and measurement error (root mean square error)	ICC range 0.81 to 0.95; root mean square error range 2 to 3
GONIOMETRY (ADAIR, MARCELLIN-LITTLE AND LEVINE, 2016)	4 joints	3 repeats, plus 3 repeats after 4 hours	17	ICC of multiple goniometric measurements were calculated within raters	ICC range 0.950 to 0.995
TAPE MEASURE AND CALLIPERS (BERGH, SVERNHAGE AND CONNYSSON., 2018)	Synovial swellings by palpation, tape measure and slide calliper	Repeated measures one day apart (test-retest), two assessors tested individually	16	ICC	ICC range Tape measure - assessor 1: 0.88 to 0.97; assessor 2: 0.81 to 0.97. Slide calliper - assessor 1: 0.87 to 0.94; assessor 2: 0.84 to 0.84
PA: BACK PAIN AND EFFECTS OF CHIROPRACTIC TREATMENT (HAUSSLER & ERB, 2003)	52 locations	3 repeats, 3 seconds apart	26	Descriptive analysis for trends	Increased MNT in 26%, decreased in 6%, no change in 68%
PA: MNT IN THE AXIAL SKELETON OF HORSES (HAUSSLER AND ERB, 2006)	MNT - 62 location	3 repeats, 3 seconds apart	36	Descriptive analysis for trends	Increased MNT in 24%, decreased in 8% and no change in 68%
PA: MNT IN RACEHORSES (VARCOE-COCKS ET AL., 2006)	MNT - 8 locations	4 repeats	12	95% confidence intervals (CI) for sample mean and co-efficient of variation. ANOVA for order bias	Mean 51.9N/cm2 ±4.5 (95% CI = ±4.4, CV = ±8.7%). Reading for middle 2 measures were sig. lower than first and last.

PA: MNT IN WARMBLOODS (DE HEUS ET AL., 2010)	MNT - 35 locations	3 repeats morning and afternoon	6	Friedmans test	No sig diffs in 3 individual measures, sig diff between morning and evening
PA: MNT IN THE AXIAL SKELETON OF HORSES (MENKE ET AL., 2016)	MNT - 11 Anatomical Landmarks by two examiners measured individually	4 sets of short-term measures: 3 repeats, 3 seconds two days apart and 4 sets of longer-term measures: 3 repeats after 3 weeks	9	Short term: % ranges of change in MNT. Longer term: ICC for two individual examiners	Short term: range of no change 62-70%, range of decreased 16-23%, range of increased 10-20%. Longer term: Examiner 1: ICC 0.46 ($p<0.001$) Examiner 2: ICC 0.78 ($p<0.001$)
US: MULTIFIDUS CSA (STUBBS ET AL., 2010)	CSA multifidus	4 thoracolumbar levels, 3 US images at each level, analysed 3 times	22	Mean typical measurement error and CV as per Hopkins (2000)	No sig diffs in individual measurement of CSA
US: EFFECT OF DYNAMIC MOBILISATION EXERCISES (STUBBS ET AL., 2011)	CSA multifidus	6 thoracolumbar levels, 3 US images at each level.	8	Mean ± s.d.; ANOVA	No sig diffs in 3 individual measures
US: EFFECT OF WHOLE BODY VIBRATION (HALSBERGHE, GORDON-ROSS AND PETERSON, 2017)	CSA Multifidus	2 thoracolumbar levels (left and right) on 5 consecutive days. Each image measured 5 times	1	Friedmans test, SEM	No sig diffs between repeats, SEM ranged from 0.012 to 0.014
MUSCLE THICKNESS (ABE, KEARNS AND ROGERS, 2012)	Ultrasound measurements	Repeated measures one day apart (test-retest) of four muscle sites	13	% diff, Paired t-tests, ICC and Bland-Altman plots	Mean Diff 1.4-2.2%, p-value range: 0.25-0.81, ICC range: 0.95-0.98
FCR: REPEATABILITY OF MEASUREMENT TECHNIQUE (GREVE AND DYSON, 2013)	Thoracic profile	3 differently shaped horses, 10 times and 5 measurements of 10 horses	13	Measurement error	Measurement error ±2mm

Table 5: Summary of inter-reliability testing of objective measures (ObjM) research for tools relevant to equine rehabilitation (ICC = Intraclass correlation; PA = pressure algometer; MNT = mechanical nociceptive threshold; CSA = cross-sectional area; CV = coefficient of variation; US = ultrasound imaging; sig = significant; diff = difference).

ObjM ASSESSED	INTER-RATER TESTING	NUMBER OF REPEATED MEASURES	SAMPLE SIZE	STATISTICAL TEST	RESULTS
GONIOMETRY (LILJEBRINK AND BERGH, 2010)	6 pairs of assessors	3 repeats	30	ICC and measurement error (root mean square error)	ICC range 0.03 to 0.89; root mean square error range 3 to 10
GONIOMETRY (ALRTIB ET AL, 2015)	2 assessors	5 repeats	10	Paired t-test and repeatability coefficient (Bland and Altman test)	p= 0.052 and 95% limits of agreement were from -2.7; CI -5.3 to 0.0 to 5.7; 30 to 8.3 degrees
GONIOMETRY (ADAIR, MARCELLIN-LITTLE AND LEVINE, 2016)	3 assessors	Triplicate measures of 4 joints	17	ICC of multiple goniometric measurements were calculated within raters	ICC range 0.942 to 0.989
TAPE MEASURE AND CALLIPERS (BERGH, SVERNHAGE AND CONNYSSON, 2018)	2 assessors and repeated 1 day apart	3 repeats	16	ICC	ICC range Tape measure - 0.40 to 0.94. Slide calliper - 0.34 to 0.85
MUSCLE SCORE (WALKER ET EL., 2016)	5 assessors	Single measure	10	Weighted (Fleiss) kappa	Moderate (0,06-0,79) to very good (0.80-0.90)
PALPATION: TEMPERATURE/PAIN/MUSCLE TONE/MOBILITY (DE HEUS ET AL., 2010)	3 examiners	Single measures of each element	6	Friedman's test for palpation score and Spearman's rank test for Palpation v MNT	Sig diff for temperature, muscle tone and mobility but not for pain between examiners. Negative correlation: pain, temperature and muscle tone with MNT
PA: MNT IN THE AXIAL SKELETON OF HORSES (MENKE ET AL., 2016)	2 examiners	3 repeats	9	ICC	0.64 (P<0.001)
US: MUSCLE THICKNESS (LINDNER ET AL., 2010)	3 assessors and 3 consecutive days	3 repeats	5	Mean ± s.d., CV, one-way ANOVA	CV ranged 2.46- 19.65 %, effect of examiner no significant in 14 of 16 muscles measured.

5.4 Paper VI

To establish the reliability of a system to score soft tissue palpation and to establish if correlations existed with two pressure measurement tools, the studies included in Paper II and evaluated in Tables 4 and 5 were used as a framework for the methods of Paper VI. Assessment of mechanical nociceptive threshold (MNT) in the thoracic region of ten horses was conducted using a pressure algometer (FDK40; Wagner Instruments Inc, Greenwich, CT, US) and a Flexiforce sensor (Tekscan Inc, South Boston, MA, US) as well as being graded according to a palpation scoring scale (Table 6), by three ACPAT physiotherapists.

Table 6. Manual palpation scoring scale, modified from Varcoe-Cocks *et al* (2006) and the Modified Ashworth Scale (Ravara *et al*, 2015).

Score	Description
0	Soft, low tone
1	Normal
2	Increased muscle tone but not painful
3	Increased muscle tone and/or painful (slight associated spasm on palpation, no associated movement)
4	Painful (associated spasm on palpation with associated local movement, i.e., pelvic tilt, extension response)
5	Very painful (spasm plus behavioural response to palpation, i.e., ears flat back, kicking)

The same three measures were used by one ACPAT physiotherapist on a further 22 horses to assess intra-rater reliability. The repeated measures design was adapted from previous studies (Table 4 and 5) and sampled a comparable number of horses to previous reports concerning palpation testing (6, de Heus *et al*., 2010; 12, Varcoe-cocks *et al*., 2006).

5.5 Paper VII

Using the same measurement method of gaining an objective measurement of spinal posture used in Paper IV, photographs were taken and measurements collected from 71 horses. To investigate whether there was a relationship between spinal posture and pain, the subjects were divided in two groups, back pain or no back pain. The aim of this method was to test the validity of measuring posture to establish if, in clinical practice, the technique would show differences for horses with or without back pain. A binary measure of presence of back pain or no back pain on palpation was tested against the objective posture measurement. The groupings were based on assessment by an ACPAT physiotherapist and the photographs were measured by an assessor who was blinded to the grouping of the horse. In addition to thoracolumbar angle, the lumbosacral angle was measured from photographs of the horses stood in square stance. This method to measure both angles was tested for reliability prior to data collection for Paper VII. No significant differences were found with three repeated measures and one assessor for 98 horses, however there were significant differences between the three assessors measuring thoracolumbar and lumbosacral angle, therefore only one assessor was used in Paper V and VII (Mann, 2017, unpublished data).

5.6 Measurement bias (Papers V – VII)

Within Paper V, a single assessor was required to measure pre- and post-intervention posture and in the intra-rater reliability portion of Paper VI a single assessor measured MNT and behaviour response to palpation in the same horse. Single assessors have greater reliability than multiple assessors, although this could skew the results because a failure to blind assessors of outcomes in trials may result in bias (Hróbjartsson *et al*., 2013). However, if translated to use in real-world practice, a single physiotherapist is more likely to assess and re-assess a horse, plus they will not be blinded to the intervention. In randomised controlled trials the risk of observer bias can be reduced by blinding assessors to the treatment the subject received until after the experiment (Tuyttens *et al*., 2014) and this, although logistically challenging, is a minor change to planning and running trials that reduces the risk of bias considerably (Hróbjartsson *et al*., 2013). When testing inter-reliability of MNT testing in Paper VI, the approach to blinding suggested by Tuyttens *et al*. (2014) was modified to fit the methods by ensuring the assessors were blinded to each-others' scores and in Paper VII the assessor was blinded to the back pain grouping of each horse.

Training in the use of a goniometer prior to data collection has been shown to increase inter-rater reliability in goniometric measurement and Adair, Marcellin-Little and Levine (2016) cited this as justification for their higher agreement, when compared to Liljebrink and Bergh (2010). Taking this forward into Papers V to VII, physiotherapists undertaking the measurement methods received training with the tools used. Whilst beneficial in reducing measurement error, according to Hróbjartsson *et al*. (2013) conscientious non-blinded assessors may overcompensate for an expected bias and may induce bias as a result. During the data collection in Paper VI, where three ACPAT physiotherapists scored behavioural responses to palpation and MNT with two measuring devices, overcompensation may have been a concern. To limit this factor the physiotherapists were provided with clear written guidance on the behavioural responses anticipated when testing MNT and these were discussed as a group prior to data collection. According to Tuyttens *et al*. (2014) when assessing behaviour changes subjectively, *a priori* expectations can also influence interpretation, due to experience and personal views although in this study the assessors had been given false information deliberately. To limit *a priori* expectation bias, the order of assessors collecting the data and the tools were randomised plus the assessors were aware all the horses used had met inclusion criteria of prior assessment (no clinical signs of pain, muscle spasm or other abnormalities). In Paper VII assessors were blinded to the grouping of the horses to reduce conscious and unconscious bias during observation and when recording data due to their prior expectations and assumptions of posture in relation to pain. Unfortunately, it was not possible to blind the assessor when measuring the effect of the intervention in Paper V due to the positions the horses were in when measured, making it apparent which element of the intervention was being measured.

5.7 Sample size (Papers V – VII)

A sample size for evaluating reliability should be the same as would be used in an experiment that measures the smallest worthwhile effect of a treatment (Hopkins, 2000) however, this cannot be estimated without running a trial to establish the typical measurement error. Adair, Marcellin-Little and Levine (2016) undertook a pilot study to allow *a priori* power analysis using data collected from three horses and with a power of 0.80 and an alpha of 0.05, it was determined that four to nine subjects were required. The sample sizes for the studies assessing OM in live horses varied between Papers V to VII based on a hypothesis that similar measurement error would be likely in these. Additionally, the sample sizes used are within the bounds of other comparable studies by peers which have been published (Tables 4 and 5). The intervention and subsequent measurements were performed on 13 horses in Paper V, whilst Paper VI used 10 horses for intra-rater testing and 22 for inter-rater testing. Papers IV and VII used higher numbers of horses, 190 and 71 subjects, respectively, which increases the strength of the research design.

5.8 Statistical methods

The following statistical methods were used to analysis data within the research contained in this thesis (Table 7). All data were tested for normality distribution via the Kolmogorov-Smirnov test (Field, 2013, pp. 184) and alpha set at 0.05 for primary analyses. For *post-hoc* pairwise comparisons, a Bonferroni adjusted alpha was used as a corrected value for multiple comparisons (Field, 2013, pp. 547).

Table 7: Title of study and list of statistical tests used (Koo and Li, 2016; Ayre and Scally, 2014; Field, 2013; Petrie and Watson, 1999; Lawshe, 1974).

PAPER	TITLE	STATISTICAL ANALYSIS
I	Use of outcome measures in equine rehabilitation	Descriptive reporting and Chi-squared
III	Generation of domains for the equine musculoskeletal rehabilitation outcome score	Descriptive reporting and content validation ratio
IV	Equine posture analysis	Related samples Friedman's two-way analysis of variance, intraclass correlation estimates with confidence intervals and Wilcoxon signed-rank tests
V	Altered thoracolumbar position during a spinal mobilisation	Paired samples t-tests
VI	Reliability of soft tissue palpation scoring in equine thoracic epaxial region	Related samples Friedman's two-way analysis of variance, Intraclass correlation estimates with confidence intervals and post hoc Wilcoxon signed-rank analyses
VII	Spinal posture in horses with and without back pain	Paired t-test and K-means cluster analysis

Chapter 6

Discussion

The aims for this thesis: to evaluate the current application of ObjM and OM in equine physiotherapy practice; to investigate and test the reliability and validity of ObjM and OM, considered to be practical, simple and relatively inexpensive, and to undertake development of a composite OM that can be used to measure the quality of equine physiotherapy practice, were achieved via a range of methods. The papers presented in this thesis provide evidence to progress the field of equine physiotherapy in terms of contributing to the evidence-base as well as providing support for ObjM that can be used in clinical practice. This will assist physiotherapists to demonstrate effectiveness of interventions thus improving welfare of horses receiving treatment and undergoing rehabilitation.

To evaluate the use of ObjM and OM used in equine physiotherapy practice a questionnaire was used to survey physiotherapists with 76% reporting use of objective measures. The selection of measures listed were mainly subjective assessment methods such as observation (Paper I). The overarching theme reported by physiotherapists was a lack objective tools available for use in clinical practice. Subsequently a literature search was undertaken and the available research critically appraised, to understand what tools are available for use currently (Paper II). Whilst single factor objective markers are reported in the evidence base, there is a lack of application to musculoskeletal measurement. Understanding what should be included in a composite OM, specifically for equine musculoskeletal rehabilitation, is essential as the first stage in the development of a new OM. To achieve this, a Delphi study was undertaken with a panel of experts working in equine rehabilitation (Paper III) and consensus on ten domains to be included was achieved: lameness, pain at rest, pain during exercise, behaviour during exercise, muscular symmetry, performance/functional capacity, behaviour at rest, palpation, balance and proprioception. Where a domain did not contain pre-tested, or clinically practical objective measure, studies have been undertaken to explore tools and techniques for inclusion (Papers IV - VII).

In consideration of the emergent themes across the papers, included in and through completion of this doctoral thesis, there are areas relating to outcome measurement in equine physiotherapy that warrant further discussion. In addition, moving forward there are factors that should be considered to progress the development of The Equine Musculoskeletal Rehabilitation Outcome Score (TEMROS) (Paper III), so that the OM can be confidently used to evaluate physiotherapy treatment and rehabilitation.

6.1 Evidence-based equine physiotherapy

The need for a greater amount of evidence is apparent from the paucity of currently available research that specifically relates to equine physiotherapy treatment and rehabilitation. Some studies on common musculoskeletal conditions such as over-riding dorsal spinous processes (Jacklin, Minshall and Wright, 2014; Walmsley *et al*., 2014; Coomer *et al*., 2012), sacroiliac dysfunction (Nagy, Quiney and Dyson, 2019), hindlimb proximal suspensory desmopathy (Dyson and Murray, 2012) and SDFT injuries (Witte *et al*., 2016) do include physiotherapy as part of a multi-modal treatment approach but detail as to the exact physiotherapy contribution is not included. In these papers the evaluation of outcome is often based on decisions of success from horse-owner surveys and therefore would have less objectivity than found in similar trials that report on outcomes within health interventions in human trials (Chiarotto *et al*., 2014). This use of OMs in veterinary literature could underpin the limited use of OM by equine physiotherapists but it is encouraging that the need for OM to be used was highlighted by many of those surveyed (Paper I). Similarly, the development of a suitable OM was proactively supported by physiotherapists, industry professionals and veterinary experts (Paper III). Those undertaking research into treatment for musculoskeletal conditions need to include the rationale for their choice of OM to effectively evaluate the outcome. Practising physiotherapists will then be able to use the evidence with confidence in the application to the cases they see and ultimately support their responsibility to provide the best level of care for the equine patients they see.

6.2 Scoring of domains with composite OMs

Complex constructs, such as pain and function, usually require measures that indirectly use multiple observable items (de Vet *et al.*, 2011; pp. 17) where using single item scores (ObjM) would be at the expense of detail (Sloan *et al.*, 2002). According to the expert panel (Paper III) a multi-item measurement approach was favoured to quantify multiple aspects of the horse's musculoskeletal function. The measurement of more than one item within an OM provides a holistic view of the construct being measured and the term index is given to instruments consisting of multiple dimensions summarised into one score (de Vet *et al.*, 2011; pp. 51). To decide on a scoring system for TEMROS, systems used in human OM could be modelled. The Short-form 36 (SF-36) health survey questionnaire, conceptualised nearly 30 years ago (Ware and Sherbourne, 1992) and since translated in more than 50 countries as part of the international quality of life assessment project, has become the most extensively validated and used generic instrument for measuring quality of life (Contopoulos-Ioannidis *et al.*, 2009). In the SF-36, the scoring in the original response categories related to eight health concepts (physical functioning, bodily pain, role limitations due to physical health problems, role limitations due to personal or emotional problems, emotional well-being, social functioning, energy/fatigue, and general health perceptions) are recoded to fit on a 0 to 100 scale. In an OM in use for assessing human disability (Roland-Morris Disability Questionnaire) the scores for each domain are summed to provide a scale score allowing a dichotomous response of presence or absence of disability to be reflected in a binary outcome: 'yes = 1' and 'no = 0', with total score ranges from 0 to 24 (Roland and Morris, 1983). In the Finnish canine neurological function testing battery, 11 tasks are scored from 0 to 4, with a maximum sum-score of 44 reflecting dogs with normal motor function (Böstrom *et al.*, 2018). These examples from human and canine OMs show that there is a range of methods that could be used for scoring and therefore it is apparent that the potential scoring system for TEMROS requires further consideration.

Each of the individual OM chosen for the ten identified domains in Paper III have their own scores but summing these may not be the most effective method for generating a composite score as this may result in inequalities between domains. This would occur if palpation were scored between 0 and 5 (Table 6 and Paper VI) and pain during were scored between 0 and 24 (Dyson *et al.,* 2018). One option is that the domains could be organised as a list with equal value and reported using a binary scoring method. If lameness or pain on palpation were scored as being present or absent, a resulting score for all ten domains would range from 0 to 10. However, this would arguably reduce the sensitivity of the measure. Within TEMROS this could mean potentially a horse would score the same for mild muscle soreness and lameness (condition present in both domains: score = 2) as for a horse with an extreme reaction to palpation and a severe non-weightbearing lameness (condition present in both domains: score = 2). Alternatively, each domain could be rated through a restricted ordinal scale using existing scoring systems. An example of an ordinal scale already applied in the horse is grading lameness with the 0-5 American Association of Equine Practitioners scale, however, although frequently used, there are questions as to its reliability, especially when used to assess mild lameness (Keegan *et al*., 2010), which may be the level of lameness present in horses undergoing rehabilitation. The nine-category scale used by Dyson (2011) is an alternative although this would introduce different values within the score, i.e. 0 to 8, in all circumstances in which the horse was assessed (in hand, on the lunge, ridden; Dyson and Van Dijk, 2018). The resultant effect would create inequalities between the domains with more categorical scores culminating in different discrimination parameters. Alternatively, weights could be obtained from factor analysis (Hays *et al.*, 2018) but this would be challenging, where the specific value of each domain in relation to the construct of rehabilitation outcomes are currently unknown. Recording scores for each domain, as per the SF-36, may be practical to negate this potential bias effect or scores from each domain could be recorded, without summation, so that a profile is developed. The complexities of weighting each domain revolves around the consideration of whether all clinical signs should have equal weights or if some are more important than others. Without testing a range of scoring systems, the effect of using weighted or unweighted scores is currently conjecture and therefore a study designed to compare scoring systems needs to be undertaken. A simpler binary option for each domain e.g. lame/not lame, pain on palpation/no pain on palpation, could be trialled and compared against a more sensitive, discriminatory scoring system. However, the overall aim of TEMROS remains, which is to capture how small changes in different systems come together to gain improvement and progress through rehabilitation, increasing the necessity for a sensitive scale.

6.3 Effect size

The effect size, for quantitative data from an OM looking at change as a result of an intervention, should be considered. As effect sizes give the true magnitude of the effect, when calculated between groups (e.g. Cohen's *d),* it is appropriate to report as a statistic supplementary to p-values (Dankel *et al*., 2017). In addition, it has been stated that the presentation of effect sizes with confidence intervals should be obligatory for any journal publishing biological literature (Nakagawa and Cuthill, 2007). Despite this, there is a minimal amount of effect size reporting for studies on musculoskeletal treatment and rehabilitation interventions, leading to difficulties for the reader who wishes to interpret the magnitude of differences from a practical perspective.

Effect sizes, as well as meaningful and functional outcomes of treatment interventions need to be linked to the therapy used to provide an evidence-base for physiotherapists to use in practice. An example are differences found in spinal motion following cycloidal vibration therapy (Mackechnie-Guire *et al*., 2018). In the treatment group wither motion in a vertical direction increased (pre 69.00±8.77mm, post 70.84±8.79mm, p=.04) as well as mediolateral motion of the 13th thoracic (T) vertebral segment (Pre 26.45±4.29 mm, Post 29.27±5.29 mm, p = .01). Thoracolumbar musculature dimensions increased at T10 (Pre 20.90 ± 3.42 mm, Post 21.72 ± 3.30 mm, p = .02) and T13 (Pre 27.01

± 5.11 mm Post 28.23 ± 5.56 mm, p= .02). Whilst accepting the results were statistically significant, these outcomes should be evaluated in terms of effect sizes and clinical significance. Effects sizes calculated using data from the paper result in d = 0.22 for wither motion and d = 0.61 for motion at T13. For the reported increase in thoracolumbar muscular dimensions the effect size at T10 is d = 0.25 and at T13 d = 0.24. The effect sizes for wither motion and muscular change would be reported as small (0.2 – 0.6) and reported as moderate (0.6 – 1.2) for motion at T13 (Hopkins, 2006). The clinical significance, relating to how effective the treatment is and what affect did the therapy have in terms of performance, in relation to pain or even rider rated outcomes, were not assessed by Mackechnie-Guire *et al*. (2018). Although use of the MCID is paramount to interpret change scores (Van Dulmen *et al.,* 2017) where these have not been established authors should be encouraged to include effect size calculations to give a starting point for evaluation of clinical significance.

When reviewing studies on therapeutic interventions, it is apparent that many interventions reported upon have not been tested in horses with a diagnosed clinical problem. Statistical differences in muscle cross sectional area and spinal kinematics have been shown as a result of equine therapeutic exercises but have yet to be demonstrated to have significance in clinical populations (Pfau *et al*., 2017; de Oliveira *et al*., 2015; Walker, Dyson and Murray, 2013; Stubbs *et al*., 2011). During therapeutic exercise, changes in muscle recruitment patterns discussed within these papers have not been empirically determined and theory presented by Pfau *et al*. (2017), relating to improved dynamic stability and core postural muscle development (termed core stability), again has yet to be quantified. In human sports medicine, core stability can be assessed with a combination of tests of isometric strength and endurance, flexibility, motor control and function (Waldhelm and Li, 2012). Therefore, core stability would be an extremely complex construct to measure in horses, so objectively measured levels of function and pain, as agreed in Paper III, could be used as an alternative to monitor performance of horses undergoing the above methods of rehabilitation.

In addition to equine therapeutic exercises, manipulation of the equine spine has been shown to change spinal motion (Alvarez *et al*., 2008; Haussler *et al*., 2007), although the effects of chiropractor treatments are small and variable, typically seen only immediately post-treatment. Paper V also observed the immediate and positive influence of a spinal mobilisation intervention on spinal angles. However, unlike previous work which uses video motion analysis, Paper V uses an OM that could be quickly used in clinical practice (Paper IV). The effect sizes for the results were determined using Cohen's *d* and the effect sizes for statistically significant change in position at the 13th and 17th thoracic vertebra during the spinal mobilisation were d = 0.76 and d = 0.97 respectively, suggesting a large practical effect (Fritz, Morris and Richler, 2011). This provides physiotherapists with an indication of the value of the technique and therefore, it could be clinically reasoned as a suitable method of increasing flexion in the thoracic spine in horses.

6.4 Sample size for composite outcome measure testing

For a research study to be considered adequately powered, to avoid type I error (false positive) or type II error (false negative), data must be generated from a sufficient sample size (Akobeng, 2016). The challenge with reliability studies is determining what size sample is needed to achieve this when previous data, by the nature of the type of study, are not available to use within calculations for sample size (Hopkins, 2000). This would apply when looking to test the reliability of a new OM. Samples sizes could be established from previous studies investigating similar ObjM (Bergh, Svenrhage and Connysson, 2018; Adair, Marcellin-Little and Levine, 2016; Menke *et al*., 2016; Greve and Dyson, 2013; de Heus *et al*., 2010; Varcoe-cocks *et al*., 2006) and this method was used to set the sample sizes for the inter-reliability testing of palpation assessment (Paper VI). The sample size of 22 for intra-rater testing was partially constrained due to the availability of resource. However, a *post-hoc* power analysis based on pair-wise comparison of means, with an alpha set at 0.05 and power of 80%, (Clincalc, 2020; Ackobeng, 2016) resulted in suggested sample sizes ranging from 4 to 16 per variable. Therefore, the study conducted within Paper VI was considered suitably powered.

Thoracolumbar posture was objectively measured before and after an intervention directed at flexion of the spinal region in 13 horses for Paper V. This was a convenience sample and no *a priori* power analysis was undertaken. Published research into treatments, have smaller sample sizes than the 13 horses used in Paper V (7, Pfau *et al*., 2017; 8, Stubbs *et al*., 2011; 9, Halsberghe, Gordon-Ross and Peterson, 2017; 10, Alvarez *et al*., 2008). None of these studies, including Paper V, have a control group which is considered necessary to limit judgement of effect due to outcomes related to other factors, such as the natural history of the condition or participant/researcher expectations (Kinser and Robins, 2013). Although the double blinded randomised control trial (RCT) is considered the gold-standard in research quality (Sackett *et al*., 1996) these are often not feasible due to economical and ethical considerations. Physiotherapy interventions do not typically have an obvious placebo or sham intervention for the benefit of the assessor, owner or caregiver, even with reliable OM, similar to the patient in mind-body therapy research (Kinser and Robins, 2013).

There are a few published studies of interventions for musculoskeletal conditions that use a design with a control group (de Oliveira *et al*., 2015; Tabor, 2015; Sullivan, Hill and Haussler, 2008), however no between group effect sizes were discussed. The addition of a control group increases the number of horses required and it is feasible that low sample sizes in studies such as these could be due to the difficulties of logistics, in terms of the time required to undertake the intervention or measurement (de Vet *et al*., 2011: pp. 126), as well as access to suitable subjects to be enrolled on the trial.

Study design and sample sizes have been considered within evaluated published research but fortunately, if no randomised trial has been carried out for the condition of interest, then Sackett *et al*. (1996) suggest using the next best evidence. Alternatives to a randomised control study include a longitudinal prospective or retrospective cohort study or case-control studies, but these require outcome data to be available (Song and Chung, 2010) and therefore careful selection of the OM used for this purpose must be taken. Lower on the hierarchy of evidence but still applicable to evidence-based practice are case series (Bondemark and Ruf, 2015). Although in contrast with epidemiological cohort studies, case-series are mainly descriptive and follow one small group of subjects (Song and Chung, 2010). However, these may provide the next best evidence in the absence of randomised trials, according to Sackett *et al*. (1996), and examples such as Pfau *et al*. (2017) and Stubbs *et al*. (2011) would fit this research design due to single groups and small sample sizes. Whilst positive effects of the approaches were demonstrated in these case-series, the outcome measures used were motion capture systems or ultrasound imaging, neither of which are suggested as commonly available to physiotherapists in practice (Liljebrink and Bergh, 2010) nor reported as being used by physiotherapists (Paper I).

Pragmatically, more case-series would be useful to guide selection of physiotherapy treatment interventions for musculoskeletal conditions. If case-series research design studies used standardised OM that could allow data collection *in vivo*, these data could then be used for retrospective case-control series, increasing sample size, therefore increasing statistical power and the level of evidence. For larger scale randomised controlled trial style studies using similar interventions to Paper V but with a clinical population of horses, the effect size data can be used to establish a recommended sample size to be confident that the outcome is based on the intervention and not biological variation (Hopkins, 2000). Based on calculated effect sizes (Paper V), with power at 0.8 and alpha of 0.05, Fritz, Morris and Richler (2012) calculate that for one- and two-tailed tests, 20 and 26 participants, respectively, would be required. In terms of resource and time, this number of horses as subjects seems reasonable and should be used to guide design of future studies.

6.5 Functional testing

An objective within this thesis was to determine what ObjMs and OMs are required by equine physiotherapists to use to evaluate treatment and rehabilitation interventions. Once these were identified the literature was reviewed for the domains, to explore possible options for specific OM to fit within the composite score. One of the domains that was suggested, and then reached agreement to be included in TEMROS, was assessment of performance and functional capacity of the horse undergoing rehabilitation (Paper III). The definition of functional capacity is what people (or horses) are able to do (de Vet, 2011), compared to physical activity, which is what they are actually doing. Whilst changes of physiological variables (e.g. heart rate, respiratory rate, blood lactate levels) and physical variables (e.g. velocity) as a result of training have been frequently reported (Sloet and Barnfield, 1995; Courouсé, 1999; Munk, Møller and Lindner, 2013; Munsters *et al*., 2014), the functional capacity of horses, from a rehabilitation perspective, has not been studied to date.

A factor in reporting functional capacity in horses is the requirement to consider the post-surgery or treatment protocol that has been prescribed. For instance, following interspinous ligament desmotomy for impinging thoracolumbar spinous processes, horses are placed on box rest with hand walking for three weeks (Coomer *et al.*, 2012). Recording of functional capacity would need to take into account the externally prescribed restrictions to activity and not just due to inability to perform at that level. A suggested scale for assessing capacity during rehabilitation has recently been reviewed by five experienced physiotherapists for face validity and could be taken forwards for further testing (Tabor, 2020, unpublished). This scale is based on the anticipated stages of rehabilitation during phases of recovery post-injury or post-surgery, starting from box-rest and progressing through controlled exercise. The scale is designed to be used by horses returning to exercise, for any equestrian discipline and notes the use of medication alongside functional capacity at the time of assessment (Table 8). This scale or one similar could be integrated into TEMROS to fulfil the requirement of measurement of function.

Table 8: Example measurement scale for functional capacity in horses. Scores from each of the three categories (Veterinary mediation information; non-exercise activity; exercise activity) would be summed to provide a composite score for functional capacity.

Veterinary Medication information

0	The horse is receiving regular non-steroidal anti-inflammatory analgesic medication
1	The horse has received medication to support rehabilitation e.g. corticosteroid injection, intra-articular medications or regenerative therapies.
2	The horse is not receiving any medication

Non-exercise activity

0	The horse is on complete box rest
1	The horse is turned out in a restricted area (grass or artificial surface)
2	The horse is turned out in an unrestricted area for restricted time periods
3	The horse is turned out without restriction, or is allowed to be turned out but this is currently limited due to environment or non-rehabilitation management constraints

Exercise activity

0	The horse is not undertaking any form of locomotory exercise, although may be completing stable based exercises such as stretches of limbs, spine or neck
1	The horse is on box rest but undertaking some in-hand exercise such as grazing or walking
2	The horse is undertaking some form of non-ridden exercise such as long-reining, lunge work or on a horsewalker
3	The horse is being ridden e.g. light schooling and/or hacking but not undergoing equine sport discipline specific training. The exercise programme may include long-reining, lunge work or a treadmill/horsewalker, in addition to the ridden work.
4	The horse is being ridden at a moderate level including equine sport discipline specific training. The exercise programme may include long-reining, lunge work or a treadmill/horsewalker in addition to the ridden work.
5	The horse has returned to exercise and/or competition but not to level of pre-injury performance OR is performing at a maximal level considered achievable following the rehabilitation. The exercise programme may include long-reining, lunge work or a treadmill/horse walker in addition to the ridden work.
6	The horse has returned to previous level of exercise and/or competition. The exercise programme may include long-reining, lunge work or a treadmill/horsewalker in addition to the ridden work.
7	The horse has returned to exercise and/or competition at a higher level compared to before injury. The exercise programme may include long-reining, lunge work or a treadmill/horsewalker in addition to the ridden work.

6.6 Reliability testing of composite outcome measures

Composite OM undergo similar strategies of testing as ObjM and once the individual measurement tools for each of the domains selected in Paper III are confirmed, TEMROS will require further testing. The testing of reliability is essential to establish the degree to which the measurement is free from measurement error (Mokkink *et al*., 2010a) and test-retest, inter-rater and intra-rater testing should be performed for TEMROS. Practical arrangements for a group of assessors and subjects, which would be horses for TEMROS, for live data collection could be challenging and if scoring via a video session could be used, this would enable a more rapid progression of the research as well as greater numbers and range of participants to represent breadth of profession. In human sports medicine research, the Functional Movement Screen™ has been tested in person and via video. Shultz *et al*. (2013) included a comparison of repeated testing one week apart, in person and via video with excellent reliability (ICC=0.92). The measurement tool for each domain within TEMROS would have to be evaluated for reliability via video first, but then could be used as part of training the assessors, especially if the score given during live session or via video sessions are comparable (Shultz *et al*., 2013).

Arguably using video may be difficult for scoring palpation, which could be considered an assessment that can only be undertaken 'live'. If palpation response can be successful captured on video, this would allow the assessors the ability to repeatedly visualise the sequences, which may give more precision to the evaluations (Bussières *et al*., 2008). Agreement on behavioural observations and lameness at walk in horses with orthopaedic pain have been tested with kappa values ranging from 0.54 to 1 (Bussières *et al*., 2008; Goodrich *et al*., 2002). Postural changes were measured from still images taken from video for Paper V, suggesting the use of video as positive. An alternative to assessing factors via video is using still photographs such as those used successfully for taking posture measurements in Paper IV. Photographs were also used by Mullard *et al*. (2017) when developing an ethogram to describe facial expressions in ridden horses, which demonstrated that musculoskeletal pain (causing lameness) could be identified from photographs (Dyson *et al*., 2017). Based on the domains to be measured within TEMROS, the use of photographs or video could be justified for a trial of testing TEMROS reliability.

6.7 Limitations of research using horses considered to be free from lameness or back pain

The horses within this study were all in ridden work, from a general sports horse population and considered free from lameness or back pain by their owners. However, research into physiotherapy or rehabilitation interventions that use horses, may be subject to potential issues due to the numbers of these horses that have lameness or non-clinical motion asymmetries that are in ridden work (Van Weeren *et al.*, 2017). This was illustrated in Rhodin *et al.'s study* (2015) investigating symmetry of vertical head and pelvic motion during lunging in 201 riding horses. All horses were considered sound by their owners however a large proportion of horses (53%) were excluded from the second stage of data collection during lunging, due to head and pelvic asymmetries that were above a threshold of asymmetry considered to denote lameness. The threshold for asymmetry was listed as absolute differences larger than 6 mm in the forelimbs and 3 mm in the hindlimbs on a straight line. Whether these asymmetries are biological variation or related to pain was not established in this study, nor if those horses with less asymmetry had bilateral lameness. When investigating the frequency of saddle slip and its association with lameness and thoracolumbar shape/symmetry, Greve and Dyson (2014) found a similarly large proportion of horses (45.7%; n=506) had gait abnormalities including fore- and/or hind-limb lameness, stiff or stilted canter or a quadrilaterally reduced cranial phase of the step. Therefore it is likely that some of the horses used within this study had motion asymmetries, however this research applied a pragmatic epistemology and therefore whilst important to control for lameness, selecting 'real-world' horses as a sample was key to the aims and philosophical perspective of the project.

To reduce the possible confounding effect of lameness in future studies, thorough assessment of gait should be undertaken, including assessment on the lunge in circles on a soft and a firm surface. If possible, gait assessment under saddle should be carried out, as some lamenesses are only apparent when horses are ridden, as concluded by Dyson and Greve's (2016) study of 57 horses demonstrating that freedom from lameness in straight lines is not a reliable indicator of soundness. The data from

Papers IV, V and VI should be considered with the view-point that the horses included may have had asymmetries of gait that could have influence the conclusions. However, for each of these studies, the methodology was a within-subjects design that may reduce the potential influence of underlying abnormalities.

The presence of back pain or underlying osseous pathology is a further limitation that may impact data collected in Paper IV, V and VI, as a proportion of riding school horses will have back pain despite being in full work (Lesimple *et al.*, 2013). Paper VII used horses that were categorised into back pain and no back pain groups, although the groupings were established subjectively, future studies should quantify the stratification with objective methods to measure back pain. A thorough examination of back motion and response to palpation is required, however veterinary imaging as a screening tool may not be useful based on the findings of Erichsen *et al.* (2004) that revealed a range of scintigraphic and radiographic changes in 26 of 33 asymptomatic riding horses. Interestingly the changes were mild but were present in the region of the 13^{th} to 18^{th} thoracic vertebrae, below where a rider is positioned in the saddle. Whether these horses had symptoms at a later date is not known however it is possible that therapeutic interventions would have a different effect on these horses compared with the seven horses that had no imaging abnormalities. Stubbs *et al.* (2011) found asymmetries in *m. multifidus* prior to a programme of dynamic mobilisation exercises and the same research group noted the presence of osseous pathology in the thoraco-lumbar spine (Stubbs *et al.*, 2010). Underlying clinical findings in horses with presumed normal backs is a consideration when interpreting the results from Paper V where the spinal range of motion was measured during a physiotherapy intervention.

Horses may present with clinical signs of both lameness and back pain and to understand this relationship further Landman *et al.* (2004) studied a group of horses presented with orthopaedic problems (n=805) and a control group of horses undergoing pre-purchase examination that were consider free from problems (n=399). Whilst mild lameness was found in 19.5% of the control population, nearly 80% of the horses undergoing orthopaedic assessment were lame and 74.2% of those presenting with back pain were lame. As there is a strong association between lameness and back problems, both factors were considered within the inclusion criteria for Paper VII where all 22 horses had undergone a full veterinary workup and health check in the last 6 months before the research starting and were all in full work and health monitored as per the yard protocol. Each horse also underwent a clinical assessment and was assessed by observation and palpation for any muscle spasm or significant asymmetries before taking part in the study by a qualified Association of Chartered Physiotherapists in Animal Therapy (ACPAT) Chartered Physiotherapist. The horses from Papers IV, V and VII were convenience samples from private stable yards and equestrian colleges and although all in ridden work, were therefore potentially subject to motion asymmetries and gait abnormalities (Greve and Dyson, 2014; Rhodin *et al.*, 2015; Dyson and Greve, 2016) or back pain which was not recognised by the owner/caretaker (Landman *et al.*, 2004; Lesimple *et al.*, 2018; Dyson *et al.*, 2020). The results for Paper V, where the effect of a spinal mobilisation technique, that is initiated with a forelimb elevated, may have had the differences between the left and right sides affected by back pathology. However, these differences may be reflection of the force the physiotherapist was applying, or difference in the horse's core stability in terms of the range of spinal motion achievable in a tripod position. A similar pattern of movement is recommended as a perturbation exercise, aiming in facilitate core muscle contraction to strengthen this muscle group (Stubbs and Clayton, 2008). Neither outcome was measured within this study, however the mobilisation from either side did result in a significant change thoracolumbar position which suggests the results do support the hypothesis tested. As a result of using horses from a general population of riding horses, these data can be more confidently extrapolated to the population of horses seen by physiotherapists in practice.

6.8 The future for TEMROS and outcome measures in equine physiotherapy

The next stage in development for TEMROS is the confirmation of appropriate OMs for specific musculoskeletal conditions that are treated by equine physiotherapists. TEMROS, with each domain providing an element to provide a composite score, can then be taken forward for testing for reliability and validity within specific equine musculoskeletal conditions. To identify musculoskeletal conditions, that are seen by equine physiotherapists, a survey of ACPAT registered physiotherapists (n=63) was conducted (Tabor, 2020, unpublished data). The median proportion of equine caseload that was reported to have thoracolumbar pain was 80% (Interquartile range [IQR] = 20). As primary diagnoses, without or without concurrent back pain, the proportion of horses presenting with sacroiliac region pain was 40% (IQR = 30) and distal limb tendon or ligament injuries was 20% (IQR = 20). The high frequency of horses seen with back pain highlights that the reliability and validity of TEMROS should be tested during the physiotherapy treatment and rehabilitation. Following back pain, TEMROS could be tested in its application to horses with sacroiliac pain and distal limb injuries (Figure 1). The members of the multidiscipline team and other stakeholders, such as owners, who are involved in rehabilitation can also be tested for inter-rater reliability. If the data collected from these trials highlights a need, the outline of TEMROS could then be modified and refined for different stakeholders.

Whilst TEMROS is undergoing validation, physiotherapists can use the information that has been published (Papers IV, V and VI) within their practice. Combinations of OM for palpation scoring and posture measurements should be used to objectively record clinical assessment strategies that are used by equine physiotherapists (Goff, 2016).

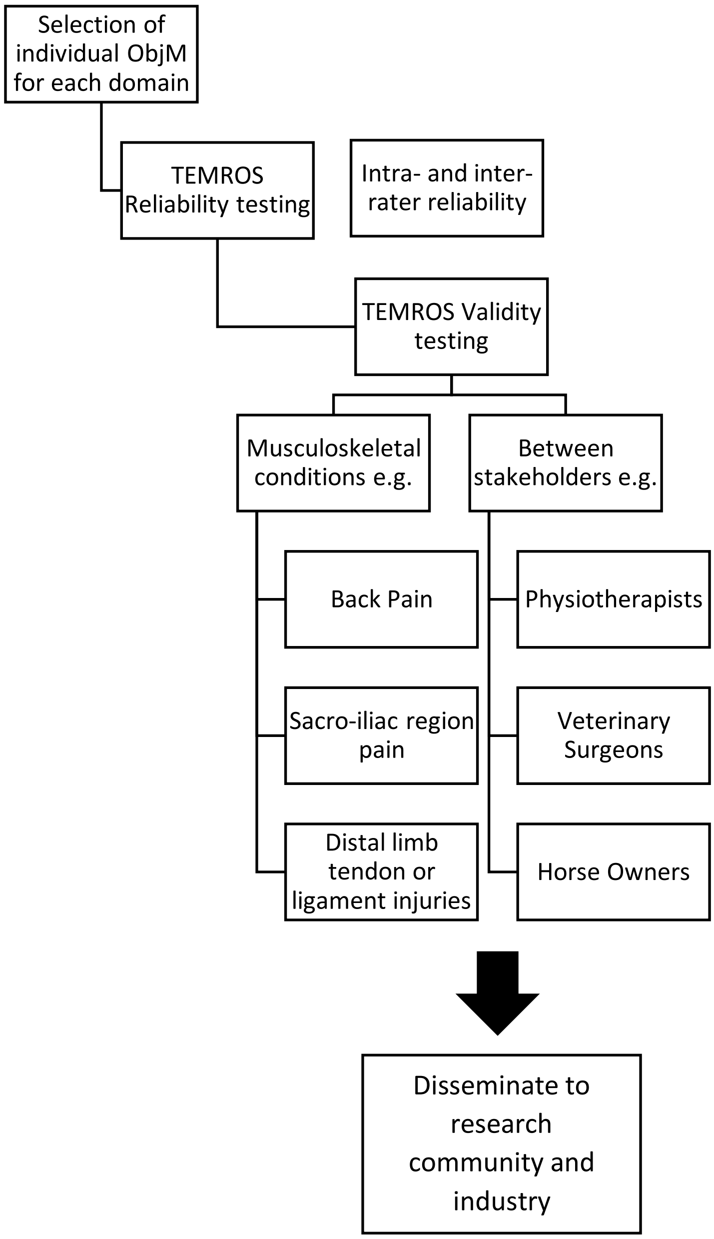

Figure 1: Process to test, validate and embed The Equine Musculoskeletal Rehabilitation Outcome Score (TEMROS) into physiotherapy practice.

Chapter 7

Conclusions

The research presented within this thesis has demonstrated that consensus from physiotherapists and experts within the field of equine rehabilitation matches that of the professional society's (CSP and HCPC) standards, concurring that OM are essential in practice (Paper I, Objective 1). The use of non-objective methods, to monitor for change in response to equine physiotherapy and rehabilitation interventions, occurs despite the availability of several OMs which, when tested, were shown to be reliable both within and between assessors (Paper II, Objective 2). Nevertheless, equine physiotherapists agree that more OMs are required, to assist in gathering data about their patients and to use to evaluate treatment effectiveness. This thesis has established ten domains of measurement that should be included in a future equine rehabilitation specific outcome measure (Paper I and III, Objective 1, 3 and 4). With the domains for measurement agreed and methods to evaluate each explored, an initial version of a composite OM has been developed: The Equine Musculoskeletal Rehabilitation Outcome Score (TEMROS).

The domains to be included in TEMROS did not all have objective and reliable measurement methods previously established, therefore methods to fill the gaps for objective posture and palpation assessment were tested. A simple method for measuring posture that could be used to objectively record a baseline score was established (Paper IV, Objective 5) and shown to be reliable. Specifically, this method can measure change during interventions that seek to alter spinal posture in the sagittal plane, demonstrating a positive correlation between the amount of lordosis and back pain in horses exists (Paper V and VII, Objective 5). A categorical palpation scoring system and its relationship to previously tested measures was investigated for intra- and inter-rater reliability (Paper VI, Objective 5) and could therefore be a valid component for inclusion in TEMROS.

The research undertaken has contributed to the existing literature by adding new knowledge of OM use in horses and increasing understanding of the OM required by equine physiotherapists, as well as supporting clinical practice with reliability studies on ObjM not previously tested. This thesis and the papers included will aid equine physiotherapists with their clinical reasoning by providing collation and critique of existing research. Clinically useful tools are presented for physiotherapists to use when evaluating treatment and rehabilitation interventions in their own practice and for use in the wider equine musculoskeletal research community.

Whilst the development of a specific outcome measurement tool that encompasses all facets of a horse's recovery is immensely challenging, within this thesis essential steps in the pathway to generate a reliable, valid, clinician-friendly and useful OM have been taken. With reliably measured domains, and subsequent validity testing, a composite score for equine physiotherapy will support clinical practice and enhance the evidence base as well as substantiate treatment choices to improve horse welfare.

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Appendix 1

Author Contributions to each paper included within the thesis

I **- Tabor, G.** and Williams, J. (2018) The use of outcome measures in equine rehabilitation. *The Veterinary Nurse* 9 (9) 2-5.

Conceptualization, G.T; Methodology, G.T and J.W; Investigation and Data Curation, G.T; Writing – Original Draft Preparation, G.T; Writing – Review & Editing, G.T AND J.W; Supervision, G.T.

II - **Tabor, G.** and Williams, J. (2020) Objective measurement in equine physiotherapy. *Comparative Exercise Physiology* 16 (1): 21-28.

Conceptualization, G.T; Methodology, G.T.; Investigation, G.T.; Writing – Original Draft Preparation, G.T.; Writing – Review & Editing, G.T. and J.W.

III - **Tabor, G.,** Nankervis, K., Fernandes, J. and Williams, J. (2020) Generation of domains for the equine musculoskeletal rehabilitation outcome score: Development by expert consensus. *Animals* 10 (20): 203-217

Conceptualization, G.T.; Methodology, G.T. and J.W.; Investigation, G.T.; Data Curation, G.T.; Writing – Original Draft Preparation, G.T.; Writing – Review & Editing, G.T., K.N., J.F. and J.W.

IV - **Tabor, G.,** Elliott, A., Mann, N. and Williams, J., (2019) Equine Posture Analysis: Development of a Simple Tool to Record Equine Thoracolumbar Posture. *Journal of Equine Veterinary Science* 73: 81-83.

Conceptualization, G.T.; Methodology, G.T., A.E. and N.M.; Investigation, G.T.; Data Curation, G.T., A.E. and N.M.; Writing – Original Draft Preparation, G.T.; Writing – Review & Editing, G.T., A.E., N.M AND J.W.

V - Taylor, F., **Tabor, G.** and Williams, J.M., (2019) Altered thoracolumbar position during application of craniocaudal spinal mobilisation in clinically sound leisure horses. *Comparative Exercise Physiology 15*(1): 49-53

Conceptualization, G.T.; Methodology, G.T. and F.T.; Investigation, G.T. and F.T; Data Curation, G.T., F.T. and J.W.; Writing – Original Draft Preparation, G.T. and F.T..; Writing – Review & Editing, G.T., F.T. and J.W.

VI - Merrifield-Jones, M., **Tabor, G.** and Williams, J. (2019) Inter and Intra-rater reliability of soft tissue palpation in the equine thoracic epaxial region. *Journal of Equine Veterinary Science* 83: 102812

Conceptualization, G.T.; Methodology, G.T. and M.M; Investigation, G.T and M.M.; Data Curation, G.T., M.M. and J.W.; Writing – Original Draft Preparation, M.M.; Writing – Review & Editing, G.T., M.M. and J.W.

VII - **Tabor, G.,** Mann, N. and Williams, J. (2018) Spinal posture in horses with and without back pain. The 10th International Symposium of The Association of Veterinary Rehabilitation and Physical Therapy. Knoxville; USA (Poster).

Conceptualization, G.T.; Methodology, G.T and N.M.; Data Curation, G.T., N.M. and J.W.; Writing – Original Draft Preparation, G.T.; Writing – Review & Editing, G.T., N.M. and J.W.

Key to authors: G.T. – Gillian Tabor; J.W. – Dr Jane Williams; K.N. – Dr Kathryn Nankervis; J.F. – Dr John Fernandes; A.E. – Ami Elliott; N.M. – Natasha Mann; F.T. – Fiona Taylor; M.M. – Megan Merrifield-Jones.

Appendix 2: Credited Learning

Training completed:

Postgraduate Independent Project (UINV5D-30-M) 30 M level credits (Feb 2020)

Accredited learning:

- Details of module(s) of study passed for the course:
    - Postgraduate research Skills (BIO5124) University of Plymouth 20 M level credits
    - Contemporary issues in Biosciences (BIOL3303) University of Plymouth 20 M level credits
- UWE modules(s) against which accredited learning has been matched:
    - The Research Process (UINXKT-15-M) 15 M level credits
    - Postgraduate Independent Study (UINVL4-15-M) 15 M level credits

Researcher Skills Development Workshops

WELCOME to postgraduate research at UWE	9th April 2019
Quantitative Research Methods	30th October 2019
Statistical Reasoning	13th November 2019
Introduction to Doctoral Supervision: Pedagogy and Practice	15th January 2020
The Final Viva Examination	6th February 2020

No part of this submission has been submitted for another academic award

Appendix 3: Questionnaire (Paper I)

Introduction: I would like to invite you to take part in a research study looking at the use of outcome measures in equine rehabilitation. In this study I will be investigating how those involved with the treatment and training of horses measure the progress and outcome during a rehabilitation programme.
Please note that all information which is collected about you during the course of the research will be kept securely with the researcher. Any information which enters the public domain will be anonymised so that you cannot be recognized from it unless you wish to be publicly acknowledged. Questionnaire data will be held but information will be coded for anonymity. The results will be aimed for publication in an appropriate research journal.
It is up to you to decide whether or not to take part in this research. By filling out this questionnaire you are indicating your voluntary informed consent to participating in the research and also granting consent for the data obtained from this to be used and analysed over the course of the research study.

Question 1: Please state your qualification: ACPAT Chartered Physiotherapist / Veterinary Physiotherapist / Veterinary Surgeon / Osteopath / Chiropractor / Soft-tissuesTherapist / Trainer/Instructor / Other
Question 2: Which professional bodies, related to your work in equine rehabilitation, do you belong to?
Question 3: Where do you work?
Question 4: On average, how many horses do you work with per week?
Question 5: How many years have you been working / involved with equine rehabilitation?
Question 6: How would you define an outcome measure?
Question 7: Do you use outcome measures in practice?
Question 8: Please list the outcome measures you use:
Question 9: How do you select which outcome measure to use?
Question 10: What tools / equipment do you use to collect the data for the outcome measures?
Question 11: What are your reasons for not using OM in your practice?
Question 12: How frequently do you use outcome measures?
Question 13: What are your reasons for not using outcome measures in your practice?
Question 14: What are the benefits to using outcome measures?
Question 15: What are the barriers to using outcome measures?
Question 16: If you have any other comments you would like to make, please do so here: