CLINICAL PREDICTION RULES

FOR LOW BACK PAIN

Robin Haskins

B.Phty (Hons), Cred.MDT

Thesis submitted for the degree of

Doctor of Philosophy

The University of Newcastle, Australia

February 2015

STATEMENT OF ORGINALITY

The thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968.

……

Robin Haskins Date: 20/02/15

ACKNOWLEDGEMENT OF AUTHORSHIP

I hereby certify that this thesis is submitted in the form of a series of published papers of which I am a joint author. I have included as part of the thesis a written statement from each co-author; and endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications (Appendix 1).

……

Robin Haskins **Date: 20/02/15**

ACKNOWLEDGEMENTS

I would first like to acknowledge my supervisors Professor Darren Rivett and Dr Peter Osmotherly. Their support, expertise and generosity over these years has been sincerely appreciated. I am very proud of the work we have achieved together and acknowledge that none of it would have been possible without their flexibility, enthusiasm and commitment. Darren and Peter are highly regarded researchers, clinical experts and professional role models who will continue to inspire me.

I wish to also give my appreciation to Dr Erica Southgate and Dr Frank Tuyl for their respective expertise and mentoring in the fields of qualitative research methods and statistics. Erica and Frank were integral to the success of several aspects of this work and I sincerely thank them for their generosity, kindness and wisdom.

Thank you also to Dane Fehlberg for his assistance with screening and appraising the literature for the systematic reviews that form part of this thesis. His valued and tireless commitment to the long hours involved in study selection and quality appraisal is sincerely appreciated.

I also give thanks to my colleagues in Hunter New England Local Health District. Throughout my journey as a part-time research student, the flexibility and support I have received from Hunter England Health has enabled me to

remain working as a clinician. I genuinely appreciate the opportunities, assistance and encouragement they have provided to me.

Finally and above all, I wish to give my sincere appreciation to my beautiful wife Lauren. I thank her for her unwavering support and for maintaining my sanity throughout this journey. She is my best friend and I owe her everything.

PUBLICATIONS AND PRESENTATIONS

The following publications and presentations were a direct result of the work completed in this thesis:

Published papers

1. Haskins, R., Rivett, D. A., & Osmotherly, P. G. (2012). Clinical prediction rules in the physiotherapy management of low back pain: a systematic review. *Manual Therapy*, *17*(1), 9-21.
2. Haskins, R., Osmotherly, P. G., Southgate, E., & Rivett, D. A. (2014). Physiotherapists' knowledge, attitudes and practices regarding clinical prediction rules for low back pain. *Manual Therapy*, *19*(2), 142-151.
3. Haskins, R., Osmotherly, P. G., Southgate, E., & Rivett, D. A. (2015). Australian physiotherapists' priorities for the development of clinical prediction rules for low back pain: a qualitative study. *Physiotherapy 101*(1), 44-49.
4. Haskins, R., Osmotherly, P. G., Tuyl, F., & Rivett, D. A. (2014). Uncertainty in Clinical Prediction Rules: The Value of Credible Intervals. *Journal of Orthopaedic & Sports Physical Therapy*, *44*(2), 85-91.
5. Haskins, R., Osmotherly, P. G., & Rivett, D. A. (2015). Diagnostic clinical prediction rules for specific subtypes of low back pain: A systematic review. *Journal of Orthopaedic & Sports Physical Therapy, 45*(2), 61-76.

6. Haskins, R., Osmotherly, P. G., & Rivett, D. A. (2015). Validation and impact analysis of prognostic clinical prediction rules for low back pain is needed: a systematic review. *Journal of Clinical Epidemiology, 68*(7), 821-832.

Editorial

1. Rivett, D.A., & Haskins, R. (2009). Weighing up CPRs. *In Touch* (pp. 4). Victoria, Australia: Musculoskeletal Physiotherapy Australia, Australian Physiotherapy Association.

Published abstracts

1. Haskins, R., Rivett, D. A., & Osmotherly, P. G. (2011). Clinical prediction rules in the physiotherapy management of low back pain: a systematic review. In *APA Physiotherapy Conference 2011 Abstract Presentations,* Brisbane, Australia. October 2011.
2. Haskins, R., Osmotherly, P. G., Southgate, E., & Rivett, D. A. (2013). Physiotherapists' knowledge, attitudes and practices regarding clinical prediction rules for low back pain. In *APA Physiotherapy Conference 2013 'New Moves' Conference Abstracts*, Melbourne, Australia. October 2013.

Poster presentations

1. Haskins, R., Osmotherly, P. G., Southgate, E., & Rivett, D. A. (2013). Physiotherapists' knowledge, attitudes and practices regarding clinical

prediction rules for low back pain. e-Poster. *APA Physiotherapy Conference 2013 'New Moves',* Melbourne, Australia. October 2013.

2. Haskins, R., Osmotherly, P. G., & Rivett, D. A. (2015). Prognostic and prescriptive clinical prediction rules for low back pain: a systematic review. *World Confederation for Physical Therapy Congress 2015.* Singapore. May 2015.

Conference and other invited presentations

1. Haskins, R., Rivett, D. A., & Osmotherly, P. G. (2011). Clinical prediction rules in the physiotherapy management of low back pain: a systematic review. Oral presentation. *APA Physiotherapy Conference 2011.*Brisbane, Australia. October 2011.
2. Haskins, R., Rivett, D. A., & Osmotherly, P. G. (2011). Clinical prediction rules in the physiotherapy management of low back pain. Oral presentation. *Hunter New England Health Allied Health Research Forum*. Newcastle, Australia. October 2011.
3. Haskins, R. (2012). Clinical prediction rules for low back pain. Oral presentation. *Rural Spinal Seminar.* Tamworth, Australia. June 2012.
4. Haskins, R. (2012). Clinical prediction rules. Are we building better mousetraps? Oral presentation. *University of Newcastle Physiotherapy Seminar.* Newcastle, Australia. August 2012.
5. Haskins, R. (2013). Probabilistic reasoning and clinical prediction rules. Oral presentation. *Cessnock District Hospital.* Cessnock, Australia. June 2013.

6. Haskins, R (2014): Clinical prediction rules for low back pain. Readiness for clinical application. Oral presentation. *University of Newcastle Physiotherapy Seminar.* Newcastle, Australia. November 2014.
7. Haskins, R., Rivett, D. A., & Osmotherly, P. G. (2015). A systematic review of diagnostic clinical prediction rules for low back pain. Oral presentation. *World Confederation for Physical Therapy Congress 2015*. Singapore. May 2015.

TABLE OF CONTENTS

STATEMENT OF ORGINALITY ..... **II**

ACKNOWLEDGEMENT OF AUTHORSHIP ..... **III**

ACKNOWLEDGEMENTS ..... **IV**

PUBLICATIONS AND PRESENTATIONS ..... **VI**

LIST OF TABLES ..... **XIX**

LIST OF FIGURES ..... **XXIII**

LIST OF EQUATIONS ..... **XXVI**

ABSTRACT ..... **XXVII**

CHAPTER 1

INTRODUCTION **1**

1.1 Background and context 1

1.2 Structure of the thesis 6

1.3 Overview of the thesis 7

1.4 Delimitations 14

1.5 Significance and research aims 14

CHAPTER 2

LITERATURE REVIEW: LOW BACK PAIN **18**

2.1 Introduction 18

2.2 A brief historical perspective 18

2.3 The problem of low back pain 23

2.3.1 Epidemiology 25

2.3.2 Burden of disease 30

2.3.3 Economic considerations 36

2.4 Heterogeneity and diagnostic triage of low back pain 43

2.5 Sub-classification of low back pain 60

2.6 Summary 80

CHAPTER 3

LITERATURE REVIEW: CLINICAL PREDICTION RULES 81

3.1 Introduction 81

3.2 An overview of statistics in healthcare decision making 81

3.3 The clinical-statistical controversy 84

3.4 Clinical prediction rules 93

3.5 Development of clinical prediction rules 100

3.5.1 Derivation 101

3.5.2 Validation 106

3.5.3 Impact analysis 109

3.6 Methodological considerations 112

3.7 Readiness for application in clinical practice 115

3.8 Barriers to the adoption of clinical prediction rules 117

3.9 Clinicians' priorities and the need for a CPR 121

3.10 Summary 125

CHAPTER 4

CLINICAL PREDICTION RULES IN THE PHYSIOTHERAPY MANAGEMENT OF LOW BACK PAIN: A SYSTEMATIC REVIEW 127

4.1 Abstract 128

4.2 Introduction 129

4.3 Methods 134

4.3.1 Data sources and searches 134

4.3.2 Study selection 136

4.3.3 Data extraction and quality assessment 138

4.3.4 Data synthesis and analysis 141

4.4 Results 141

4.4.1 Study selection 141

4.4.2 Characteristics of included studies 142

4.4.3 Qualitative appraisal of included studies 159

4.5 Discussion 163

4.5.1 Summary of evidence 164

4.5.2 Methodological quality 168

4.5.3 Study limitations 170

4.6 Conclusions 172

CHAPTER 5

PHYSIOTHERAPISTS' KNOWLEDGE, ATTITUDES AND PRACTICES REGARDING CLINICAL PREDICTION RULES FOR LOW BACK PAIN 174

5.1 Abstract 175

5.2 Introduction 176

5.3 Methods 182

5.3.1 Design 182

5.3.2 Participants 182

5.3.3 Data collection 183

5.3.4 Data analysis 192

5.4 Findings 193

5.4.1 Knowledge 197

5.4.2 Attitudes 198

5.4.3 Practices / behaviours and implementation issues 202

5.5 Discussion 205

5.6 Conclusions 208

CHAPTER 6

AUSTRALIAN PHYSIOTHERAPISTS' PRIORITIES FOR THE DEVELOPMENT OF CLINICAL PREDICTION RULES FOR LOW BACK PAIN: A QUALITATIVE STUDY 210

6.1 Abstract 211

6.2 Introduction 213

6.3 Method 215

6.3.1 Design 215

6.3.2 Participants 216

6.3.3 Data analysis 217

6.4 Results 219

6.4.1 Participants 219

6.4.2 Types of LBP CPRs that physiotherapists wish to see developed 221

6.4.3 Physiotherapists' desired characteristics of LBP CPRs 224

6.5 Discussion 228

CHAPTER 7

UNCERTAINTY IN CLINICAL PREDICTION RULES: THE VALUE OF CREDIBLE INTERVALS 232

7.1 Synopsis 233

7.2 Introduction 234

7.3 Uncertainty in clinical prediction: credible intervals 236

7.4 Calculating the credible interval 239

7.4.1 Step 1 240

7.4.2 Step 2 242

7.4.3 Step 3 244

7.4.4 Step 4 244

7.4.5 Step 5 245

7.4.6 Step 6 246

7.5 Quick and simple approximations 249

7.6 A brief discussion on selected alternative methods..... 251

7.7 Future directions 252

7.8 Conclusion 255

CHAPTER 8

DIAGNOSTIC CLINICAL PREDICTION RULES FOR SPECIFIC SUBTYPES OF LOW BACK PAIN: A SYSTEMATIC REVIEW..... 256

8.1 Abstract..... 258

8.2 Introduction 260

8.3 Methods 263

8.3.1 Literature search..... 263

8.3.2 Study selection 266

8.3.3 Data extraction 268

8.3.4 Statistical analysis 268

8.3.5 Quality appraisal 269

8.3.6 Qualitative synthesis 272

8.4 Results 273

8.4.1 Search results 273

8.4.2 Characteristics of included studies 275

8.4.3 Qualitative appraisal of included studies 288

8.5 Discussion 293

8.5.1 Lumbar spinal stenosis 294

8.5.2 Inflammatory back pain 297

8.5.3 Methodological considerations 300

8.5.4 Limitations 301

8.6 Conclusions 302

CHAPTER 9

VALIDATION AND IMPACT ANALYSIS OF PROGNOSTIC CLINICAL PREDICTION RULES FOR LOW BACK PAIN IS NEEDED: A SYSTEMATIC REVIEW 304

9.1 Abstract 306

9.2 Introduction 307

9.3 Methods 310

9.4 Results 321

9.5 Discussion 367

9.5.1 Characteristics of included studies 367

9.5.2 The Cassandra rule 368

9.5.3 Five-item Flynn manipulation CPR 369

9.5.4 Two-item Flynn manipulation CPR 372

9.5.5 Methodological considerations 373

9.5.6 Limitations 375

9.5.7 Conclusion 377

CHAPTER 10

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS 379

10.1 Summary of findings 379

10.1.1 Research aim 1 380

10.1.2 Research aim 2 392

10.1.3 Research aim 3 396

10.2 Implications 400

10.2.1 Clinical implications 400

10.2.2 Research methodology implications 404

10.3 Limitations 409

10.4 Further research 412

10.5 Summary of thesis 415

APPENDIX 1 STATEMENTS OF COLLABORATION FROM CO-AUTHORS 419

APPENDIX 2 ETHICAL APPROVAL FOR STUDIES PRESENTED IN CHAPTER 5 AND CHAPTER 6 426

APPENDIX 3 INFORMATION STATEMENT AND CONSENT FORM FOR STUDIES PRESENTED IN CHAPTER 5 AND CHAPTER 6 433

APPENDIX 4 PUBLISHED PAPERS 438

REFERENCES 521

LIST OF TABLES

Table 1.1 Primary research aims 15

Table 2.1 Minimal definition of an episode of LBP for prevalence research as proposed by Dionne et al. (2008) 25

Table 2.2 Recommended definition of recovery from low back pain (LBP) and recurrence of LBP, as proposed by Stanton, Latimer, et al. (2009) 29

Table 2.3 Disability Weights for Low Back Pain (LBP) (with 95% confidence intervals) from Salomon et al. (2013) 32

Table 2.4 Top 10 health conditions contributing to Years Lived with Disability (YLD) globally and within Australia (Institute for Health Metrics and Evaluation, 2013) 34

Table 2.5 Top 10 health conditions contributing to Disability-Adjusted Life Years globally and within Australia (Institute for Health Metrics and Evaluation, 2013) 35

Table 2.6 Quebec Task Force's classification of activity-related spinal disorders as it relates to LBP (Spitzer, 1987) 45

Table 2.7 Red flag variables from the history and physical examination suggestive of serious spinal pathology (Delitto et al., 2012) 48

Table 2.8 Diagnostic criteria for lumbar discogenic pain and internal disc disruption using provocation discography (Merskey & Bogduk, 1994) 55

Table 2.9 Primary care research agenda from studies on attendees of the International Forum for Primary Care Research on Low Back Pain presented as rankings of priority (Borkan & Cherkin, 1996; Borkan et al., 1998; Costa et al., 2013) 61
Table 2.10 Diagnostic classification systems for chronic low back pain (adapted from Fairbank et al. (2011)) 71
Table 2.11 Prognostic classification systems for chronic low back pain (adapted from Fairbank et al. (2011)) 73
Table 2.12 Treatment-based classification systems for chronic low back pain (adapted from Fairbank et al. (2011)) 74
Table 3.1 Types of cognitive biases in human judgement as they relate to the process of diagnosis (adapted from Croskerry (2003)) 89
Table 3.2 Example of a diagnostic clinical prediction rule: The Ottawa Knee Rule (Stiell, Greenberg, et al., 1995) 97
Table 3.3 Example of a prognostic clinical prediction rule: The $ABCD^2$ score (Johnston et al., 2007) 98
Table 3.4 Techniques used to develop clinical prediction rules (adapted from Grobman and Stamilio (2006) and Adams and Leveson (2012)) 103
Table 3.5 Methodological considerations common to the derivation of all forms of clinical prediction rules 113
Table 3.6 Methodological considerations common to the validation of all forms of clinical prediction rules 114

Table 3.7 Methodological considerations common to the impact assessment of all forms of clinical prediction rules 115
Table 4.1 Database search strategies 135
Table 4.2 Diagnostic clinical prediction rules included in qualitative synthesis 145
Table 4.3 Prescriptive clinical prediction rules included in qualitative synthesis 150
Table 4.4 Prognostic clinical prediction rules included in qualitative synthesis 157
Table 4.5 Derivation study quality appraisal 160
Table 4.6 Validation study quality appraisal 162
Table 5.1 Literature-informed potential barriers to the adoption of LBP CPRs in physiotherapy practice 179
Table 5.2 Schedule of activities for focus groups 185
Table 5.3 Participant characteristics 194
Table 5.4 Summary of themes 196
Table 6.1 Participant characteristics 220
Table 7.1 Two-by-two table to obtain prevalence, sensitivity and 1-specificity 241
Table 7.2 Two-by-two contingency table derived from the data by G. E. Hicks et al. (2005) 242
Table 7.3 Two-by-two contingency table derived from the data by Flynn et al. (2002) 243
Table 8.1 Search strategy 264
Table 8.2 Study eligibility criteria 267

Table 8.3 Derivation study quality appraisal criteria 270
Table 8.4 Validation study quality appraisal criteria..... 272
Table 8.5 Characteristics of the diagnostic low back pain clinical prediction rules included in this review 277
Table 8.6 Risk of potential bias of included studies as appraised using QUADAS-2..... 289
Table 8.7 Methodological appraisal of included derivation studies... 291
Table 8.8 Methodological appraisal of included validation studies ... 292
Table 9.1 Study eligibility criteria 311
Table 9.2 Search strategy 312
Table 9.3 Derivation study quality appraisal criteria 318
Table 9.4 Validation study quality appraisal criteria..... 321
Table 9.5 Prognostic/prescriptive low back pain clinical prediction rules..... 325
Table 9.6 Risk of potential bias of included studies as appraised using QUIPS..... 361
Table 9.7 Risk of potential bias of included studies as appraised using PEDro 363
Table 9.8 Methodological appraisal of included derivation studies... 364
Table 9.9 Methodological appraisal of included validation studies ... 366

LIST OF FIGURES

Figure 2.1 Purported pathoanatomic causes of LBP described in 464 studies published in Deutsche Medizinische Wochenschrift from 1900 – 1999 (data from Lutz et al. (2003)) 22

Figure 2.2 Box plots detailing the median, interquartile range and 10% and 90% percentiles of the point, 1 month, 1 year and lifetime prevalence estimates of LBP from Hoy et al. (2012) 27

Figure 2.3 Australian hospital separations and average length of stay (days) for low back pain (ICD-10-AM code M54.5) from 1998-99 to 2011-12 (Australian Institute of Health and Welfare, 2013d) 38

Figure 2.4 Lower back injury workers' compensation claims resulting in absence from work $\geq$ 1 week in Australia from 2005/06 to 2010/11 (Safe Work Australia, 2013)..... 42

Figure 2.5 Rate of workplace back injuries per 1,000 employees in New South Wales, Australia from 1999/00 to 2008/09 (WorkCover New South Wales, 2010)..... 43

Figure 2.6 Proportion (95% CI) of patients with acute non-specific LBP presenting in primary care with pain at 1, 3, 6 and 12 months. Data from pooled results of Itz et al. (2013) 64

Figure 2.7 Standardised (0-100) mean pain outcomes (95% CI) in patients with acute and persistent non-specific LBP across 1 year. Data from pooled results of Costa et al. (2012) 66
Figure 2.8 Standardised (0-100) mean disability outcomes (95% CI) in patients with acute and persistent non-specific LBP across 1 year. Data from pooled results of Costa et al. (2012) 68
Figure 2.9 Hypothesised distribution of treatment effect and subgroup of responders (adapted from Foster et al. (2011)) 69
Figure 3.1 Growth of the clinical prediction rule medical literature. Unique records containing synonyms of ‘clinical prediction rule’ in the title or abstract across Medline, Embase, PsychInfo, and Amed 95
Figure 3.2 Illustration of a treatment effect that is modified by a patient’s status on a baseline variable 100
Figure 3.3 Stages in the development of a clinical prediction rule (adapted from Childs and Cleland (2006)) 101
Figure 4.1 Flow chart of search strategy and study selection 143
Figure 5.1 Case scenario 190
Figure 5.2 Examples of clinical prediction rules for low back pain 191
Figure 6.1 Summary of the types of LBP CPRs physiotherapists wish to see developed 218

Figure 6.2 Summary of physiotherapists' desired characteristics of LBP CPRs 219
Figure 7.1 The relationship between pre-test probability and post-test probability for specified likelihood ratios. The slope of each curve illustrates the degree to which variation in the pre-test probability influences the post-test probability. 238
Figure 7.2 R syntax commands and output for the calculation of the posterior probability 95% credible interval using the objective Bayesian method with Monte Carlo simulation. (A) Stabilization-exercise CPR example data. (B) Lumbopelvic thrust manipulation CPR example data. 248
Figure 8.1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study selection flowchart for systematic review of diagnostic clinical prediction rules for low back pain..... 275
Figure 8.2 Summary and scoring of 3 diagnostic clinical prediction rules for specific subtypes of low back pain that have undergone validation 295
Figure 9.1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study selection flowchart for systematic review of prognostic clinical prediction rules for low back pain..... 324

LIST OF EQUATIONS

Equation 2.1 Disability-Adjusted Life Year (Prüss-Ustün et al., 2003) 31

Equation 2.2 Years of Life Lost (World Health Organization, 2014b) 31

Equation 2.3 Years Lived with Disability (Prüss-Ustün et al., 2003) 32

Equation 7.1 Calculation of the posterior probability using Bayes' Theorem 235

Equation 7.2 Calculating the slope of the curve which illustrates the relationship between pre-test probability, likelihood ratio, and post-test probability..... 239

Equation 7.3 Defining the shape parameters of the beta distributions for prevalence, sensitivity and 1-specificity..... 243

Equation 7.4 Combining randomly drawn values for prevalence (P_0), sensitivity (P_1), and 1-specificity (P_2) 245

ABSTRACT

Low back pain (LBP) is prevalent, costly and a significant contributor to societal burden. It is not a single specific condition, but instead generally considered to be comprised of smaller more homogenous subgroups of patient presentations that meaningfully differ with regard to their symptomology, prognosis and responsiveness to different interventions. The identification of subgroups of patients with LBP is a research priority and several classification mechanisms have been proposed. Traditionally, such classification approaches have been predominantly based upon expert opinion and biologic plausibility, with little concordance among them. More recently, there has been a greater focus upon empirically derived subgrouping methods, notably including the development of clinical prediction rules (CPRs). A CPR is a clinical tool designed to be used with an individual patient, and is based on the statistical identification of a parsimonious composite of variables that facilitate the prediction of a given diagnosis or outcome.

The main objective of this thesis is to facilitate the development of CPRs with the greatest potential to positively influence the physiotherapy management of LBP. This was achieved through a series of five published studies and a published Clinical Commentary that together sought to address three primary research aims:

1. Identify and assess the degree to which CPRs for LBP may be confidently applied in clinical practice using a hierarchical framework for CPR development and an appraisal and synthesis of the existing evidence base.
2. Explore the range of factors that may influence the implementation of CPRs for LBP within Australian physiotherapy practice.
3. Examine the areas of perceived need for LBP CPRs and the range of characteristics such tools need to encompass to be considered clinically meaningful and useful within Australian physiotherapy practice.

Three systematic reviews were conducted which sought to synthesise the available body of evidence to; (1) identify CPRs relevant to the assessment and management of LBP; (2) assess the degree to which such tools may be confidently applied in clinical practice; and (3) identify opportunities to improve the methodological quality and reporting of LBP CPR development studies. The evidence considered within these reviews identified that a large number of diagnostic, prognostic and prescriptive LBP CPRs are under development, however the majority of these tools have not undergone validation and therefore cannot be recommended for direct use in clinical practice at this time. The current lack of impact analysis studies also prevents the assessment of whether the application of LBP CPRs in clinical practice results in beneficial effects on patient outcomes or resource efficiencies. A small number of LBP CPRs have undergone validation, such that clinicians may have some confidence in the predictive accuracy of these tools when applied in similar patient populations and settings. Further, several

opportunities to improve the methodological rigour of future CPR development studies have been identified.

Two qualitative studies using focus groups and involving a sample of Australian physiotherapists who manage patients with LBP were undertaken concurrently to address research aims 2 and 3. The findings of the first of these studies highlighted that physiotherapists' knowledge of LBP CPRs may be quite varied and few participants in that study reported having ever used them to inform their clinical decision-making. Barriers to the use of LBP CPRs included a negative connotation associated with the term 'rule', a perception that CPRs are overly-complex and infrequently applicable, clinical experience obviating the need for such tools, and the potential threat to clinical autonomy and for misuse by third-party payers. Physiotherapy participants felt that LBP CPRs were best used within the suite of clinical reasoning processes physiotherapists typically employ and considered as second opinions or safety nets that were able to be overruled by the clinician.

The findings of the second qualitative study indicated that prognostic forms of CPRs for LBP that function to predict future meaningful outcomes may be welcomed by practising physiotherapists. CPRs that identify likely responders to interventions are likely to be considered useful, as well as diagnostic forms of CPRs that function to identify serious causes of LBP such as fracture and cancer. CPRs that identify which patients are more likely to experience an adverse outcome or to not require physiotherapy intervention may also be welcomed by clinicians. Participants thought that LBP CPRs should be

uncomplicated, easy to remember, easy to apply, accurate and precise, and well-supported by research evidence. It was believed that LBP CPRs should not contain an excessive number of variables, use complicated statistics, or contain variables that have no clear logical relationship to the dependent outcome. It was further considered by participants that LBP CPRs need to be compatible with traditional clinical reasoning and decision-making processes, and sufficiently inclusive of a broad range of management approaches and common clinical assessment techniques.

A published Clinical Commentary was produced as a resource for clinicians and researchers based on findings arising from this research indicating the potential importance of the predictive precision of CPRs. The Clinical Commentary highlights the importance of considering uncertainty in clinical prediction, and provides a technical guide to the calculation and approximation of posterior probability uncertainty intervals. This and other study findings presented in this thesis have direct immediate implications for clinicians contemplating the application of LBP CPRs in clinical practice, and for researchers involved in the development of these tools. Opportunities for further research in this area have also been identified and are presented in the final chapter of this thesis. It is anticipated that consideration of the study findings in this program of research may support the development of CPRs with the greatest capacity to benefit the physiotherapy management of patients with LBP, and also strategies and future research projects designed to facilitate the successful translation of CPR research evidence into clinical practice.