EXPLORING INNOVATIVE REHABILITATION FOR THE KNEE USING EHEALTH, BIOFEEDBACK AND ONLINE COMMUNITIES

Thesis submitted at the University of Kent in fulfilment of the requirements of the degree for Doctor of Philosophy

by

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September 2017

(Word count: 42,591)

ACKNOWLEDGEMENTS

I would like to thank my supervisors, Karen, Mark and Sam, for their help and guidance at the various stages of this process. Karen; it was always a joy to discuss and collaborate on so many things. I would also like to thank colleagues at the University of Kent, SSES who assisted in providing time and resources: Kyra, Sadie, Mrs. T., James and Deanna. My gratitude goes out to my former students Jodie, Hannah and Lee for their extra efforts and application in capturing the exercise data. Thanks to the European School of Osteopathy for providing funding around the venture; Brenda Mullinger, Steven Bettles and the late Adrian Barnes were instrumental in securing this opportunity to support their vision for the ESO.

Personally, this has been a difficult journey over the duration of study; physical, mental and emotional challenges abounded. Thanks to my wife, George, for love and perseverance. Thanks to my boys, Joe and Ollie who shine daily and have achieved their own academic milestones with autonomy and grace. Thanks to Hazel and Graeme for the writing refuge of the Urban Café and free coffee ‘n’ cake. Lastly, I dedicate this work to the members of my family who will sadly not see this achievement. Mum, Dad and my brother, Charles John Bright; my role model, early mentor, motivator and co-instigator in corny jokes. The process was in tents! I hope this serves to honour your memory in some way.

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LIST OF ABBREVIATIONS

ACL	Anterior cruciate ligament
MCL	Medial collateral ligament
PCL	Posterior cruciate ligament
ACI	Autologous chondrocyte implantation
ACR	Articular cartilage repair
MACI	Matrix-induced/assisted autologous chondrocyte implantation
CMS	Coleman Methodology Score
OA	Osteoarthritis
MSK	Musculoskeletal
TKR	Total knee replacement
PRP	Platelet-rich plasma
NICE	National Institute for Health and Care Excellence
ACR	Articular cartilage repair
CCI	Characterised Chondrocyte Implantation
SORT	Strength of Recommendation Taxonomy
GCP	Good clinical practice
OATS	Osteochondral autograft transfer system
NHS	National Health Service
QAA	Quality Assurance Agency
CSP	Chartered Society of Physiotherapists
GOsC	General Osteopathic Council
GCC	General Chiropractic Council
SST	Society of Sports Therapists
CDSS	Clinical decision support system
OHC	Online health community
QOL	Quality of life
EMG	Electromyography
PFPS	Patellofemoral pain syndrome
SAQE	Short arc quadriceps extension
VMED	Vastus medialis
GMED	Gluteus medius
VLAT	Vastus lateralis
GMAX	Gluteus maximus
MVIC	Maximum voluntary isometric contraction
BMI	Body mass index
WTH-R	Waist-to-height ratio
VMO	Vastus medialis obliquus

LIST OF PUBLICATIONS

Articles published in peer-reviewed journals:

Bright, P. and Hambly, K., 2014. A systematic review of reporting of rehabilitation in articular-cartilage-repair studies of third-generation autologous chondrocyte implantation in the knee. Journal of Sport Rehabilitation, 23(3), pp.182-191. https://kar.kent.ac.uk/id/eprint/57549

Bright, P., and Hambly, K., 2016. Exploring Cross-Curriculum Content of Undergraduate Musculoskeletal Therapy Courses Regarding Articular Cartilage; Implications of Surveying UK Healthcare Curriculum Providers. Journal of Musculoskeletal Disorders and Treatment, 2(1). https://kar.kent.ac.uk/id/eprint/57557

Bright, P. and Hambly, K., 2017. What Is the Proportion of Studies Reporting Patient and Practitioner Satisfaction with Software Support Tools Used in the Management of Knee Pain and Is This Related to Sample Size, Effect Size, and Journal Impact Factor?. *TELEMEDICINE and e-HEALTH*. https://kar.kent.ac.uk/id/eprint/65838

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Bright, P. and Hambly, K., 2018. Patients Using an Online Forum for Reporting Progress When Engaging With a Six-Week Exercise Program for Knee Conditioning: Feasibility Study. *JMIR Rehabilitation and Assistive Technologies*, *5*(1), p.e9. https://kar.kent.ac.uk/id/eprint/66865

EXECUTIVE SUMMARY OF THE THESIS

This thesis was supervised by Dr. Karen Hambly (University of Kent, UK) and co-supervised by Prof. Samuele Marcora (University of Kent, UK) and Dr. Mark Burnley (University of Kent, UK)

Knee pain is regarded as an inevitable outcome in an ageing population and subsequent management, treatment and rehabilitation may exacerbate demand on stretched health services globally. Knee pain can be influenced by a number of factors; gender, body mass, activity profile, arthrokinematics, patient biopsychosociology and predisposing injury or trauma. Treatment options are typically viewed as pharmacological and non-pharmacological. Exercise and physical therapy are key elements within the latter option, alongside surgical procedures. Knee pain sufferers may vindicate their condition through clinical diagnosis and shift of locus of control; compliance to exercise interventions can depend on the scope of this shift. Such values should be acknowledged when monitoring individualised progression in the management of knee pain. Technology may have a role to play in capturing and influencing compliance within the scope of knee rehabilitation.

The main aim of this thesis was to explore the use of innovative rehabilitation interventions for the knee that integrated eHealth, biofeedback and online communities. As this constitutes a complex scenario, this thesis has been reported using elements of the Medical Research Council (MRC) framework for the development and evaluation of complex interventions to improve health (Blackwood et al., 2010; Craig et al., 2008); notably the Preclinical (theory) stage, the Phase I (modelling) stage, and Phase II (exploratory trial). The findings further inform the options for rehabilitation around knee pain, encompassing latest generation techniques for addressing progressive joint disease and eHealth initiatives. These also included options for self-management and reporting that could be generalised to knee pain sufferers; an approach informed by the

exploration of the reported experiences of individuals engaging with an online health community for knee pain. The eHealth component of the thesis looked to explore the use of simple Web 2.0 solutions and readily available domiciliary equipment for efficacy and accessibility.

Preclinical - Theory stage

Three studies explored relevant design issues, rehabilitation and technological background prior to intervention development. The initial study explored whether the standard of the reporting of rehabilitation in articular cartilage repair studies involving third generation autologous chondrocyte implantation in the knee had improved since 2007. This contextualised the quality of reporting rehabilitation in the latest surgical studies in the area, using the Coleman Methodology Score (CMS) as an outcome measure. The consistent finding was that, while reporting scores had improved, the presence of a designated rehabilitator as an author was directly associated with a higher CMS for reporting rehabilitation elements. This highlighted a need for greater reporting of compliance in the field of prescribed protocols for knee management strategies and raised the question as to which musculoskeletal therapy the requisite rehabilitators could be drawn from.

Chapter 2 explored the scope of coverage of specific articular cartilage educational content, surveying UK musculoskeletal therapy undergraduate course providers. The aim was to determine if final professional award was an influence on coverage reporting. While no major differences were observed between therapies, generic reporting of standard rehabilitation approaches prevailed over specific surgical approaches to cartilage repair. The equivocal evidence around the latest generation of techniques was mooted as a reason. While low response was a critical factor, potential lack of exposure for advances in surgery determined that both patients and practitioners may need to engage with innovative modes of treatment in non-pharmacological knee pain approaches.

Chapter 3 sought to determine what technological interventions are used in the management of the dysfunctional knee. The aim was to explore satisfaction reporting on these interventions and establish if this related to reporting of sample size, effect size and listed journal impact factor. Practitioner and patient satisfaction with the eHealth technology, including telemedicine, biofeedback and clinical decision tools, was poorly reported. No pre-defined predictors were seen to influence the inclusion of satisfaction reporting; implicated studies revolved around function or pain outcome measures. Patient preferences were rarely explored in these eHealth initiatives suggesting that technical advancement was positively biased. This raised the question as to what would motivate knee pain sufferers to engage with such technology and to what end.

Phase I - Modelling stage

Components for intervention development were explored: Chapter 4 engaged with individuals joining the KNEEguru online health community to elucidate the role of online initiatives in mitigating response to knee pain. Using a mix of quantitative and qualitative approaches, participants' responses to a questionnaire regarding their backgrounds and motivations were analysed. The major finding was that social network use was associated with sharing experiences and outcomes of knee pain. Individuals were able to rationalise their emotive knee issues through the forum and validate their predicament. This suggested that clinician-moderated, online environments could have a role to play in mitigating the effects of knee pain.

Consequently, a simple and novel solution was conceived to enable patients to report change around their knee condition. The use of bathroom scales as an outcome measure has been explored in respect to graded weight bearing. Further validation was required to establish the reliability of using this equipment as a potential outcome measuring strength. Chapter 5 validated the agreement between electromyography and dynamometry measures of quadriceps and gluteal muscles in short arc quad and seated clamshell exercises augmented by the use of bathroom scales.

This provided evidence that electromyography data was consistent when comparing the exercises with and without the scales. The force reporting was also significantly associated with dynamometry readings.

Phase II - Exploratory trial stage

Phase I findings informed the approach for Chapter 6; a randomised, experimental study into the effect of biofeedback on quadriceps and gluteal generated force when used as an adjunct to the aforementioned hip and knee exercises. In a sample of moderately active students, calculated standardised effect sizes were found to be comparable to other exercise studies; a large effect was seen in the arm exercising without biofeedback. Compliance was well-reported in the biofeedback arm which suggested a potential issue with dosage over the six weeks of the study.

Further elucidation was provided within Chapter 7, the final study, where feasibility of using an online forum was investigated to facilitate community engagement with the biofeedback exercise programme. This encouraged participants to openly report progress, experiences and adverse effects from exercising. Bathroom scale-derived force measures were posted that enabled single subject analysis to be conducted, demonstrating individual conditioning responses. Commentaries provided indicated that participants felt the need to rationalise wavering progress based on mitigating factors such as injury and pain. The online forum provided an effective tool for measuring compliance, and facilitating individualised data that has meaning to participants outside of meta-analysis.

In conclusion, the original work of this thesis increases the body of knowledge in terms of viable home-based exercise and Web 2.0 eHealth approaches to managing knee pain. The findings offer alternative measures for use in the clinical practice of physical therapists, sport rehabilitation professionals and researchers. Further work is required in terms of applicability to symptomatic knee pain sufferers, pre-operative patients and strength monitoring within ongoing clinical trials. This may warrant inclusion in a range of knee conditions or procedures that require prehabilitation, rehabilitation or post-surgical care. The key reporting of important change back to individual patients and the satisfaction of this engagement also demands further exploration.

GENERAL INTRODUCTION AND LITERATURE REVIEW

1. Knee function and dysfunction

The knee is a complex joint that facilitates bipedal ambulation and weight bearing and contributes to the distinguishing physical characteristics of humans (Lovejoy, 2007). The anatomy determines the function of the joint and the multifactorial orientation of structures promotes flexibility of movement but also implicates a complexity of injury (Gaillard et al., 2015). Identifying impaired structures can be challenging and sufferers of knee pain face uncertainty of diagnosis and treatment options based on severity of injury and individual perspective (McAlindon et al., 2014). The arthrokinematics are determined by the congruency of the bicondylar structures, shock-absorbing menisci and balance of the soft-tissues controlling movement at the joint (Hoshino and Tashman, 2012). Knee joint anatomy is considered to be a non-modifiable factor in terms of predisposition to injury, and biological gender-specific nuances contribute to this risk (McLean et al. 2010; Dargel et al. 2011).

1.1 Knee pain

Knee pain is, reportedly, a global concern; estimates suggest that prevalence of degenerative knee joint issues are approximately 4% (Cross et al., 2014), and 70-90% of anterior knee pain sufferers have chronic symptoms (Sanchis-Alfonso and Dye, 2017). The concept of knee pain can be defined by implicated structure and dysfunction, relative location within the anatomical joint boundaries (bony and soft-tissue landmarks), and temporal profile (Brukner, 2012).

Altered joint structure can impair the biomechanics of the knee, with the potential for injury and long-term alteration of arthrokinematics and loading of the joint (Bohnsack et al., 2009; Woo et al., 2006; Gaillard et al., 2015). Increasing pain arising from long-term structural change is viewed as the predominant indicator for selective surgery (Beswick et al., 2012). Triangulation of knee pain quality and quantity is required to inform patient and practitioner shared-decisions around treatment and management.

The scope for definition of pain implicates the associated knee outcome measures used in clinical studies. Generic measures, such as the numeric rating scale (NRS), and visual analog scale (VAS), provide potential for contextualization with the impact of other conditions on pain processing, and minimal important difference reporting (Hawker et al., 2011). These may lack a nuanced sophistication due to their unidimensional representation of pain, but arguably provide a pivotal measure to facilitate triangulation. Specific knee measures afford further sensitivity, and can be condition-focused (Howe et al., 2012). Validated instruments refine knee pain into further domains informing pathology and pain-related activity: osteoarthritis (The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)); ligament injuries (Lysholm, Tegner); meniscal lesions (Western Ontario Meniscal Evaluation Tool (WOMET)); patellofemoral pain (Anterior Knee Pain Scale (AKPS)); generic knee conditions (Oxford Knee Score, American Academy of Orthopaedic Surgeons (AAOS) Hip & Knee Score, Knee injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC)) (Filipe Santos-Magalhaes and Hambly, 2014; French et al., 2010; Howe et al., 2012; Watson et al., 2018).

The scope for these measures to represent a central tendency that indicates relatable, and reliable, pain threshold reporting is variable. Large effect sizes are generally reported for changes in each outcome, related to temporal profile (Collins et al., 2011), but patient-acceptable symptoms are not fully qualified.

Mid-points on these various scales can provide indicative threshold pain reporting, but shifts in central tendency may be relative to regional lesions or conditions of the knee (Arendt-Nielsen et al., 2010). The proposal for a knee pain definition for this thesis is, therefore, pain reported by recognised knee outcome measures, exceeding a mid-point on this scale measure, affecting any bony or soft-tissue structure, recognised as pertaining to the knee; the tibiofemoral joint, patellofemoral joint (Flandry and Hommel, 2011), proximal tibiofibular synovial joint and related capsule (Jabara et al., 2014).

1.2 Mechanisms of injury and conditions

The knee's complexity of structure predisposes a range of dysfunction and injury (Blalock et al., 2015). The problems encompass sprains/strains, anterior knee pain, menisci or cartilage damage, osteoarthritis (OA), tendonitis, bursitis (prepatellar, pes anserine, semimembranous, infrapatellar, iliotibial or popliteal), torn/ruptured ligaments or tendons; any of which could predispose haemarthrosis (NICE, 2011). The basis of injury mechanism can be activity-related in the young and sporting populations: ligamentous and soft-tissue knee trauma are common in sports requiring pivoting actions such as football and basketball (Bahr and Krosshaug, 2005); contact sports such as club-level rugby and American football accrue between 12 and 21% of all injuries as knee-related sprains, dislocations and fractures (Willigenburg et al., 2016). The mechanisms at play may be analogous to the coupled shearing and lateral bending forces implicated with pedestrian knee injuries in road traffic accidents (Mo et al., 2013). The biomechanics of functional and dysfunctional loading through the joint are common, and important factors (Suri et al., 2012).

OA may be the long term sequelae of knee trauma; Hip and knee OA is ranked 11th in terms of global disability with knee OA showing greater prevalence in the population (Cross et al., 2014). Patients with trauma or disease-related knee disability are likely to suffer excessive loading of the structures at the knee due to the mal-alignment of the mechanical axes of femur and tibia (Heller et al., 2003; Maly, 2009). The sequelae of this can be further cartilage degradation, joint space narrowing, osteophytic growth, subchondral sclerosis and increased OA biomarkers such as C-terminal telopeptide of type II collagen (CTX-II) and cartilage oligometric matrix protein (COMP) (Ishijima et al., 2014). The complexity of further comorbidity is an additional factor that demands consideration; chronic metabolic, cardiovascular and respiratory diseases are reported as common alongside knee disability (van Dijk et al., 2008), influenced by the reciprocal relationship with obesity (Roberto et al., 2015). The limited sample size sourcing van Dijk et al.'s observation, and topographical profile of the study's locale, limit external validity. Age is considered to be a confounding factor in considering comorbid effects on knee dysfunction, but obesity is seen as the biggest modifiable factor, trebling the risk of developing OA (Suri et al., 2012). Indication of association in these studies (Gill et al., 2017), rather than causation, suggest a range of biopsychosocial factors may account for the variance in physical activity. Limitations based on the cultural and environmental factors also affect generalisation; the relative limited physical and health literacy of any given population could be a vital contributory factor (Edwards et al., 2018).

2. Treatment and Rehabilitation of the Knee

2.1 Treatment options

Treatment is typically split between non-surgical and surgical options (Zhang et al. 2007). Non-surgical treatment is further divided into pharmacological and non-pharmacological interventions (Zhang et al., 2010). Non-pharmacological approaches include: education; knee strengthening; water-based exercise; weight reduction; transcutaneous electrical nerve stimulation; Ultrasound. Pharmacology includes: Acetaminophen; non-steroidal anti-inflammatories (oral and topical); topical capsaicin; opioids; intra-articular corticosteroid and hyaluronic acid injection (Zhang et al., 2010). The non-surgical, conservative treatment of knee OA is reportedly underused due to perceived barriers around use of physical therapy, lifestyle and dietary advice (Hofstede et al., 2016).

As a non-invasive, non-pharmacological approach, resistance exercise is determined to be beneficial for reducing pain and stiffness while improving physical function in OA knee patients (Li et al., 2016). There may also be application for increasing activity levels in the management of other knee conditions (Kwee et al., 2016) and those patients with additional comorbidities (de Rooij et al., 2016). Recent recommendations describe the ongoing need for further research into non-pharmacological and non-surgical interventions with a focus on guidance and lifestyle modification (Fernandes et al., 2013). This may be further warranted given the year-on-year increase in knee replacement surgeries (Carr et al., 2012), but it is not clear how strongly associated these rates are with population expansion, longevity increase or physical and health literacy (Kabel et al., 2015; Lee et al., 2004). Cost-effective, accessible initiatives, underpinned by wider awareness of knee pain management, would seem warranted.

Intra-articular hyaluronic acid injections are also reported as a safe, non-surgical option, with favourable patient global assessment and high satisfaction outcome scores, although publication bias may be influential with this product and pain modulation is limited (Mcarthur et al., 2012). Corticosteroid and platelet-rich plasma (PRP) knee injections may provide patients with effective analgesia lasting months, but patient-reported side effects are systemic hyperglycemia, septic arthritis, and joint degradation (Richards et al., 2016). The placebo effect is strongly implicated in these injection-based interventions and may only appease short-term patient expectations (Saltzman et al., 2017). This contrasts with the nocebo effects seen with certain pharmacological interventions; topical anti-inflammatory gel is favoured by OA knee patients over tablet variants, avoiding the reported and publicised side effects of the oral counterpart (Baraf et al., 2011). Patient preference and individual responsiveness have to be considered in prescribing such interventions, given the modifiable psychosocial factors that underpin pain in musculoskeletal presentations (Booth et al., 2017).

Mainstream surgical options can be divided into open or arthroscopic, and be structure-specific (repair/reconstruction or replacement procedures). Common repairs and reconstructions include the anterior cruciate ligament (ACL) grafts (Irarrázaval et al., 2016), and, more recently, meniscus (Getgood et al., 2009), and articular cartilage defects (Simon and Jackson, 2018). The options of biological engineering and stem cell proliferation are becoming more established in treating these chondral and sub-chondral lesions (Makris et al., 2015). (The derivative elements within this field are further covered in the next sub-section and Chapter 1). There is some way to go to usurp the mainstay of open procedures, knee arthroplasty, which can be unicompartmental (medial, lateral, or patello-femoral), or a total knee replacement (TKR) (Carr et al., 2012). This procedure has reportedly good pain outcomes (5 times the minimal, minimum clinically important difference in the UK (Edwards et al., 2018)), with future projection suggesting exponential increase in procedural use commensurate with obesity incidence (Culliford et al., 2015). There is still indication that successful, long-term outcomes of TKR are mitigated by social deprivation and inequality (Edwards et al., 2018), potentially a common limiting factor in any knee pain management strategy.

Arthroscopy has been routinely conducted for debridement and meniscectomy since the 1980s (Salzler et al., 2014), but more recent guidance and review suggest deleterious effects outweigh the benefits (Siemieniuk et al., 2017; Thorlund et al., 2015). There is potentially a three-fold increase in likelihood of undergoing a knee replacement (Rongen et al., 2017), and propensity for ongoing neuropathic pain (Valdes et al., 2014). While modifiable and non-modifiable factors were considered equal in comparative cohorts in the Rongen et al. study, the propensity for surgery to beget further surgery can be attributable to cultural and social influences on the patient (Jasinski et al., 2017); this may be exacerbated by inappropriate, risk-tolerance attitudes in surgeons (Bruinsma et al., 2015; Kadzielski et al., 2015). Surgery should still be viewed as selective rather than elective; potentially avoidable and an end-stage solution once all other options have been exhausted (Carr et al., 2012).

2.2 Rehabilitation and repair

Typically rehabilitation is seen as a process that takes place following injury or surgical intervention to address impairment of body function (Escorpizo, 2014). Current approaches would extend that to pre/post-operative condition or injury prevention/recovery with a view to engage with activity built on a structure/function reciprocity (Whyte and Barrett, 2012). The ideal outcome for this reciprocal arrangement would be mitigation of the global burden of musculoskeletal (MSK) conditions (Smith et al. 2014; Hoy et al. 2014). Mitigation of perception and contextualization is arguably vital when non-modifiable factors of healing response may induce anxiety in patients (Rajendran et al. 2012; Ringstad 2014).

The physical response to injury is dependent on the tissues involved; muscle damage can be defined as proximal, middle or distal by location and further qualified as intramuscular, myofascial, myofascial/perifascial or myotendinous with implications on the type of injury affecting healing rates (Järvinen et al., 2013). Muscle repair encompasses the destruction, repair and remodeling phases with the added complication of sarcopaenia and chronic low-grade inflammation increasing with age (Peake et al., 2010). Tendon injury can also follow this general phased response with added complications of tendinopathy due to pathological change in the collagenous and neurovascular tendinous structure. Tendon healing progresses through a short inflammatory phase (7-10 days) followed by a proliferative phase (11-60 days) and finally a remodeling phase of 3-6 months or longer. Optimal rehabilitation strategies depend on the particular muscle and tendon's function and environmental factors (Nourissat et al., 2015; Thomopoulos et al., 2015). Prognosis for return to full pre-injury function is equivocal but controlled mechanical loading is seen as vital in musculotendinous rehabilitation (Müller et al., 2015).

Ligaments can also offer challenges to recovery within the familiar phases of biological healing. As with muscles and tendons there is a tri-staged process: an inflammatory phase (7-10 days); proliferation phase (6 weeks to 3 months after trauma); remodeling/maturation phase (until 1 year after trauma) (van den Bekerom et al., 2013). Ligamentous injuries can range from mild sprains (grade I) through to rupture or full tear (grade III) often requiring surgical intervention. Rehabilitation principles, either post-surgery or acute response, require a strategy of: initial partial to full weight-bearing; passive and active mobilization; close chain and open chain exercises with progression; proprioceptive challenge and depending on activity levels, sports-specific drills and strength training (van den Bekerom et al., 2013; van Melick et al., 2016). Within the context of the knee, ACL lesions are the predominant ligamentous injury (20.3%), followed by MCL lesions (7.9%) while LCL lesions (1.1%), and PCL lesions (0.65%) account for the smallest proportions (Majewski et al., 2006).

Meniscal injury of the knee is reported as the most common injury with an incidence of 23.8/100,000 per year (Clayton and Court-Brown, 2008). The peripheral vascular and inner, avascular areas of the meniscus have distinct implications in terms of injury with diminishing vascularisation with age. The peripheral tear may respond to surgical repair (although equivocal results are currently reported) while prognosis for avascular injuries is generally poor, requiring meniscectomy (Makris et al., 2011). Physical therapy and rehabilitation around meniscal injury can follow a three-stage structured program to address inflammation, range of motion, concentric and eccentric muscle strength, muscle-length restrictions, aerobic conditioning, functional mobility, and proprioception (Katz et al., 2013).

Fracture injuries to the bony structures proximal to the knee joint are common in acute trauma cases but the elderly have increased risk of peri-articular fractures that may require total knee replacement (TKR) (Mallina et al., 2010). Rehabilitation requires early full weight-bearing to avoid complications of immobilization but complexity is added when other intra-articular structures are involved (Malviya et al., 2011). Articular hyaline cartilage lesions are the predominant bone and joint injury with a reported 63% of knees demonstrating chondral lesions (Falah et al., 2010). The capacity for intrinsic healing of these lesions is very limited as hyaline cartilage is an avascular and aneural tissue that defies hypertrophic differentiation of chondrocytes implicit in full ossification (Lee et al., 2012).

Strategies for repair range from clot-forming procedures (abrasion arthroplasty, subchondral drilling and microfracture), harvest and graft techniques (osteochondral auto or allo-grafting, autologous chondrocyte implantation (ACI) and matrix-induced ACI (MACI)), through to stem cell treatments (Autologous matrix induced chondrogenesis (AMIC)) (Falah et al., 2010; Richter et al., 2016). There is suggestion that the stem cell option now provides a treatment option for the Over 45s years with functional outcomes that are comparable to younger patients at final follow-up (Gobbi et al., 2017). While no one approach has unequivocal supporting evidence (NICE, 2017a), the rehabilitation is complex and multi-factorial; lesion size, gender, age, activity levels, comorbidity and biomechanics are all considerations. Tri-staged progression begins with protection and joint activation; phase two, progressive loading and functional joint restoration; phase three, concomitant activity restoration for the patient (Mithoefer et al., 2012). Untreated chondral lesions will likely degenerate further and develop into osteoarthritis, with full-thickness cartilage defects seemingly predictive of knee replacement surgery (Guermazi et al., 2016), preceded by long-term pain and sub-chondral bone changes (Barr et al., 2015).

The natural healing cycle of the various tissue components of the knee determines that non-pathological injury will be self-limiting, and any adjunctive therapy looks to optimise recovery where physiologically possible (Dwyer et al., 2015). This may require modifying activity behaviour and expectations in knee pain sufferers that can address the discord between knee pain symptoms, wellness perception and clinical evidence of impaired knee structure (Hamilton et al., 2017). There is general support for progressive exercise in the treatment and management of knee OA, improving activity levels, knee stability and pain management using appropriate outcomes (Knoop et al., 2013). Clinical outcome measures regarding function should be married to subjective patient perception in order to demonstrate nuances of attention bias; psychological improvements are noted with exercise (Booth et al., 2017), but further research is warranted on the impact of exercise and goal-setting for coping with knee pain (Maly and Robbins, 2014).

3. Patient experience

Within the UK, quality of care is defined within three domains: patient safety, clinical effectiveness and patient experience. The latter dimension is viewed as highly modifiable depending on the demonstrable influences of safety and effectiveness (Doyle et al., 2013). Guaranteeing patient safety requires conscientious leadership, engagement with patients' values and utilising evidence-led practice to show clinical effectiveness (Sammer et al., 2010). Viewed through the lens of knee pain, there are some key implications for patient care.

3.1 Patient perspectives

Prevention of knee problems is seen by non-sufferers as the responsibility of the individual with the role of society and exercise being potentially divisive (Ali et al., 2012). Initially the insidious onset of joint pain prompts a cautious behaviour modification in sufferers, that seemingly reduces disease development (Maly and Cott, 2009). Patients report the impact on quality of life as being the most severe effect of knee OA when there is failure to arrest progression; pain ranges from a mild background nuisance to intense and debilitating in nature (Hawker et al., 2008).

If TKR is the potential sequelae of OA and chronic knee pain, then one in five patients report dissatisfaction with the outcome of this procedure; seen to be strongly related to pre-surgical expectations and catastrophisation tendencies (Bourne et al., 2010; Riddle et al., 2010; Vissers et al., 2012). Patients reported better outcomes post-surgery in knee/hip injury when trust was explicit with the doctor involved (Black et al., 2014). This may have an effect when exploring advocacy for rehabilitation practice. Exercise with knee pain is reportedly safe, with high tolerance, but compliance is known to reduce over time, particularly if self-belief in a worsening prognosis is evident (Bennell and Hinman, 2011). Exposure to combinations of rehabilitative exercise, with educational strategies for patients, has reportedly modified negative attitudes and engagement with knee pain management, although participation bias may be a contributing factor (Hurley et al., 2010). This can be potentially enhanced by use of patient-driven goal-setting, with appropriate subjective and clinical outcomes (Rose et al., 2017).

This goal-setting may be influenced by long-held, but modifiable, patient behaviours, particularly with ‘risk’ activities such as sedentary lifestyle and poor dietary choices (Pronk et al., 2004). Expectations can then be driven by attitudes towards remaining active, fuelled by public health initiatives and changing perspectives as generations age (Phelan et al., 2004). The traditional viewpoints of growing old through a process of decline, deferring physical demands to the pursuits of the young, are now challenged (Katz and Calasanti, 2015). The drive towards ‘exercise as medicine’ (Pedersen and Saltin, 2006), and growing demand on the health services for non-communicable diseases, has ignited a desire to promote, and engage with, physical activity that straddles the class system (Hanson et al., 2016). With educational attainment and socioeconomic status seemingly an indicator of health autonomy (Wiltshire et al., 2017), there has also been the rise of the ‘worried well’, who misinterpret the context of symptoms and catastrophise as a consequence (Glasziou et al., 2013).

These individuals may hyperbolise the self-assessment of their presentation, but also their response to treatment, exacerbated by access to unfiltered medical information that drives anxiety (Newhouse et al., 2015). Participants’ choice of knee treatment can be influenced by their perceptions of adverse events, other comorbidities, nature of their pain and pertinent clinical guidance in this area (Carnes et al., 2008). These details are vital in an age of patient-informed choice, and shared decision-making, in which vicarious experience and beliefs may modify compliance to treatment. Landmark decisions, such as the Montgomery ruling in 2015, emphasise the importance of informed consent, negotiation and mutual understanding on the part of both patient and practitioner (Westlake et al., 2013). Sharing of information in this process is vital and interpersonal communication can, reportedly, have a direct impact on patient satisfaction (Al-Abri and Al-Balushi, 2014).

Patient satisfaction is seen as a potential means to improve quality of care but is suggestible, heavily influenced by expedient access to services; a US study detailing 11,000 responses from a large medical centre, indicated that wait times had a major deleterious effect on perceptions of treatment (Bleustein et al., 2014). Satisfaction monitoring is also influencing practitioner subservience to patient preference; recommendations for physical therapy as pain management are, reportedly, poorly received from patients, in the form of dissatisfied survey ratings, when they simply want “quick wins” with oral pain medication (Adams et al., 2016). The scope of assessing both patient and practitioner satisfaction in the clinical setting would offer further contextualisation, and eHealth measures may support this (De Rosis and Barsanti, 2016). This patient and practitioner dynamic warrants further investigation, particularly with technology interventions alleging to intensify patient participation (Dedding et al., 2011).

3.2 Patients and health technology support

Patients may rationalise their situation with their own meaningful ‘research’ data based on inherent values, or unqualified internet search strategies, and not just evidence based medicine (Hu and Shyam Sundar, 2010; Joseph-Williams et al., 2014). As such, clinicians need to engage with patient preferences for a combination of self-management strategies and healthcare interventions (Ballantyne et al., 2007). The growing area of eHealth and the smart-phone enabled, mobile device sub-classification of mHealth (Free et al., 2013), offer potential benefits in knee pain management. EHealth as a concept is constantly being refined, but can be summarised as an interface with medical and healthcare information, delivered or enhanced through the Internet and related devices or platforms (Boogerd et al., 2015). The concept of eHealth has also developed symbiotically with the progression of Web technology; Web 2.0, or the ‘read-write’ Internet, facilitates data-sharing (Choudhury, 2014), that would seemingly underpin the ethos of shared-decision making and informed consent. The Web 3.0 Internet platform development may allow ‘Big Data’ views of patients, with Artificial Intelligence informing decisions, but this is arguably conceptual at this stage. ‘Small data’, generated through wearable technology and biofeedback, may be more meaningful in relation to the individual patient’s perspective (Hansen et al., 2014).

Mobile technology has provided an extension to this view that has potential to provide global access to outcome capture and engagement, but it is unclear how cost-effective these strategies are (LeFevre et al., 2017). The World Health Organisation identified that minimal support exists in terms of software apps (smartphone applications) specific to knee pain or knee OA management (Martínez-Pérez et al., 2013). There is a need to explore how cost-effective interventions within the scope of eHealth or mHealth can further benefit patients suffering with knee pain. This technology can assist in taking the controlled exercise environment out of the laboratory, and into a pragmatic setting for those most in need, and avoid the so-called ‘efficacy trap' (Beedie et al., 2016). Internet resources can potentially provide a satisfying shared experience between patient and practitioner (regardless of patient age) with use of physical therapy eHealth resources in domiciliary settings (Shulver et al., 2017; Tousignant et al., 2011a).Exploring the use of further home-based measures, and patient reporting, including satisfaction, around these measures, is warranted.

In clinical rehabilitation scenarios, patients and practitioners concur that understanding cannot be achieved by just verbal instruction, and patients need to contextualise their progress and limitations (Ringstad, 2014). This contextualization may be possible through the use of online health communities (OHC) that offer platforms for sharing experiences in a clinician-moderated environment; these have been shown to be efficacious in chronic conditions such as Parkinson's Disease (van der Eijk et al., 2013). Challenges around the use described by van der Eijk include overcoming the traditional paternalistic model of patient-practitioner interaction; dissolution of this perceived anachronism would facilitate shared-decision making (Schickedanz et al., 2013).

Other barriers to wider adoption of OHCs are perceived around management and finance; cost-effective alternatives have not been readily reported that support clinician administration, or a distributed network of decision support (Gruzd and Haythornthwaite, 2013). There would also seem to be a potential burden or bias in ongoing management, where key authoritative members, with most influence in the OHC, are responsible for presenting 'best' evidence. The patient expectation of trustworthy information may be offset by the standing of experts in relation to the evidence hierarchy (Cassel and Guest, 2012; Légaré et al., 2012). Evidence around patient choice should be disseminated, weighed and appraised in collaborative open discussion, rather than presented as immutable dogma or 'cherry-picked' expert opinion. Empowering patients to have the belief they can question clinical decisions is key (Joseph-Williams et al., 2014); OHCs may provide the strength in numbers to enable patients to have this power.

4. Aims and Outline of the Thesis

The present thesis comprises seven studies divided into three stages in accordance with initial elements of the MRC framework: The first stage complied with the Preclinical, theory component consisting of three studies. These explored the state of reporting of rehabilitation in the latest approaches to knee pain including surgery, education and technology-based interventions with a view to identify confounders and design issues. The second modelling or Phase I stage consisted of two studies; one looked to establish the profile and motivations of users of an OHC for knee pain sufferers, the second looked to validate a biofeedback process to complement home-based exercises for the knee. This was to identify components of an intervention and potential prediction of outcomes. The final Phase II stage, consisted of a two-part, exploratory trial of a novel rehabilitation intervention using a bespoke OHC, biofeedback and eHealth. The aim of this phase was to assess feasibility and determine a suitable comparative intervention. The use of the initial components of the MRC framework provided an approach to identify and address further modifiable barriers to attaining physical activity targets recommended to offset or prevent knee pain.

The specific aims of each chapter were:

Chapter 1: To identify the standard of rehabilitation in studies dealing with third generation articular cartilage repair that report post-surgery follow-up.

Chapter 2: To investigate if UK musculoskeletal-related undergraduate physical therapy courses differ in specific articular cartilage content based on the final professional membership award?

Chapter 3: To determine the proportion of studies reporting satisfaction with software support tools used in the management of knee pain?

Chapter 4: To investigate the profile of individuals joining the KNEEguru online health community?

Chapter 5: To explore the electromyography and dynamometry profile of quadriceps and gluteal muscles in short arc quad and seated clamshell exercises with and without biofeedback?

Chapter 6: To determine the effect of biofeedback on generated force from quadriceps and gluteals when used as an adjunct to short arc quad and seated clamshell exercises?

Chapter 7: To investigate the feasibility of patients using an online forum for reporting progress when engaging with a six-week exercise programme for knee rehabilitation?

All study chapters are either published or are in the process of finalisation for submission. Furthermore, the published material resulting from this PhD can be found in the Kent Academic Repository (KAR).

PRECLINICAL

Theory: Exploring the state of reporting of rehabilitation in the latest approaches to knee pain including surgery, education and technology-based interventions.

CHAPTER 1: Has the standard of the reporting of rehabilitation improved in articular cartilage repair studies involving third-generation autologous chondrocyte implantation in the knee?

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Published in:

Bright, P. and Hambly, K., 2014. A systematic review of reporting of rehabilitation in articular-cartilage-repair studies of third-generation autologous chondrocyte implantation in the knee. *Journal of Sport Rehabilitation*, *23*(3), pp.182-191. https://kar.kent.ac.uk/id/eprint/57549

Introduction

Autologous chondrocyte implantation (ACI) is a tissue-engineered surgical technique initially developed for articular cartilage repair (ACR) of isolated chondral lesions of the knee. The first generation of cell transplantation for cartilage defect repair, described by Brittberg et al. (1994), was based on the implantation of a suspension of cultured harvested autologous chondrocytes, frequently sealed beneath a periosteal cover. Second generation ACI replaced this periosteal flap with a bilayer collagen membrane to reduce surgical morbidity (Marlovits et al., 2006).

Third generation ACI (ACI3) procedures are now available that deliver harvested, cultured chondrocytes into the chondral defect using selective cell carriers, cell-seeded or polymer scaffolds as a basis for proliferation (Bekkers et al., 2009). The Characterised Chondrocyte Implantation (CCI®) and Matrix-assisted (or induced) autologous chondrocyte implantation (or transplantation) (MACI®/MACT) are examples of two commonly performed ACI3 procedures in Europe. ACI3 procedures use minimally invasive incision techniques but may also deliver the chondrocytes arthroscopically (in accordance with country-specific medical regulation).

These approaches are generally 2-stage procedures differentiated by nuances in tissue engineering: CCI® is a selective process that uses a specific chondrocyte cell population that expresses an optimum scored marker profile (Saris et al., 2009). A particular resultant gene score is deemed predictive of a phenotype likely to form consistent hyaline-like cartilage. With the CCI® technique, only patients with a high potential for success based on the score receive their own implanted viable chondrocytes to repair defects (Vasiliadis and Wasiak, 2011). MACI® is one of the latest generation of ACI3 techniques that could claim superiority over microfracture and plug techniques for ACR (Brittberg, 2010). The MACI® requires a healthy cartilage sample taken arthroscopically from a non-weight-bearing area of the knee for chondrocyte cell culture and subsequent scaffold seeding.

The seeded scaffold is then implanted into a prepared cartilage-defect site through a miniarthrotomy (Filardo et al., 2013). This bioengineering technology deploys type I/III collagen membrane or hyaluronic acid (Hyalograft®) as a scaffold combined with the harvested chondrocytes to create a cultured, hyaline-like cartilage tissue that is proposed to improve surgical outcomes over first generation ACI (Filardo et al., 2013; Kon et al., 2012). Other ACI3 methods include the polymer-based scaffold, Bioseed-C® and the collagen gel chondrocyte carrier method of CaRes®; these are described as experimental with limited clinical data (Marlovits et al., 2006). Table1 provides a summary of the various ACI3 derivatives and the date the procedure first appeared in publication. New techniques that utilise scaffold-free, mesenchymal stem cell–based therapy are extending the scope of intervention, but these are being considered as fourth-generation techniques (Shimomura et al., 2017; Yasui et al., 2016).

ACI3 procedure	Culture medium	Date of first publication
MACI®	Collagen membrane	1998[1]
Hyalograft®	Hyaluronic acid	1999[2]
Bioseed-C®	Polymer	2001[3]
CCI	Collagen membrane[*]	2003[4]
Novocart3D®	Collagen membrane	2003[5]
CaRes®	Collagen gel	2006[6]
Cartipatch®	Hydrogel	2007[7]

Table1. ACI3 procedure summary.*

1 (Gillogly et al., 1998), 2 (Grigolo et al., 2002), 3 (Marlovits et al., 2004), 4 (Dell'Accio et al., 2003), 5 (Behrens et al., 2004), 6 (Andereya et al., 2006), 7 (Selmi et al., 2007) * As at 2013.

ACI3 is purported to reduce pain and dysfunction for a population classed as 'young patients with old knees' (Lohmander, 2008); achieving a successful clinical outcome invokes the envelope of function theory where optimum joint function correlates with optimum joint loading (Dye, 1996) and places dependency on appropriate rehabilitation after surgery. Effective rehabilitation programs are necessary for individuals to optimise recovery and avoid mechanical degeneration of the joint surface. The outcome and efficacy of ACI3 techniques relate to the pre-surgical and post-surgical patient care, with rehabilitation protocols currently based on the results of studies often involving other joint procedures (Hirschmuller et al., 2011). Rehabilitation programs generally present comparable aims of restoring muscle strength, re-establishing joint mobility and neuromuscular control and, with the appropriate compliance, facilitate the patients return to optimum function (Andrews et al., 2011).

Surgical interventions all incur initial detriment to structure and function due to their invasive nature (Uçkay et al., 2013). The rehabilitation that follows any orthopaedic surgery will include specific goals depending on the area of the body involved but is underpinned by established principles. For ACI3, this often follows regimes and protocols which are embedded in experience and basic science but may have no or limited levels of ratified evidence to support their inclusion in the rehabilitation process (Hambly et al., 2006). There are also a number of further considerations to take into account which may have implications for rehabilitation of the individual; location of defect, size and number of defects, previous surgery, age, general health, body mass index, symptomatology and activity levels (Ebert et al. 2013; Brittberg et al., 2003; Mithoefer et al., 2012).

The general understanding is that, where indicated, concomitant procedures will take place alongside the cartilage repair to optimise the surgical outcome for ACI3 (Brittberg, 2010).The success of ACI3 would then seem to be intuitively linked to the rigour of the associated rehabilitation process, but no trials have been completed to evaluate how differences in rehabilitative practice could influence knee pain and functional outcomes. Rehabilitation is lengthy, and there are limited data on return to sports and exercise activities after ACI3 in non-elite-athlete populations. The return to full function is based on graft cell quality (Pietschmann et al., 2009) and individual compliance (Stone and Schaal, 2012) coupled with other key patient characteristics. Studies indicate that outcomes from ACI3 are generally good with improvement in activity levels (Kreuz et al., 2011) but that some key rehabilitation components, such as return to full strength, may remain compromised up to five years post-surgery (Ebert et al., 2012).

The process to return to optimum function appears to be heterogeneous and the challenge for the rehabilitator is to ascertain how a generalised approach can be suitably tailored for the patient (Mithoefer et al., 2012).The relevant evidence for rehabilitation stages and modalities following ACI3 is limited: Studies advocate the necessity for individualized rehabilitation (Mithoefer et al., 2009) but existing protocols combine various phases, stages and modalities (Hirschmuller et al., 2011) that can make the reporting within studies a challenge. There is currently no review that provides a graded assessment of the quality of the reporting of rehabilitation described for ACI3. Rehabilitators should have an understanding of the standard approaches underpinning post-ACI3 surgery supported by evidence-based medicine; the practice of meeting the requirements of patients with the best evidence and critically appraising that evidence for its validity and clinical applicability (Sackett, 1997). The grading of the quality and applicability of this supporting evidence has not been established to date; to facilitate this would give the rehabilitator greater insight into the efficacy and reliability of the reported rehabilitation in ACI3 studies and potentially aid clinical decision making.

Jakobsen et al.(2005) found that ACI studies were generally low in methodological quality and recommended better quality design and reporting when instituting studies in cartilage repair. In particular, they stated that rehabilitation protocols are insufficiently detailed when appraised within trials and cohort studies. This was supported by low grading for this element in the Coleman Methodology Score (CMS) that was used to assess each paper in their review. The CMS provides a quality and limited bias reporting tool, in accordance with PRISMA, initially developed for orthopaedic studies reporting patellar and Achilles tendinopathy outcomes(Coleman et al., 2000), but modified to cartilage repair studies (Jakobsen et al., 2005). This grading component places particular emphasis on the description of post-operative rehabilitation, awarding points for clear established protocols and patient compliance. The review's conclusion was that a major improvement in methodological quality was necessary and, subsequently, caution has to be applied when interpreting the results from studies in the field of ACR (Jakobsen et al., 2005).

Aims & Objectives

The objective of this review was to answer the following clinical question: has the standard of reporting of rehabilitation improved in articular cartilage repair studies involving ACI3 to the knee?

The aim of this study was to establish if an increase in scored evidence was apparent compared to the previous reviews in the area which had investigated all elements based on the CMS (Jakobsen et al., 2005; Kon et al., 2009). A secondary question was: Did the presence of a rehabilitator or therapist in the investigative team have an effect on scores for the rehabilitation element in original research studies?

Method

Design: Systematic review

Procedure

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) and was comprised of a systematic literature search with data extraction and analysis.

Systematic Literature Search

For this review, a literature search was performed to identify all published, peer-reviewed clinical studies of third-generation autologous chondrocyte transplantation using the following medical electronic databases: MEDLINE, MEDLINE preprints, EMBASE, CINAHL, SciVerse, Pedro, Cochrane, EBSCO, PsycInfo and Google Scholar. The search period was January 1, 2007 to February 28, 2013 in order to extend the findings from the previous reviews primarily conducted by Kon (2009) and Jakobsen (2005). The medical databases were searched using combination of the AND/OR/NOT Boolean operators initially conducted with the following terms:

Articular cartilage repair; rehabilitation; protocol; chondrocyte; implantation; ACR; closed; open; arthroscopy; exercise; ROM; tibia; femoral; autologous; chondrocyte transplantation; patellar; hyaline; ACI; MACI; ACT; MACT; CCI; CCT; CaRes; Bioseed; sport; third-generation; knee.

The full search string was further refined, following an initial pilot, to:

(((("cartilage, articular"[MeSH Terms] OR ("cartilage"[All Fields] AND "articular"[All Fields]) OR "articular cartilage"[All Fields] OR ("articular"[All Fields] AND "cartilage"[All Fields])) AND ("wound healing"[MeSH Terms] OR ("wound"[All Fields] AND "healing"[All Fields]) OR "wound healing"[All Fields] OR "repair"[All Fields])) AND ("rehabilitation"[Subheading] OR "rehabilitation"[All Fields] OR "rehabilitation"[MeSH Terms])) AND ("chondrocytes"[MeSH Terms] OR "chondrocytes"[All Fields] OR "chondrocyte"[All Fields]))

AND (""implantation "[All Fields])

pub-date > 2006 and (articular cartilage repair) and rehabilitation

[All Sources(- All Sciences -)] pub-date > 2006 and MACT and rehabilitation

[All Sources(- All Sciences -)] pub-date > 2006 and (articular cartilage repair) and rehabilitation) AND (pubdate > 2006 and MACI) [All Sources(- All Sciences -)] pub-date > 2006 and CCI and rehabilitation

[All Sources(- All Sciences -)]

The presence of a rehabilitator or therapist in the investigative team was based on the qualifications assigned to the authors in the study detail. Where this was lacking, additional information was obtained from the International Cartilage Repair Society (ICRS) website and personal contact in order to avoid journal requirement bias.

Criteria for Selecting Studies

Any English-language, peer-reviewed study type which evaluated or described the process of third-generation autologous chondrocyte implantation in the knee and subsequent rehabilitation with a systematic programme (with or without outcome measures) was selected for primary review. Overviews of surgical procedures, protocols, abstracts, secondary analysis articles and conference proceedings were excluded. ACI3 Studies that detailed outcomes for surgery alone with no mention of rehabilitation were also excluded as were first and second generation ACI studies.

The search included all languages, but only English sources were evaluated. The studies in other languages were recorded when abstracts in English were available. In addition, the bibliographies of relevant studies and reviews on autologous chondrocyte transplantation were manually searched. This review process was divided between original research studies and review articles each assessed and reported via separate rating systems. The range of study designs for inclusion were systematic reviews, randomised control trials, low quality clinical trials, cohort studies, consensus guidelines and case-control studies.

Initial title screening and abstraction was conducted by the lead reviewer (PB) from a primary dataset produced from each database interrogation. Two reviewers (PB and KH), working independently, verified all reports for inclusion by combining all search returns in an Endnote (Version 14; Thomson Reuters, Philadelphia) library, removing duplicates, and short-listing by title and abstract. Full-texts were obtained if the titles and abstracts were indicative of inclusion criteria being met. Further exclusion processing was applied at full text screening by the lead author and this was verified independently by the second reviewer. Any discrepancies over inclusion were discussed and agreed. The study retrieval process was depicted using a PRISMA flowchart to indicate application of inclusion and exclusion criteria.

Assessment of Methodological Quality

The original research articles identified were scored separately using the CMS as modified by Kon and Verdonk with better sensitivity for the evaluation of cartilage repair studies (Kon et al., 2009). The methodological quality of the studies were assessed as per CMS criteria for (Part A): study size; follow-up; number of different surgical procedures; type of study; description of surgical procedure given; description of postoperative rehabilitation; MRI assessment; histological assessment. Part B assessed the elements of: outcome criteria; procedure for assessing clinical outcomes; description of subject selection process. CMS outcomes were determined for each study by both reviewers; Part A is scored out of a total of 75 points (only one score per item assessed), and Part B, can accrue a maximum 25 points for multiple criterion met (full CMS can be viewed in Table2).

***Part A**—only one score to be given for each of the eight sections*		**Score**
1 Study size—number of lesions	>60	10
	41-60	7
	20-40	4
	<20, not stated	0
2 Mean follow up (months)	>60	10
	24-60	5
	12-24	2
	<12 or not stated	0
3 Number of different surgical procedures included in each reported outcome. More than one surgical technique may be assessed but separate outcomes should he reported undergoing the one procedure	One surgical procedure only	10
	More than one surgical procedure, but >90% of subjects undergoing the one procedure, <10% concomitant procedures	7
	<90% of subjects undergoing the one procedure, >10% concomitant procedures and exact numbers on concomitant procedures are reported	4
	Not stated, unclear	0
4 Type of study	Randomized control trial	15
	Prospective cohort study	10
	Retrospective cohort study	0
5 Description of surgical procedure given	Adequate (technique stated and necessary details of that type of procedure given)	5
	Fair (technique only stated without elaboration)	3
	Inadequate, not stated or unclear	0
6 Description of postoperative rehabilitation	Well described	5
	Not adequately described	2
	Protocol not reported	0
7 Inclusion MRI outcome	MRI assessment • reported for >80% of patients	10
	• reported for <80% of patients	5
	• not reported	0
8 Inclusion histological outcome	Histological assessment • reported for >50% of patients	10
	• reported for <50% of patients	5
	• not reported	0
***Part B**—scores may be given for each option in each of the three sections if applicable*		
1 Outcome criteria (If outcome criteria are vague and do not specify subjects sporting capacity, score is automatically 0 for this section)	Outcome measures clearly defined	2
	Use of outcome criteria that has reported good reliability and sensitivity	3
2 Procedure for assessing clinical outcomes	Subjects recruited (results not taken from surgeons' files)	3
	Investigator independent of surgeon	4
	Completion of assessment by subjects themselves with minimal investigator assistance	2
3 Description of subject selection process	Selection criteria reported and unbiased	3
	Recruitment rate reported: *>80%; or	5
	*<80%	3
Source: Originally published in Kon E, Verdonk P, Condello V, et al. Matrix-assisted autologous chondrocyte transplantation for the repair of cartilage defects of the knee: systematic clinical data review and study quality analysis. *Am J Sports Med.* 37(Suppl 1):156S-166S. Copyright © 2009 by Sage. Reprinted by permission of SAGE Publications.		

Table2. Coleman Methodology Score Modified by Kon et al. and Verdonk et al. .

The interpretation of rehabilitation scores was: ‘Well-described’ criteria included a referenced protocol, with expanded description, which incorporated full staged progression including considerations of extenuating factors (i.e. age, gender, body mass index); ‘not adequately described’ criteria was a referenced protocol adopted, but no expanded commentary, lacking extended discussion of staging or extenuating factors (sample isolated text being; “rehabilitation was run in accordance with the protocol described by Mithoefer et al. (2009).” ; ‘protocol not reported’ criteria was brief rehabilitation overview without a referenced protocol or supporting evidence-base from the literature.

The review studies retrieved were assessed and rated according to the strength of recommendation taxonomy (SORT) (Ebell et al., 2004). This instrument has been extensively used in relation to sports-related injuries and associated scenarios (Bolgla and Boling, 2011; Casa et al., 2012; Harmon et al., 2013). The SORT level of recommendations, based on individual study designs within the reviews, can range from 1 to 3, with 1 indicating good-quality, patient-orientated evidence supported by the elevated hierarchy of the design; 2 indicates limited-quality, patient-orientated evidence; and 3 indicates non–patient-oriented evidence due to limitations in the design restricting generalisation.

The SORT strength of recommendations range from A to C and relate to the overall review standing; A indicates that the recommendation is based on consistent and good-quality, patient-oriented evidence in the review; B that it was based on inconsistent or limited-quality, patient-oriented evidence; and C that it was based on evidence other than patient-oriented evidence. The evaluation of quality can be gauged from highest (1A) to lowest (3C), although many studies only report the letter grading. The authors chose the alphanumeric rating in order to illustrate the range of study designs and scope of evidence within the area of ACI3, in accordance with practice adopted by McKeon and Hertel (2008).

The process for rating the quality of reporting was established a priori using these validated scoring systems and subsequently applied with particular emphasis on the surgical and rehabilitation descriptions in articles retrieved for review. The quality of reporting was assessed using the modified CMS and SORT ratings to allow for inclusivity of a potential broad range of study types. The first author (PB) performed the initial grading and analysis with corroboration of findings provided by the second author (KH) and an independent statistician.

Statistical analysis

Statistical analysis was limited to calculating mean values and standard deviation for the CMS, key surgical and rehabilitation elements and providing inferential examination of scores and author characteristics. Microsoft Excel was used to catalogue the various aspects of the studies, apply the CMS and SORT grading and report descriptive statistics. Evidence ratings were completed for inclusive studies using a tabulated format. Inferential statistics were calculated using the Excel-based Analyse-IT software (Standard Edition 3.15). The Mann-Whitney U test was used to compare CMS scores between studies, with a recognised rehabilitation therapist and those without, in relation to surgery and rehabilitation reporting. Odds ratios were used to investigate any predictive effects of rehabilitator involvement on high/low overall CMS in the original research studies; a high overall CMS was determined if it was greater than or equal to the mean overall CMS.

Results

A total of 117 articles were retrieved from the databases and exclusion criteria applied as depicted in Figure1. Twenty-nine studies were included in the final analysis; of these, twenty-two were original research studies with the remainder composed of review papers. The average CMS was 58 ± 13.9 (range 30-88). The SORT scores ranged from 3C to 1A with a mode of 2A. The elements of the CMS that were analysed inferentially and SORT scores are depicted in Table3 and 4 respectively. Table3 also contains a column with a ternary value to indicate: the presence of a rehabilitation therapist within the named authors of the studies; no rehabilitators included within the authors; qualification of authors unknown (see Appendix I for an expanded version of this table). Table4 contains the associated journal of publication illustrating an even spread of surgical, clinical and therapy based publications.

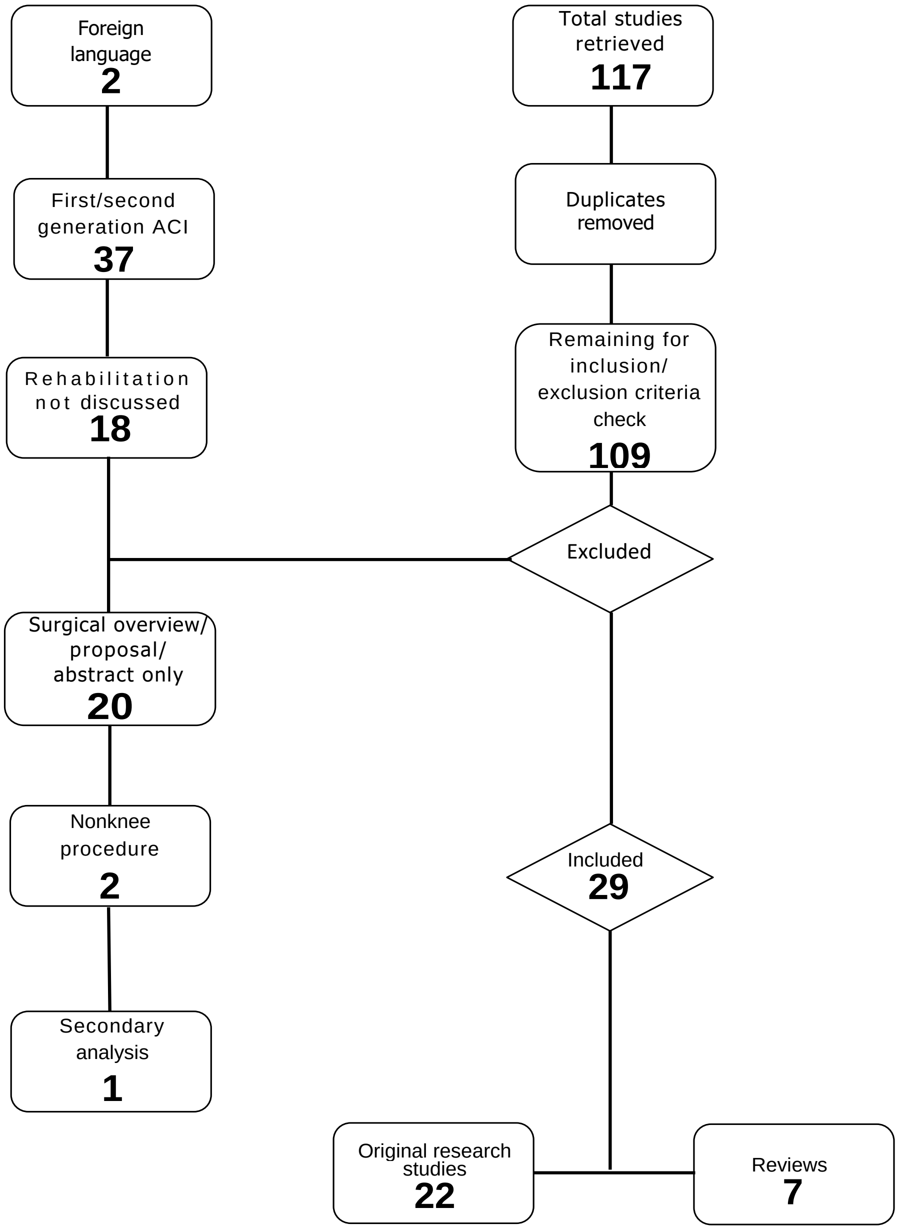

Figure1. PRISMA Flowchart illustrating study selection.

First Author/year	Overall CMS Score	CMS surgical description score (0-5 points)	CMS rehabilitation score (0-5 points)	Therapist involved* (Y/N/U) Proportion 11/9/2
Bauer, S. (2012)	49	5	2	Y
Clar, H. (2010)	30	5	0	U
Crawford, D.C (2012)	64	5	0	N
Crawford, D. C. (2009)	46	5	0	N
Dai, X. S. (2012)	50	5	0	N
Della Villa, S. (2010)	59	3	5	N
Ebert, J. R. (2012a)	63	3	5	Y
Ebert, J. R. (2012b)	88	3	5	Y
Ebert, J. R. (2010)	71	5	5	Y
Ebert, J. R. (2012c)	52	3	5	Y
Ebert, J. R. (2008)	72	3	2	Y
Gigante, A. (2009)	47	3	0	U
Kreuz, P. C. (2011)	50	3	2	N
Nehrer, S. (2009)	45	5	0	N
Niemeyer, P. (2008)	41	5	0	N
Saris, D. B. (2008)	63	0	0	N
Saris, D.B. (2009)	72	3	0	N
Van Assche, D. (2009)	41	0	5	Y
Van Assche, D. (2010)	71	3	5	Y
Van Assche, D. (2011)	63	0	5	Y
Vanlauwe, J. J. (2012)	65	3	0	Y
Wondrasch, B. (2009)	74	3	5	Y
Mean ± SD Standard error of the mean Median	58 ± 13.9 3 61	3.3 ± 1.6 0.4 3	2.3 ± 2.4 0.5 2	Mode Y

Table3. Study Coleman Methodology Scores.*Therapists included physiotherapist, physical therapist, sports therapist, sports physiologist, osteopath, chiropractor, exercise physiologist, rehabilitator.*

First Author (year)	***Journal***	***SORT* Evidence level**
Batty, L .(2011)	*ANZ Journal of Surgery*	*2A*
Carey-Smith, R. (2010)	*Techniques in Knee Surgery*	*3C*
Mithoefer, K. (2009)	*American Journal of Sports Medicine*	*2A*
Kalson, N. S. (2010)	*International Journal of Clinical Practice*	*2A*
Nho, S. J. (2010)	*Clinical Sports Medicine*	*3B*
Schindler, O. S. (2010)	*Orthopaedics and Trauma.*	*3C*
Strauss, E. J. (2011)	*Bulletin of the NYU Hospital for Joint Diseases.*	*2A*

Table4. SORT scores for review studies.

The total scores for surgical description when compared to described rehabilitation protocols (as seen in Table3) illustrates a clear difference in quality of the level of reporting between clinical outcomes and rehabilitation; using a total available score of 110 (5 [highest single score] x 22 [number of original studies]) the surgical grading equates to 66% as opposed to 46% for rehabilitation. Mann-Whitney U test established that there was no significant difference between the scores for surgery and rehabilitation ($P = .1$) and no difference between scores for studies that had a rehabilitator on the study team and a higher overall CMS ($P = .09$). The odds ratio for a CMS being higher than the mean score was calculated to be 3.33 (95% CI 0.51–21.58) in favour of studies with rehabilitators involved in authorship, despite the Mann-Whitney test outcome not showing significance ($P > .05$). However, Mann-Whitney U indicated a highly significant effect of rehabilitator involvement on high scores in the individual CMS rehabilitation element when comparing studies with designated rehabilitators with those without ($P = .0029$).

Discussion

The objective of this review was to determine the quality of the reporting of rehabilitation following ACI3 to the knee. The main finding was that while rehabilitation is described as a key element in ACI3, the CMS on reporting of rehabilitation in published studies is lower than that for the reporting of the surgical procedure. This was not seen to be significant in comparison of median values but a percentage score difference of 22 was found. Studies which state rehabilitation as an *a priori* focus alongside a minimum two-year follow up scored highly on the CMS; of the 6 studies reviewed achieving overall CMS above 70, 5 reported 2-5 year outcomes and only one failed to provide adequate detail on rehabilitation protocol. The emphasis on this higher-rated reporting was further reinforced by the finding that where therapists were involved in the authorship of the publication there was a significant effect on high individual CMS for rehabilitation assessment.

To put these results into perspective, Kon, Verdonk et al. (2009) stated that the mean CMS for the 18 studies reviewed in their paper was 53.1 ± 1.5 (range,49; 82-33) compared to the 58 ± 13.9 we report. This indicated a further incremental increase from the earlier review conducted by Jakobsen et al. (2005) of the quality of ACR studies; here the mean CMS was 43.5 ± 1.6 for 61 studies (using the original CMS, which scored rehabilitation out of 10). These previous reviews did not emphasise the rehabilitation component exclusively and were broader in the categorisation of ACI. The current review was more specific targeting the latest, third-generation, ACI process and while it is encouraging to see the numbers of quality trials increasing, rehabilitation is some way behind the reporting of surgical elements especially as 18 excluded studies had no consideration for rehabilitation. The quality of evidence for reporting rehabilitation procedures in original research is suboptimal which is further reflected in the pooled data in reviews and subsequent low SORT scores.

Jakobsen et al. (2005, p2237) determined that; *“detailed rehabilitation protocols should be established and reported. Attempts should be made to monitor compliance. The protocols should be applied in a standardized manner to both patient cohorts”*. The current findings demonstrate that this has begun to take place in the level of reporting rehabilitation in original research studies. The SORT grading for the review papers, however, reflects a lack of top quality recommendation to guide rehabilitators in post-operative care. Rehabilitators can take from this that it is not possible to report the highest level of recommendation to patients for the rehabilitation approaches described in the literature. This could be improved by the inclusion of rehabilitators in the research process with specific responsibility for overseeing the management and adherence to rehabilitation protocols; a pool of potential skilled rehabilitators and underlying core disciplines requires determination.

The measure of patient adherence to rehabilitation protocol, based on these findings, is an area of contention; typically used outcome measures reflect the functional aspect of the knee recovery but not rehabilitation compliance. Exercise compliance is typically stated as difficult to enforce (Stone and Schaal, 2012) but studies support methods such as diary maintenance as an effective measure (O'Reilly et al., 1999; Tagesson et al., 2008). The inference of returning function and clinical outcomes is that rehabilitation is incidental in the process of recovery. The ability to monitor how much of this recovery is due to the initial post-surgical care and short- and subsequent long-term rehabilitation is limited.

Areas for further work in this area would be served by combining a better delivery of evidence-based protocols with compliance monitoring tools. The scope for software tools to assist this process is broad (Sveistrup et al., 2003); expanding into the growth area of hand-held devices and tablet-based software applications for both patients and rehabilitators is a must. Broad electronic evidence assimilation could be provided in this manner, embracing a range of peer-reviewed journals, as opposed to the two or three rehabilitators may have access to; compliance management for all parties could also be facilitated by this approach in a community-based enterprise (Heinonen et al., 2012).

Adopting a standard protocol and adding the nuances that an evidence-based approach demand may be the future according to Van Assche et al.

(2011). While this will increase the quality of reporting of clinical trials, it may not be productive in the evaluation of optimal rehabilitative practice as standardizing rehabilitation eliminates variability in study designs. One adaptation based on the characteristics of the patient is timed duration of graded weight-bearing regarded as an area where good evidence exists (Ebert et al., 2012a). This should be expanded to include other modalities such as closed/open chain exercises, walking, cycling and hydrotherapy.

The trend is for individualization of rehabilitation based on clinical factors such as body-mass index, age, gender and type of defect. The suggestion from the SORT findings is that patients may be exposed to greater uncertainty in management strategies around knee pain. Doubts around advocacy for ACI3 as a viable option to address increased incidence of OA in the population may not engender public confidence (Biant et al., 2015). The patient experience and needs should be at the centre of this advocacy process; further qualitative lines of enquiry are required that investigate the lived experience of the individual and how the study participants' rehabilitation, pain management and function can be assessed and improved. The recent emphasis on patient reported outcome measures details their perceived improvement (Williams et al., 2012) but further qualitative research on rehabilitation specific measures for the patient would enhance our understanding of the patients' requirements.

Conclusion

Study authors should ensure that rehabilitation protocols and criteria for progression are explicitly referenced as a core element in manuscript preparation. Changes and adaptations with regard to individual requirements are needed as this review suggests that bespoke management is under reported; full compliance details should be included as part of the evaluation of outcomes to inform individual management. These are often alluded to in the literature (Hambly et al., 2006) but rarely reflected upon in trial data. The CMS provides a general overview of methodological quality but a more specialised tool to report on the quantitative and qualitative aspects of the rehabilitation process would assist in raising the standards. The patient experience within the rehabilitation programme is also an area requiring further investigation and any revised methodological scoring should take this into account.

The monitoring of long term rehabilitation should also be reflected in the scoring; rehabilitation outcomes should extend to a minimum of five years as good practice (muscle strength can still be deficient at this time-point (Ebert et al., 2012a)). The methodology scoring for this process would then be more specific to these requirements for quality trials and subsequently allow more rigorous rehabilitative reviews to be conducted. The involvement of a designated rehabilitation therapist in the design and implementation of studies and, crucially, in the authorship of the papers could potentially increase any revised rehabilitation score in future published studies. Identifying the suitable rehabilitator and their necessary credentials in musculoskeletal practice is implicated within this. Subsequent increase in the quality of individual original research studies should then be reflected in the grading scores of the summary SORT data for subsequent review studies. It is hoped that the future will provide further incremental progression in the overall quality of conducting and reporting of research, and specifically the rehabilitation component, in order to build upon the developing trend of improvement that our findings allude to.

CHAPTER 2: Do UK musculoskeletal-related undergraduate physical therapy courses differ in specific articular cartilage content based on the final professional membership award?

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Published in:

Bright, P., and Hambly, K.., 2016. Exploring Cross-Curriculum Content of Undergraduate Musculoskeletal Therapy Courses Regarding Articular Cartilage; Implications of Surveying UK Healthcare Curriculum Providers. Journal of Musculoskeletal Disorders and Treatment, 2(1).

https://kar.kent.ac.uk/id/eprint/57557

Introduction

Assessing curriculum content across undergraduate healthcare education providers can be challenging with various factors influencing the dissemination of core knowledge to support the key attributes expected in practitioners (Keiffer, 2015). The adoption of evidence-based good clinical practice (GCP) is difficult to gauge as are transition timescales of significant research into guidelines, frameworks and curriculum (Davis and Russ, 2015). The breadth of content within healthcare education over a broad range of disciplines would suggest heterogeneity in providers (Beach et al., 2005). A focus on a single clinical research interest and a subset of healthcare may provide indication of the variability of adopting standards into curriculum. Articular cartilage lesions are a major source of debilitation in the population as a precursor to OA (Ivkovic et al., 2014). The sequelae of this can be reduced range of motion, withdrawal from physical activity and lower quality of life (Cross et al., 2014). Exercise interventions for knee OA have been identified as a priority area for research (Rankin et al., 2012) and there are a number of articular cartilage repair (ACR) procedures available. Provocative techniques such as microfracture and Pridie drilling seek to stimulate cartilage regeneration while osteochondral autograft transfer system (OATS) and mosaicplasty look to transplant healthy cartilage from low-load areas (Donaldson et al., 2015). Cell-based treatments such as platelet-rich plasma (PRP) injections and defect-filling harvested or bioengineered chondrocytes have shown varying effectiveness (Bekkers et al., 2009; Campbell et al., 2015). Third and Fourth-generation techniques such as matrix assisted chondrocyte implantation/transplantation (MACI/T) and mesenchymal stem-cell repair (MSC) are being shown to have notable efficacy (through KOOS and VAS outcomes) over traditional invasive approaches (Saris et al., 2014; Yasui et al., 2016).

The procedures available for ACR are well-documented (Marcacci et al., 2013) but the lack of high-level evidence for outcomes prevents unequivocal recommendation from the National Institute for Health and Care Excellence (NICE) in the UK (NICE, 2005). Positive outcomes could rely on sufficient support from therapists providing staged rehabilitation protocols that respect the phases of repair, remodelling and maturation (Edwards et al., 2014). The current UK provision of post-surgical ACR rehabilitation is incumbent on therapists operating within a National Health Service (NHS) setting or private therapists. Protocols are in place based on basic science and empirical studies (Hambly et al., 2006); the knowledge transfer timescale from published guidelines to standard clinical practice is not currently quantifiable. This theory-practice gap may be attributable to inherent student mind-set and inability to synthesise classroom and clinical experience (Thomson et al., 2014). Quality improvements in US physical therapists management of the critically-ill indicated that this was attributable to appropriate, entry-level, curriculum content (Ohtake et al., 2013). The core-knowledge and awareness of handling articular cartilage lesions may have a similar foundation at the initial training available to UK musculoskeletal (MSK) therapists.

MSK medicine is established in UK undergraduate healthcare curriculum (Oluwajana et al., 2011); it is not widely reported as to how the subtlety of articular cartilage tissue quality, injury, repair and rehabilitation is taught at this level across disciplines with an MSK component . This understanding is the foundation for therapists working with ACR; a previous review detailed that the standard of studies for ACR were of a higher quality when a rehabilitation therapist was party to the authorship (Chapter 1). The demand on the availability of such therapists will increase as ACR procedures may become common place in an NHS setting (NICE, 2017b). Potentially rehabilitators can be sourced from a range of any qualified provider of MSK-related therapies with the advent of Commissioning Groups under recent UK health reforms (Jones, 2013). General Practitioners will have to respond to patients' informed choice given that the reported confidence of handling MSK conditions by GP's is low as a consequence of shifting priorities in medical school curricula (Wise et al., 2014).

The potential range of MSK providers may differ in terms of entry-level skill set and their practical application of curricula requirements. Comparative curriculum review across such a range of healthcare providers is challenging. In North America, the use of a Curriculum Inventory Standard to enable education programme comparison is being explored to mitigate the diversity in interpretation of requirements (Ellaway et al., 2014).

This suggests that inter MSK-related therapy course comparison is rare although assessment is implicit within UK-regulated individual healthcare degree-level course providers. The Quality Assurance Agency (QAA) for Higher Education (HE) establishes codes for educational provision and academic standards that are generic across degree-awarding institutions and partnerships (QAA, 2014). The course content itself is a reflection of the demands of the practice standards that govern the professional conduct of physical therapies with MSK-related treatment approaches: physiotherapy; chiropractic; osteopathy; sports therapy (CSP, 2010; GCC, 2010; GOsC, 2012; SST, 2008).

Stand-alone curriculum assessment can be multi-factorial in approach: conformity to standards; problem-based approaches; peer evaluation; student experience; course-review and baseline knowledge are key elements (Dombrowski et al., 2013; Hartup et al., 2010; Lisk et al., 2014; Panzarella and Manyon, 2007; Thomson et al., 2014; Wass, 2013). This reflection by research complements the QAA guarantee of HE quality and regulators enforcing curricula that instil gross base standards per institution. Modular content will then distil these standards through individual or sessional dissemination subjected to the interpretation of the course administrators and lecturers. Determining variability in interpretation in various MSK-related curricula for the management of singular conditions or topic areas, such as ACR, has not been explored.

Aims & objectives

The aim of this study was to complete a census to determine the coverage of articular cartilage-specific content within MSK-related undergraduate physical therapy curriculum. The research question was: *do UK MSK-related undergraduate physical therapy courses differ in specific articular cartilage content based on the final professional membership award?*

The primary objective was to explore how and where MSK-related therapies present articular cartilage topics within associated curricula, using a scored questionnaire, with a cross-sectional survey approach. This was with a view to possibly identify limitations in undergraduate curriculum content within specific physical therapy professions with MSK content and determine candidature for subsequent specific knowledge transfer initiatives.

Secondary objectives were to investigate the characteristics of the courses that report variable content in the consideration of articular cartilage; *a priori* selection of course duration, HE level for content delivery and course entry requirements were determined.

Alternative hypotheses:
There is a significant difference in the scoring of reported curriculum content regarding articular cartilage between undergraduate MSK-related physical therapies based on professional membership.

Method

Design: Cross-sectional survey using an online questionnaire.

Procedure
The study deployed an online questionnaire; the questions were developed in order to support the stated primary and secondary objectives. The instrument was developed in the Bristol Online Survey (BOS, University of Bristol 2014) software platform; the following summarises the sections and questions comprising the instrument (See Appendix II for full questionnaire including patient information and consent capture).

Section1 – articular cartilage
This was composed of 4 main questions that dealt with content of the MSK-related therapies' undergraduate courses. Questions 1-4 dealt with: ACR physiology (collagen type, lamina structure, chondrocyte proliferation and tissue repair (informed by: Arden and Nevitt, 2006; Blalock et al., 2015)); arthrokinematics (load bearing, stimulus, injury and defect implications (Heller et al., 2003); surgical techniques (OATS, MACI, microfracture and PRP/MSC (Bekkers et al., 2009; Falah et al., 2010; Marcacci et al., 2013)); rehabilitation (patient characteristics, surgical characteristics, protocols, outcome measures (Mithoefer et al., 2009)). Each was composed of four further sub-questions concerning the specific element coverage. Responses were scored with one point awarded for each cartilage element selected as

covered. Answers for ‘No’, ‘Not known’ or ‘Prefer not to say’ were scored as zero. The total maximum score possible for any single responder was 16.Each sub-question also enquired as to the positioning of ACR in terms of HE levels, and allowed for any other comments the respondents were willing to provide on the topic.

Section2 – course details

This required nominal details for the course offering in question, captured the following:

1. Title of the full-time musculoskeletal undergraduate course.
2. Qualification gained.
3. Awarding institution details.
4. Entry requirements.
5. Duration of the course.
6. Regulatory standards and professional competencies supporting course validation.

Participants

The Universities and Colleges Admissions Service (UCAS) online database was selectively searched to identify UK only HE course providers of musculoskeletal therapies. Excel (2010 v14, Microsoft) was used to store course website details and email addresses for delivery of the questionnaires. The curriculum course leaders and key personnel were identified through manual verification on individual university websites via course-specific content.

Inclusion/exclusion criteria:

Any tertiary educational establishments offering an undergraduate degree level programme in a regulated musculoskeletal therapy available on UCAS was included. This was drawn from the following disciplines with MSK-related approaches: physiotherapy, osteopathy, chiropractic and sports therapy. The courses had to be affiliated to professional, regulated bodies and map curriculum to practice standards. Any non-UK, non-degree, post-graduate, discontinued course was excluded despite relevance in the field. Contact email addresses were individually identified from staff databases available on open-access, institutional websites, in order to maximise the response and ensure correct individuals were targeted. Where individual course leaders in the areas of physiology, anatomy or rehabilitation were not readily known, programme leaders were identified as primary contacts. It was a requirement of the invitation to participate, that suitable contacts should be made known, and request forwarded, if individuals were wrongly identified in the first instance.

Distribution

Participants were invited via email (Microsoft Outlook Web App, v14.3) to complete the questionnaire using an embedded hyperlink to the instrument. Invitations were personalised based on the details of course personnel sourced as previously described. Subsequent email reminders to participate were sent at 3, 6 and 10 week intervals. The questionnaire was piloted amongst the teaching staff of the University of Kent and European School of Osteopathy unaffiliated with course provision; no revisions arose from the pilot. It was hoped to achieve a 95% response rate to comply with the census approach; 89 of 107 UCAS listed, potential participating institutions (UCAS, 2014). Recruitment took place between December 2014 and April 2015.

Ethics

Ethical consideration and approval was provided by the Research Ethics Committee of the University of Kent.

Statistical Analysis

Summary descriptive and inferential statistics were calculated; to determine potential differences between the various professions, characteristics of the HE providers/courses and mean rank answer scores, the Kruskal-Wallis test was run with pairwise Mann-Whitney U post-hoc testing. Non-parametric approaches were adopted as score levels were not expected to conform to a normal distribution, given the potential floor or ceiling effects with a restricted range of 17 (Ho and Yu, 2015). This also allowed for low response rates on the understanding that statistical inference would be limited in this scenario.

Statistical significance was set at a 5% threshold. All data were recorded and analysed using a combination of Excel to generate pivot tables and SPSS (v21, IBM) for non-parametric tests.

Results

Refinement (duplicate, foundation degree filtering and internet searches) of the 107 UCAS listed courses led to 76 participants identified as course leaders or primary course contacts and invited to take the questionnaire (physiotherapy: 34, sports therapy: 33, osteopathy: 6, chiropractor: 3). Eleven responses were received but only 10 were explicitly referring to undergraduate courses and suitable for analysis (13% response rate). The proportion of final qualification of the reported courses is represented in Figure2 and the regulatory bodies underpinning the individual curriculum can be viewed in Figure3.

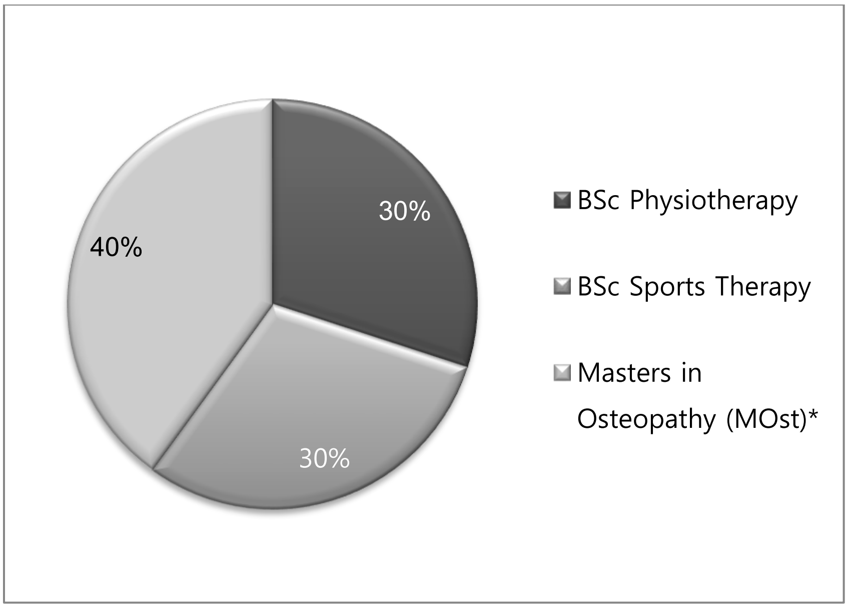

Figure2. Qualifications issued by respondent's institution.*Integrated Masters is an undergraduate programme

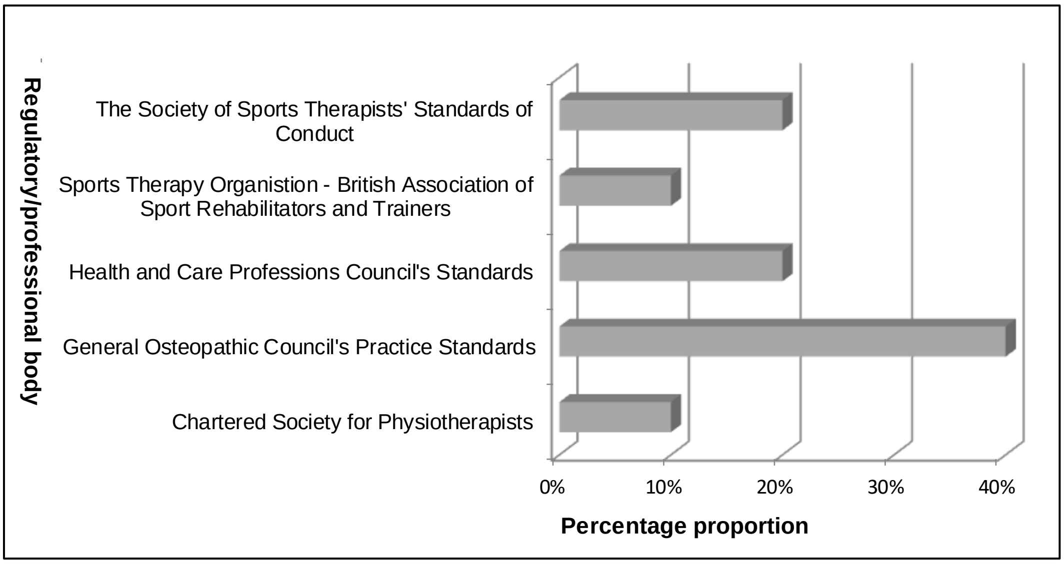

Figure3. Respondents regulatory practice standards supporting curricula.

The participants' course requirements ranged from AAB to BCC A-Level grades with generally lower entry requirements for the Masters in Osteopathy (MOst) (Table5); course duration ranged from 3 to 4 years with shorter longevity reported for the BSc programmes. Mean scores were: physiotherapy 11.33 (±4.16), sports therapy 13.67 (±3.21), osteopathy 8.5 (±2.89). No significant difference was found between content scores based on award or entry requirements, although median scores were seen to be higher (15 compared to 10 and 8.5) for the sports therapy programmes.

Final Awarded Qualification	A-Level entry range	Duration of course	Median Score	Inter-quartile range	P-Value
BSc Physiotherapy	AAB - ABB	3 Years	10	6.7	.21*
BSc Sports Therapy	ABB - BBC	3 Years	15	5.0	.66**
Masters in Osteopathy	BBB - BCC	4 Years	8.5	4.5	

Table5. Curriculum characteristics, questionnaire summary scores and levels of significance between groups.* Between awarded qualification/course duration. ** Between entry requirements.

Anatomy
Anatomy and physiology
Anatomy/MSK
Applied anatomy
Function dysfunction
Human sciences
MSK assessment and management
Orthopaedics
Osteopathic skills
Pathology
Pathophysiology and musculoskeletal diseases and disorders
Physiology
Physiology/anatomy/MSK
Sports Injuries and Rehabilitation
Structure function

Table6. Course titles representing ACR content.

The summary of coverage of articular cartilage content (Table7) demonstrates that the respondents reported the main elements of physiology, injury and repair were represented on their respective programmes. The surgical repair procedural elements were not widely included in curriculum content (the exception being sports therapy with 67% claiming coverage) and calculated scores for this question were significantly lower than other responses ($p < 0.05$). There was, however, no statistically significant difference between scores for the individual surgery elements ($p > 0.05$). Surgical rehabilitation content was commonly reported; post-surgery protocols were covered in all BSc responders and 50% of MOst responders.

HE levels for content were spread across the range available for tertiary education (4-7); level 7 is representative of Master's level study and was reported for osteopathy (MOst) and sports therapy (BSc) programmes. Individual course titles where the ACR elements were taught were typically reported as anatomy and physiology with some nuances based around the core provision (see Table6). The responses to questioning on the ideal positioning of ACR within HE programmes suggested equivocal attitudes on the topic (Figure4); fifty percent of responders were supportive of material at undergraduate level with the remainder advocating CPD and postgraduate courses.

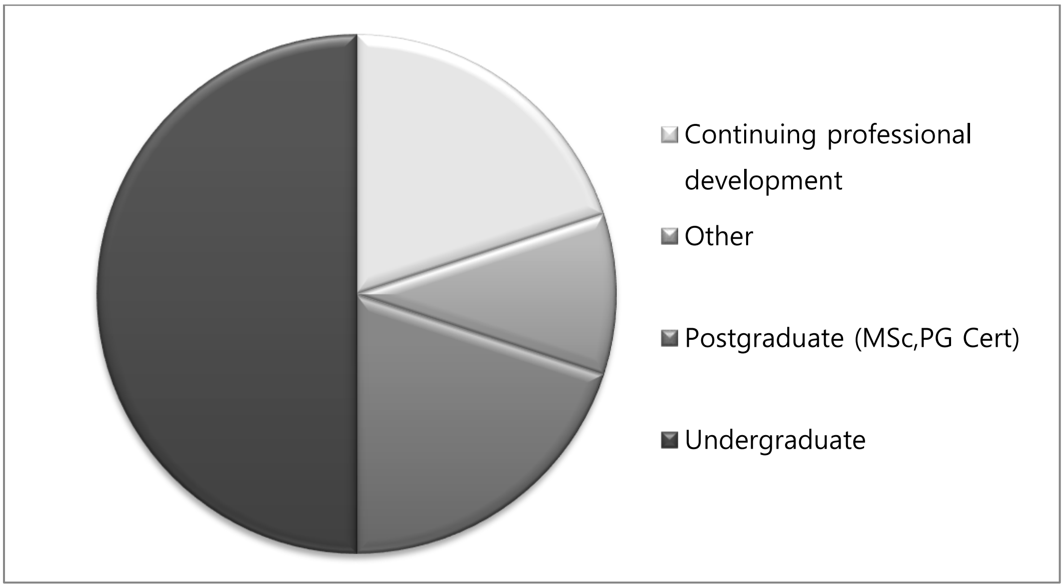

Figure4. Percentage reporting of positioning of ACR content within HE.

MSK Curriculum	AC Physiology - elements covered							
	AC Collagen type		AC Structure		AC Chondrocyte proliferation		AC tissue repair	
	*Percentage Y/N/U**	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*
BSc Physiotherapy	100/0/0	5 – 6	67/0/33	5 - 6	67/0/33	5 – 6	100/0/0	5 - 6
BSc Sports Therapy	100/0/0	4 – 7	100/0/0	4 - 7	67/33/0	4 – 7	100/0/0	4 - 7
Masters in Osteopathy (MOst)	100/0/0	4 – 6	100/0/0	4 - 6	75/25/0	4 – 6	75/25/0	4 - 6
	AC Repair - elements covered**							
	MACI/T		OATS/Mosaicplasty/plugs		Microfracture/Pridie drilling		PRP/stem cell therapy	
	Percentage Y/N/U	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*
BSc Physiotherapy	34/33/33	5 – 6	34/33/33	5 - 6	34/33/33	5 – 6	34/33/33	5 - 6
BSc Sports Therapy	67/33/0	5 – 6	67/33/0	5 - 6	67/33/0	5 – 6	67/33/0	7
Masters in Osteopathy (MOst)	25/75/0	7	0/100/0	N/A	25/75/0	7	25/75/0	7
	AC Arthrokinematics - elements covered							
	AC Load bearing		AC Stimulus reaction		Predisposing biomechanics		AC defect implications	
	Percentage Y/N/U	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*
BSc Physiotherapy	100/0/0	4 – 6	67/0/33	5 - 6	100/0/0	4 – 6	100/0/0	4 - 6
BSc Sports Therapy	100/0/0	5 – 6	100/0/0	5 - 6	100/0/0	5 – 7	100/0/0	5 - 7
Masters in Osteopathy (MOst)	75/25/0	5 – 6	25/75/0	6	100/0/0	5 – 7	75/25/0	5 - 7
	AC surgical repair rehabilitation - elements covered							
	Patient characteristics		Surgical characteristics		Rehabilitation protocols		Outcome measures	
	Percentage Y/N/U	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*	*Percentage Y/N/U*	*HE Level range*
BSc Physiotherapy	67/33/0	5 – 6	34/33/33	5 - 6	100/0/0	5 – 6	100/0/0	5 - 6
BSc Sports Therapy	100/0/0	5 – 7	100/0/0	5 - 7	100/0/0	5 – 7	100/0/0	5 - 7
Masters in Osteopathy (MOst)	50/50/0	5	25/75/0	5	50/50/0	6 – 7	25/75/0	6

Table7. AC elements percentage content reporting and corresponding HE level.* Percentage Y/NU – Yes/No/Unknown. **p < .05 pairwise Mann-Whitney U comparison.

Discussion

The aim of this study was to complete a census to determine the coverage of articular cartilage-specific content within MSK therapy undergraduate curriculum. In terms of exploring if UK musculoskeletal therapy courses differ in articular cartilage content based on final professional membership, no statistically significant difference was found between responders' professions and the reporting of specific articular cartilage content. This is potentially suggestive of alignment in content within the responding groups. The trend in calculated scores indicated greater content coverage within the sports therapy courses but this was not statistically significant. Other grouping characteristics such as entry requirements and course duration were also seen to have no effect on scoring outcome.

Healthcare curriculum content has to meet QAA requirements but effectively researching cross-curriculum is challenging and may make comparison difficult. Mapping to common terminology is possible (Komenda et al., 2015); this facilitates minutiae overview but does not directly describe the context in which the topic is delivered and requires MESH terms to be embedded as key curriculum metadata. Novel adoption of MESH and automatic term mapping at curriculum design phase may expedite research in this area. This 'Big Data' can lend itself to further visual exploration through emerging technologies and Web 3.0 development (Vaitsis et al., 2014). Lack of a clear, topic-based, curriculum mapping structure may have limited the responses in this current study; documented learning outcomes and course content are possibly too generic to facilitate detailed examination.

Models of curriculum design may be a factor influencing reporting as institutional nuances potentiate heterogeneity. The responses may be indicative of content for providers that use a constructive alignment for curriculum development based around learning outcomes (Biggs et al., 2011). The low response rate could indicate that institutions using organic approaches to curriculum design were unable to fulfil engagement as prescribed outcome is offset by students’ inquiry-based learning (Healey, 2005); no absolutes are possible at the detailed level required by this study. Consequently further consideration should be given to how students perceive content is covered and how they see curriculum development preparing them for practice in MSK disciplines ((Healey et al., 2014; Mandrusiak et al., 2014).

The recent NICE draft proposal (NICE, 2015) on limiting use of third-generation ACR to research-only proposals may indicate that this is not wholly suitable as an area to gauge curriculum conformity. It also potentially informs why recognition of surgical procedural elements was limited; possible evidence of the difficulty sourcing research material and enhancing practice knowledge reported in other areas of healthcare (Cho et al., 2011). Microfracture technique is routine practice within the NHS (Clar et al., 2005) but this procedure was not indicated over other ACR approaches in this study. The issues of knowledge transfer and lack of expedient adoption of research findings into practice are implicated to some extent (Damschroder et al., 2009); over 25 years of research data detail the ACR procedures in question (Biant et al., 2015) yet these surgical options had lowest reported representation across all professions.

The lack of adoption of a definitive approach to ACR has potentially influenced the reported knowledge of surgical approaches in this study. There is recognition that generic rehabilitation principles may be limited (Clark, 2015) and recommendations suggest that specific and targeted rehabilitation has not been sufficiently explored (Biant et al., 2015). ACR has potential requirement for specialist physical therapy dependent on the individual patient and approach used (Schmitt et al., 2014). Latest advocacy would suggest that this specialism will become more mainstream (NICE, 2017b). Although generic protocols are reportedly presented at undergraduate level, the need to specialise around ACR is arguably a post-graduate area currently, and requires further exploration before adoption into wider musculoskeletal therapy curriculum. The findings reported here may be subject to a Pygmalion effect in that a desire to meet the expectations and aspirations of research-led education influenced responders (Dauvrin and Lorant, 2015). Individuals may have answered with a more positive bias to conform to the professional expectations demanded by regulation.

Generic rehabilitation protocols may fail to engender the nuances required for individuals (Hambly et al., 2006; Mithoefer et al., 2012); the ability to recognise the necessary adaptations or specialisation may also be indicative of the complex processing developed at HE Level 7 and above (QAA, 2008). Undergraduates are becoming increasingly expected to deal with uncertainty and complexity by potentially working with pedagogues as peers from early stages of HE (Healey et al., 2014). The conflicting levels reported in this study with BSc programmes stating Level 7 content may be indicative of this shift in education. The lack of unequivocal reporting of positioning of material certainly suggests uncertainty in dealing with ACR elements and further uncertainty regarding the depth of knowledge and understanding to achieve professional competency at undergraduate level.

A focus on patient engagement, self-care and compliancy is a potential path that complements the professional competency required to recognise individual patient needs. This requires further innovative use of ubiquitous technology but has been limited due to inconsistency in study design and failure to conceptualise appropriate intervention strategies (Button et al., 2015). Potential to maximise therapist and patient interaction has not been fully explored using the new Web 2.0 and 3.0 developments or mobile device applications. In light of the uncertainty suggested by this study, development of a multi-media clinical technology interface delivering best practice advice for patients and MSK therapists is warranted. This may go some way to offset potential variability in practitioner competence by providing consistency of approach underpinned by the latest evidence.

Limitations of this study include the use of a non-validated instrument, sample size and suitable access to the necessary key personnel. The potential to increase response rate possibly resides with a multi-media approach (McPeake et al., 2014); although optimal strategies were followed, the burden of workload in academia may have been prohibitive. Perceived competitive advantage between professions may also be a possible reason why the response rate was low, restricting generalisation of the findings. While the response rate compares unfavourably with attempts to engage with Finnish physiotherapists in respect to pain education (80% compared to 13%), the actual response numbers are similar (12 versus 10) (Ehrström et al., 2018). The context to drive hypothesis testing or regression modelling is not attempted in Ehrström’s study and this may be appropriate given the parochial nature of the education in both studies. Canadian physiotherapists offered a more extensive network of educational providers (n=55), with 65% survey response rate reported in one study dealing with more generic ethics content (Laliberté et al., 2015). This provides audit, rather than inferential, analysis and suggests that this should perhaps form the basis of initial enquiry in this type of research (Chapman et al., 2015).

Chiropractic is not represented in the responders although investigation into curriculum mapping within the profession has surfaced outside of the UK (Gorrell et al., 2015; Saranchuk and Watkins, 2000). The focus has previously been on looking at evidence-based content regarding commonly treated conditions and preparedness to practise. It is possible that the field of articular cartilage repair and rehabilitation is considered to be outside this evidence-based remit. This may be of concern given that 80% of knee cartilage defects will continue to degrade, and 1 in 2 patients that present for treatment will suffer with the sequelae of this condition (Gomoll et al., 2012).

Future work requires using shared meta-data within curriculum design to allow potential mapping across providers. Repeated efforts are required to ensure curriculum content analysis becomes both an educational and healthcare research activity in MSK medicine. Further institutional strategies and innovative approaches to designing and reporting curriculum will be vital in determining how suitable research is integrated into the student experience.

Conclusion

The findings of this study provides some indication of the level of detail on articular cartilage physiology, arthrokinematics and rehabilitation considerations as represented in undergraduate curricula within UK MSK-related therapy courses. The current approaches to rehabilitating ACR patients post-surgery were not consistently represented but generic protocols were well-reported at an undergraduate level. Considerations for subsequent research are: how to measure research translation into curriculum content and which curriculum model best supports this; how to ensure student and qualified practitioners are provided with suitable contemporary knowledge to provide patient-centred, evidence-based care through programme or community delivery.

CHAPTER 3: What is the proportion of studies reporting satisfaction with software support tools used in the management of knee pain?

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Published in:

Bright, P. and Hambly, K., 2017. What Is the Proportion of Studies Reporting Patient and Practitioner Satisfaction with Software Support Tools Used in the Management of Knee Pain and Is This Related to Sample Size, Effect Size, and Journal Impact Factor?. TELEMEDICINE and e-HEALTH. https://kar.kent.ac.uk/id/eprint/65838

Introduction

The scope for technology assisted healthcare is far reaching; there are combinations of software, hardware and electronic applications across a range of platforms which come together under the banner of eHealth (Eysenbach, 2001). The growth of web-based resources and software in healthcare has made major leaps forward since the advent of Web 2.0 with the expectation that traditional methods of accessing and delivering health services will irrevocably change (Vedder et al., 2014). EHealth encompasses software technologies such as clinical decision support systems, decision dashboards, management systems, feedback systems, teleHealth, information or web-based resources such as electronic patient reported outcomes and educational packages (Mair et al., 2012). Technology driven clinical encounters are becoming accepted as a common experience within a healthcare setting, but satisfactory patient engagement in the process may be lacking (Wilson, 2009).

Clinical decision support systems (CDSS) have been used to augment primary healthcare since the wider availability of computing technology from the 1970's and, particularly, the impact of desk-top computing in the 1990's (Hunt et al., 1998). CDSS are computer systems designed to enhance clinical reasoning and can be differentiated as Computer-Based Comprehensive Clinical Support Systems (CBCCSS), expert systems or evidence-adaptive CDSS (Sim et al., 2001). They are designed to assist practitioners dealing with individual patients at the time of a clinical encounter by providing dynamic access to epidemiology and expert knowledge data (Bose, 2003). If used in an appropriate setting, CDSS are proposed to have the potential to change medical education and practice but dependency on currency and quality of information is vital (Berner and La Lande, 2016). In the time since Bates et al.'s (2003) paper on effective clinical decision support, the issues of deploying evidence-based practice in musculoskeletal medicine prevail. Bates et al.s' (ibid.) ten technology commandments that include speedy data retrieval, anticipation of needs, real time delivery and a natural fit into the mode of practice do not guarantee practitioner compliance with support systems. This may be more heavily influenced by audit requirements, punitive fear of reprisal for eschewing established guidelines and monetary incentive (Murphy, 2014).

Decision aids are used in a variety of conditions and have been seen to improve people's knowledge regarding options, facilitating rationalisation around conflicting advice and patients feeling uninformed or confused about their personal values and choices (Stacey et al., 2011). The effectiveness of evidence delivery systems and benefit to practitioner performance has been established but influence on patient reported outcome measures (PROMS) is equivocal (Garg et al., 2005). It has been suggested that software tools assist in a qualified management approach for patients in a number of clinical scenarios with adaptation to shifts in the evidence base (Sim et al., 2001). These tools exist to support a range of conditions and healthcare scenarios such as respiratory disease, diabetes, depression and anxiety (Fortney et al., 2010; Knowles et al., 2014; Litvin et al., 2012; O'Reilly et al., 2012; Velickovski et al., 2014).

Within any support system, four key attributes should be present: automatic provision of decision support as part of clinician or patient workflow, provision of recommendations rather than just assessments, provision of decision support at the time and location of decision making with a computer based platform (Kawamoto et al. 2005). In this framework of structure and conditions there appears to be a place for physical therapy (Tomaszewski, 2012); it is not clear how practitioners feel that software tools complement clinical skills and management processes in terms of musculoskeletal (MSK) medicine of the knee. In the light of equivocal evidence that entry level practitioners may not be fully equipped to deal with demands of the knee patient population and latest procedures, engagement with support tools is suggested (Chapter 2) .

The use of software tools in knee MSK medicine is expected to increase alongside delivery of physical therapy through e-measures such as teleHealth (Levy et al., 2015). A number of web-based rehabilitation tools are available which effectively provide an inventory of exercises (Pearson et al. 2016). These provide no reliable indication of the evidence supporting when to use the exercise and how challenging progression should be especially in an aging population (Taylor, 2013). There may be an abdication of responsibility with such applications but ultimately the practitioners' base knowledge has to provide the concomitant guidance to the patients in deploying these tools (Roshanov et al., 2013). Deployment in the field of MSK rehabilitation has been seen to have some success in return to work but further studies are needed to explore effective outcomes (Gross et al., 2013).

The satisfaction with the use of clinical software in the field of knee pain and rehabilitation is not fully understood and the extent of the impact on the patient has yet to be established (Hunt et al., 1998; Küçükdeveci et al., 2011). Patient satisfaction may be overlooked in the drive to embrace technological change in the clinical encounter. Satisfaction monitoring can be a divisive process, and potentially adversely influences clinical and patient shared decision making (Adams et al., 2016). Shared satisfaction perspectives are rarely observed following patient-practitioner engagement in either virtual or face-to-face situations (Rigby et al., 2015). In a recent Cochrane review exploring a range of decision aids, satisfaction was explored in respect of decision outcome; only 17.4% measured satisfaction with the outcome and a single study from the 115 reviewed described higher satisfaction related to the use of the decision instrument itself (Stacey et al., 2011). The reporting of patient and practitioner satisfaction in published studies regarding software interventions in the management of knee pain is not widely explored.

Aims & Objectives

The aim: to review how practitioners and patients satisfaction with the use of software systems in clinical support in knee pain management is reported in relevant studies.

Objective: Systematically identify relevant studies describing patient and practitioner experiences of software use within knee pain and rehabilitation studies to answer the research question:

What is the proportion of studies reporting patient and practitioner satisfaction with software support tools used in the management of knee pain and is this related to sample size, effect size and journal impact factor?

Method

Design: Systematic review

Procedure

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). This study was comprised of a systematic literature search with data extraction and regression analysis.

Systematic Literature Search

The review investigated quantitative studies exploring user experience of software for a range of knee-related conditions. A systematic search for identifying and extracting studies was undertaken by the primary author and reported using a PRISMA flow diagram. Four electronic databases were searched from January 2007 until January 2017 (Cochrane, Medline, Science Direct and Google Scholar).The initial search was set as 2007 as this marked a suitably aligned time point in terms of landmark definitions of eHealth (Ahern et al., 2006), CDSS (Berner and La Lande, 2007), and the impact of Web 2.0 on healthcare and education (Churchill, 2007; Hughes et al., 2008) The key words were:

Decision dashboard; Clinical decision; web-based resource; evidence support; knee.

The full search string used was: Search ((((((((decision dashboard) OR clinical decision) OR web-based resource) OR internet) OR software) AND knee))) Filters: published in the last 10 years; Humans; English; Adult: 19+ years. The term eHealth and rehabilitation were not included to enable broader searching and determine the range of uses for software in knee pain management. EHealth was considered as an overarching concept with software use and rehabilitation components were determined as part of the extraction process described below.

Criteria for Selecting Studies

The eligibility criteria was identified through the SPIDER (Cooke et al., 2012) framework (an acronym of sample, phenomenon of interest, design, evaluation, research type). The sample (S): Adult rehabilitation patients; for the purpose of this study, rehabilitation patients are defined as those going through an enabling process that helps them to reach and/or maintain their optimal physical knee function. The phenomena of interest (PI): To be included articles had to have considered the use of software tools with patients undergoing knee pain management or physical rehabilitation. Design (D): All types of designs were used including experimental and cohort designs; reviews and purely qualitative studies were excluded. Evaluation (E): The analysis of rating of satisfaction in relation to software interventions applied to the knee (or studies combined with hip patients due to shared management strategies). Research type (R): Quantitative and mixed-method approaches including randomised control trials (RCTs), non-randomised, quasi-experimental studies, cohort studies and single case studies/reports.

Initial title screening and abstraction was conducted by the lead reviewer (PB) from a primary dataset produced from each database interrogation. Two reviewers (PB and an independent researcher) verified all reports for inclusion by combining retrieved studies in Mendeley Desktop version 1.17.8 (Mendeley Ltd, London, UK), used to store and organise retrieved studies. Data was extracted from the articles into a Microsoft Excel version 14 (Microsoft Corporation, Redmond, WA, USA) spreadsheet table. The categories extracted were: authors, year of publication, article title, journal, intervention type, design type, population, age (range), sample size, outcome measures, effect size (reported explicitly within the study), patient satisfaction reported, practitioner satisfaction reported, journal impact factor (used as an indicator of quality along with heterogeneous study design type). Satisfaction had to be reported in regard to the experience of using the intervention under investigation and not the knee-associated outcome. An independent researcher extracted data from a randomly selected 10% of the main sample of studies which was used for process validation.

Duplicates were removed and studies short-listed by title and abstract. Full-texts were obtained if the titles and abstracts were indicative of inclusion criteria being met. Further exclusion processing was applied at full text screening by the lead author and this was verified independently by a second researcher. Any discrepancies over inclusion were discussed and agreed. The study retrieval process was depicted using a PRISMA flowchart, supported by application of the following inclusion and exclusion criteria to refine the SPIDER framework search process.

Inclusion criteria: any studies involving knee pain management or knee rehabilitation that employed software technology in the form of decision aids (patient or practitioner), patient compliance monitoring, outcome reporting, progressive goal setting and exercise management were included. Knee and hip pain studies where combined populations of sufferers were reported

Studies were excluded if interventions focused on purely non-software based interventions such as advisory, paper-based patient information sheets, verbal educational practice offering guidance only and technology assisted surgery. Studies involving technology assisted interpretation of imaging for clinicians and patient-independent evaluation, purely cost-effectiveness or epidemiological designs were also excluded.

Theses, protocols, conference proceedings, and non-peer reviewed articles were excluded because they lacked sufficient quality and detail. Articles not written in the English language were excluded because translation facilities were unavailable and selected from 2007 onwards to only include the most recent literature. Samples were limited to adults to allow for autonomous patient engagement rather than experience filtered through a parent, guardian or carer.

Statistical analysis

Summary statistics for the study characteristics were calculated using Microsoft Excel. Full texts were scanned for inclusion of explicit, stated effect size reporting, and satisfaction scales from participants and practitioners related to the use of the intervention. A binary value of Y or N was recorded to indicate the presence of the effect size and satisfaction reporting. The proportions of these values allowed for dichotomous grouping that was used to determine if a difference in impact factor score, as an indicator of quality, existed between groups that reported satisfaction and those that did not. A binary regression was run with impact factor and sample size indicated as predictors in the model with indicators for satisfaction and effect size reporting as dependent variables. Effect size, sample size and journal impact factor were selected as indicative of reporting quality (Zwarenstein et al., 2008). Odds ratios (OR) and 95% confidence intervals (CI) were calculated with a significance threshold set at 5%. Analyse-it version 3.76 (Analyse-it Software, Ltd., Leeds, UK) was used to calculate all binary regression statistics.

Results

Seventy seven studies were retrieved following title and abstract screening from a total of 743 initial returns. After application of inclusion and exclusion criteria, a total of 37 studies were included in the final analysis. The process of exclusion is detailed in Figure5.

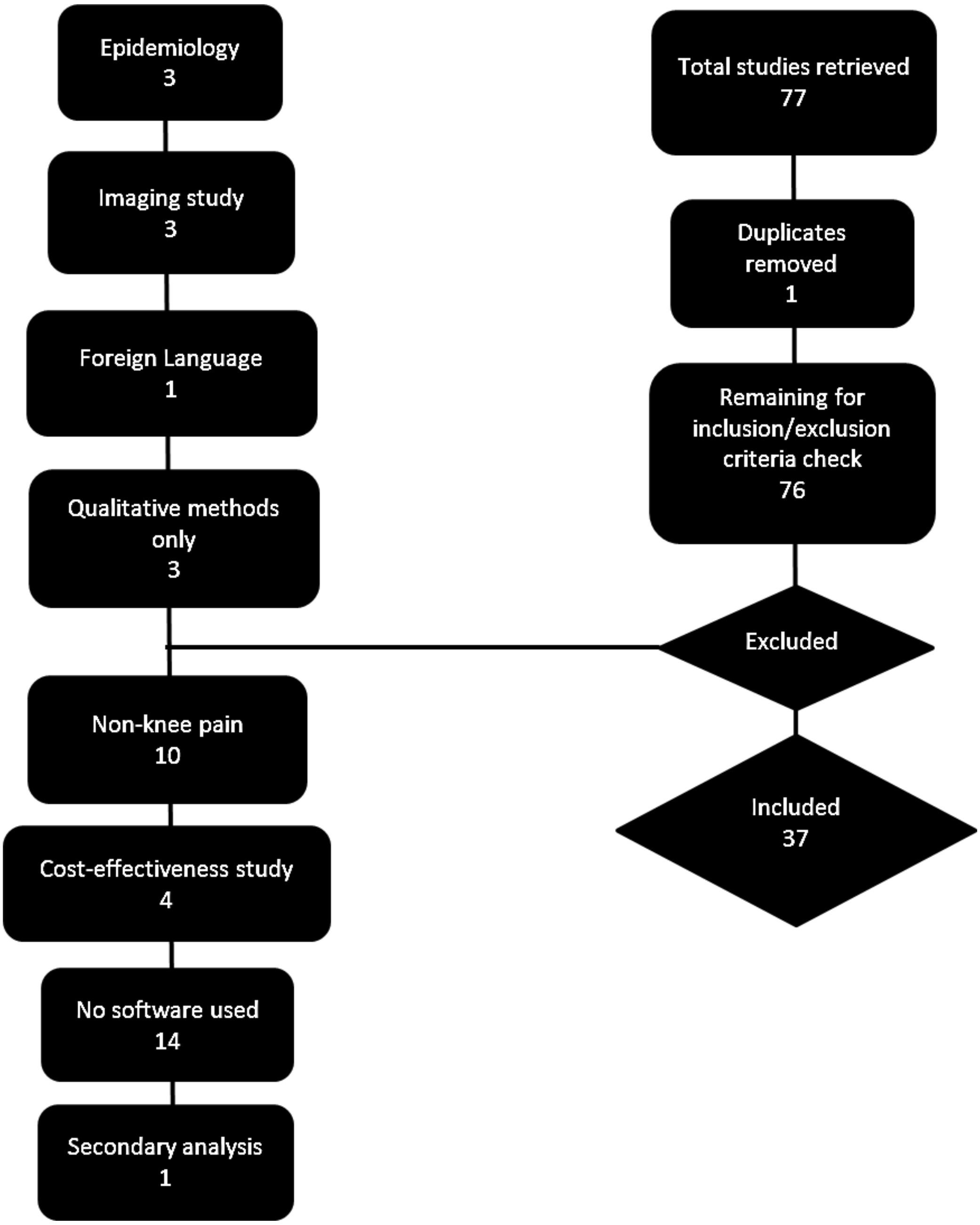

Figure5. PRISMA Flowchart depicting the extraction and selection of study retrieval.

The 37 studies analysed can be viewed in Table8 with their related characteristics; a key for the categories of intervention type, design type and outcome measures can be found in Table9-11. Ten studies reported patient satisfaction ratings (27%), while only a single study reported both patient and practitioner satisfaction (2.7%). Of the ten reporting patient satisfaction, two captured data via a 10cm analogue line (Yin et al. 2015; Russell et al. 2011);

two captured data via a multi-item (17-18) questionnaire of 5-point Likert scales (Brooks et al. 2014; Fung et al. 2012); one reported via a single 7-point scale (Marsh et al. 2014); one reported using an ordinal Acceptability Scale with a satisfaction component (Hoffman et al., 2014); three introduced satisfaction results in the discussion with no *a prior* analytical strategy described (Calliess et al. 2014; Gudbergsen et al. 2011; Marsh, et al. 2014a); one study reported satisfaction using the Healthcare Satisfaction Questionnaire for patients and a technical quality subjective appreciation questionnaire for practitioners (Tousignant et al., 2011b). Explicit effect size was reported in 6 studies (16%) and impact factor range was 5.47 (1.25 to 6.72, available for 78% of included studies). Independent extraction demonstrated 100% agreement on the presence of reporting on these measures.

Author(s) & Year	Article/paper title	Journal	Intervention Type	Design Type	Population	Age (mean or range)	Sample Size	Outcome Measures	Effect Size Reported Post Hoc?	Patient Satisfaction With Intervention Reported?	Practitioner Satisfaction With Intervention Reported?	Journal Impact Factor 2015 - Thompson Reuters
(Reeve and Williams, 2016)	When to operate: online patient-reported outcome measures (PROMs) can help decide.	BMJ Case Rep.	D	ScR	KoA	64	1	Oxford Knee Score, HowRU	N	N	N	0
(Kim et al., 2016)	Internet-Based Exercise Therapy Using Algorithms for Conservative Treatment of Anterior Knee Pain.	JMIR Rehabilitation and Assistive Technologies	E	RcT	KnP	52	60	VAS pain, UCLA activity score	Y	N	N	4.532
(Taylor and Williams, 2015)	An acute knee injury: tracking a two-year recovery online.	Int J Electron Healthc.	D	ScR	AkI	62	1	Oxford Knee Score	N	N	N	0
(Yin et al., 2015b)	Web-Based Education Prior to Knee Arthroscopy Enhances Informed Consent and Patient Knowledge Recall.	J Bone Joint Surg Am.	F	RcT	MnT	48	55	Likert Scale	N	Y	N	5.163
(Gakhar et al., 2013)	A pilot study investigating the use of at-home, web-based questionnaires compiling patient-reported	J Long Term Eff Med Implants.	D	PtS	HkA	80	21	Oxford Knee Score/ Oxford Hip Score	N	N	N	0

	outcome measures following total hip and knee replacement surgeries.											
(Slover et al., 2015)	Feasibility of integrating standardized patient-reported outcomes in orthopedic care.	Am J Manag Care.	D	CaS	KnP	18-96	666	EQ-5D, KOOS	N	N	N	1.657
(Levinger et al., 2016)	A real time biofeedback using Kinect and Wii to improve gait for post-total knee replacement rehabilitation.	Disabil Rehabil Assist Technol.	B	CaS	TkA	70	4	Timed Up&Go (TUG), ROM, Gait, WOMAC, AQoL	N	N	N	0
(Stacey et al., 2016)	Impact of patient decision aids on appropriate and timely access to hip or knee arthroplasty for osteoarthritis.	Osteoarthritis Cartilage.	F	RcT	HkA	67	343	Hip-knee osteoarthritis decision quality instrument, SURE tool, Preparation for decision making scale	N	N	N	0
(Umapathy et al., 2015)	The Web-Based Osteoarthritis Management Resource My Joint Pain Improves Quality of Care.	J Med Internet Res.	F	QeS	HkO	61	277	heiQ, OAQI	N	N	N	4.532
(Kwasnicki et al., 2015)	A wearable mobility assessment device for total knee replacement.	Int J Surg.	A	FeS	TkA	60-84	29	TUG, ROM, Gait	N	N	N	1.657
(Rini et al., 2015)	Automated Internet-based pain coping skills training	Pain.	E	RCT	HkO	68	113	AIMS2, Arthritis Self-Efficacy Scale, Pain	Y	N	N	5.557

	to manage osteoarthritis pain.							Anxiety Symptoms Scale, Positive and Negative Affect Scale				
(Pua et al., 2015)	Evaluation of the Wii Balance Board for walking aids prediction: proof-of-concept study in total knee arthroplasty.	PLoS One.	F	ObS	TKA	67	89	NRS, ROM, Active knee lag, Standing balance	Y	N	N	3.057
(Hoffman et al., 2014)	Launching a virtual decision lab: development and field-testing of a web-based patient decision support research platform.	BMC Med Inform Decis Mak.	F	FeS	KoA	18-85	126	Osteoarthritis Decision Quality Index Knowledge Subscale, Preparation for Decision Making Scale, Decisional Conflict Scale, Acceptability Scale	N	Y	N	2.042
(Calliess et al., 2014)	Clinical evaluation of a mobile sensor-based gait analysis method for outcome measurement after knee arthroplasty.	Sensors (Basel).	A	CaS	TuK	52-68	6	Knee Society Score, Oxford Knee Score, TUG,	N	Y	N	2.033
(Kawi et al., 2015)	Activation to self-management and exercise in overweight and obese older women with knee osteoarthritis.	Clin Nurs Res.	E	QeS	KoA	52-72	16	Patient Activation Measure (PAM)	N	N	N	1.359
(Bisson et al., 2014)	Accuracy of a computer-based diagnostic program for ambulatory patients with knee pain.	Am J Sports Med.	F	CoS	KnP	18-84	527	Sensitivity of diagnosis	N	N	N	4.517

(Peter et al., 2015)	Development and preliminary testing of a computerized animated activity questionnaire in patients with hip and knee osteoarthritis.	Arthritis Care Res (Hoboken).	D	QeS	HkO	46-82	110	AAQ, H/KOOS ADL subscale (19,20), and pain NRS.	N	N	N	0
(Brooks et al., 2014)	Web-based therapeutic exercise resource center as a treatment for knee osteoarthritis.	BMC Musculoskelet Disord.	E	CoS	KoA	33-76	52	WOMAC, WHO-QOL, K-SES, GRC, User satisfaction	Y	Y	N	1.684
(Marsh, Bryant, MacDonald, et al. 2014a)	Feasibility, effectiveness and costs associated with a web-based follow-up assessment following total joint arthroplasty.	J Arthroplasty.	D	RcT	HkA	38-86	256	WOMAC, Harris Hip Score, SF-12 v2	N	Y	N	2.515
(Stacey et al., 2014a)	Decision aid for patients considering total knee arthroplasty with preference report for surgeons.	BMC Musculoskelet Disord.	F	RcT	KoA	67	142	Hip-knee osteoarthritis decision quality instrument, SURE tool, Preparation for decision making scale	N	N	N	1.684
(Marsh et al. 2014)	Are patients satisfied with a web-based followup after total joint arthroplasty?	Clin Orthop Relat Res.	D	RcT	HkA	38-86	256	7-point Satisfaction Scale	N	Y	N	0
(Bossen, Veenhof, et al. 2013)	Effectiveness of a web-based physical activity intervention in patients with knee and/or hip osteoarthritis.	J Med Internet Res.	E	RcT	HkO	62	199	PASE, KOOS/HOOS, SPE, NRS (pain & fatigue), HADS, Arthritis Self-Efficacy Scale, Pain Coping Inventory	Y	N	N	4.532

(Bossen, Buskermolen, et al. 2013)	Adherence to a web-based physical activity intervention for patients with knee and/or hip osteoarthritis.	J Med Internet Res.	E	MmS	HkO	61	100	PASE, KOOS/HOOS, SPE, NRS (pain & fatigue), HADS, Arthritis Self-Efficacy Scale, Pain Coping Inventory	N	N	N	4.532
(Senanayake et al., 2013)	3-D kinematics and neuromuscular signals' integration for post ACL reconstruction recovery assessment.	Conf Proc IEEE Eng Med Biol Soc.	A	QeS	AcL	31	12	Activity Based Recovery Classification	N	N	N	0
(Marsh, Bryant, Macdonald, et al. 2014b)	Patients respond similarly to paper and electronic versions of the WOMAC and SF-12 following total joint arthroplasty.	J Arthroplasty.	D	QeS	HkA	50-90	59	WOMAC, SF-12(v2), Global Rating of Change	N	N	N	2.515
(Bossen, Veenhof, et al. 2013)	The usability and preliminary effectiveness of a web-based physical activity intervention in patients with knee and/or hip osteoarthritis.	BMC Med Inform Decis Mak.	E	PtS	HkO	64	20	KOOS, HOOS, SQUASH	N	N	N	2.042
(Puh et al., 2014)	Effects of Wii balance board exercises on balance after posterior cruciate ligament reconstruction.	Knee Surg Sports Traumatol Arthrosc.	E	CaS	PcL	22	1	ROM, Stabilometry	N	N	N	3.097
(Piqueras et al., 2013)	Effectiveness of an interactive virtual	J Rehabil Med.	E	RcT	TkA	73	142	Goniometry, Dynamometry, TUG test,	N	N	N	1.595

	telerehabilitation system in patients after total knee arthoplasty.							VAS (pain), WOMAC				
(Howells et al., 2013)	The assessment of postural control and the influence of a secondary task in people with anterior cruciate ligament reconstructed knees using a Nintendo Wii Balance Board.	Br J Sports Med.	E	CaS	AcL	26	90	Centre of Pressure	N	N	N	6.724
(Arterburn et al., 2012)	Introducing decision aids at Group Health was linked to sharply lower hip and knee surgery rates and costs.	Health Aff (Millwood).	F	ObS	HkO	66	951 5	Surgery Rates	N	N	N	5.23
(Fung et al., 2012)	Use of Nintendo Wii Fit in the rehabilitation of outpatients following total knee replacement.	Physiotherapy.	E	RcT	TkA	38-81	50	Length of outpatient rehabilitation, 2-minute walk test, knee range of motion, timed standing, Activity-specific Balance Confidence Scale, Lower Extremity Functional Scale and Numeric Pain Rating Scale	Y	Y	N	1.814
(Baltaci et al., 2013)	Comparison between Nintendo Wii Fit and conventional rehabilitation	Knee Surg Sports Traumatol Arthrosc.	E	RcT	AcL	29	30	Star Excursion Balance Test (SEBT), Functional Squat, Leg Tracking	N	N	N	3.097

	on functional performance outcomes after hamstring anterior cruciate ligament reconstruction.							Ability, Dynamometry				
(Hawamdeh et al., 2012)	Development of a decision support system to predict physicians' rehabilitation protocols for patients with knee osteoarthritis.	Int J Rehabil Res.	C	VtS	KoA	55	170	Prediction Accuracy	N	N	N	1.25
(Gudbergsen et al., 2011)	Test-retest of computerized health status questionnaires frequently used in the monitoring of knee osteoarthritis.	BMC Musculoskelet Disord.	D	CxS	KoA	54-76	20	KOOS, VAS pain, function and patient global, SF-36, Physical Activity Scale, pain DETECT, and the ADL Taxonomy	N	Y	N	1.684
(Tousignant et al., 2011b)	Patients' satisfaction of healthcare services and perception with in-home telerehabilitation and physiotherapists' satisfaction toward technology for post-knee arthroplasty.	Telemed J E Health.	E	RcT	TkA	66	42	Patients' perception of teleHealth, Patients' satisfaction with healthcare services received, Health professionals' satisfaction with the technology	N	Y	Y	1.791
(Russell et al., 2011)	Internet-based outpatient telerehabilitation for patients following total knee arthroplasty.	J Bone Joint Surg Am.	E	RcT	TkA	68	65	WOMAC, Patient-Specific Functional Scale, Spitzer Quality-of-Life Uniscale36, TUG, VAS (pain), ROM, Knee lag, Girth measurements at the	N	Y	N	5.163

								knee, Gait Assessment Rating Scale				
(Hambly and Griva, 2010a)	IKDC or KOOS: which one captures symptoms and disabilities most important to patients who have undergone initial anterior cruciate ligament reconstruction?	Am J Sports Med.	D	CrS	AcL	33	126	KOOS, IKDC	N	N	N	4.517

Table8. Study characteristics and reporting.

Summary statistics

The interventions, design types and populations under investigation in the reviewed studies including percentage reporting are described in Table9-11.

Intervention	ID	Total Reported (%)
Activity sensor	(A)	3 (8.33)
Biofeedback	(B)	1 (2.7)
Clinician Decision Aid	(C)	1 (2.7)
ePROM	(D)	10 (27.03)
eTraining	(E)	14 (37.84)
Patient Decision Aid	(F)	8 (21.62)

Table9. Intervention types with identifiers.

Design	ID	Total Reported (%)
Case Study	(CaS)	5 (13.51)
Cohort Study	(CoS)	2 (5.41)
Crossover Study	(CxS)	1 (2.7)
Cross-sectional study	(CrS)	1 (2.7)
Feasibility study	(FeS)	2 (5.41)
Mixed-methods	(MmS)	1 (2.7)
Observational	(ObS)	2 (5.41)
Pilot Study	(PtS)	2 (5.41)
Quasi-experimental	(QeS)	5 (13.51)
Randomised Trial	(RcT)	13 (35.14)
Single Case Report	(ScR)	2 (5.41)
Validation Study	(VtS)	1 (2.7)

Table10. Study types with identifiers.

Population	ID	Total Reported (%)
ACL Repair	(AcL)	4 (10.81)
Acute Knee Injury	(AkI)	1 (2.7)
Hip/Knee OA	(HkO)	7 (18.92)
Knee OA	(KoA)	7 (18.92)
Knee Pain	(KnP)	3 (8.11)
Meniscal Tear	(MnT)	1 (2.7)
PCL Repair	(PcL)	1 (2.7)
Total Knee Arthroplasty	(TkA)	7 (18.92)
Hip/Knee Arthroplasty	(HkA)	5 (13.51)
Total/Unicompartment	(TuK)	1 (2.7)

Table11. Population of interest with identifiers.

Electronic patient reported outcome measures and web-based training initiatives were the most common intervention investigated while biofeedback and wearable sensors were less represented. Randomised control trials were the most reported study design and the most common knee populations of interest were knee OA (with and without hip OA) (37.84%). The age range of study participants encompassed 18-96 year olds (mean $59.95_{\pm 16.71}$) and an equal representation of gender was seen. The most common knee outcome measures (14% each) were range of motion and the Western Ontario and McMaster Universities Arthritis Index (WOMAC), implicated by the OA prevalence; the variety of outcome measures can be viewed in Figure6.

Figure6. Word cloud representing reported outcome measures.

Regression analysis

The OR demonstrate that there was no significant prediction within the models (p>.05) with regard to journal impact factor or sample size influencing the reporting of effect size, patient satisfaction or practitioner satisfaction. Table12 provides the details of OR and CI for the associated models.

Dependent variable	Predictors	Odds ratio	95% CI
Effect size	Journal Impact Factor	1.33	0.81 to 2.19
	Sample Size	0.99	0.99 to 1.01
Patient satisfaction	Journal Impact Factor	0.99	0.67 to 1.46
	Sample Size	0.99	0.99 to 1.00
Practitioner satisfaction	Journal Impact Factor	0.82	0.26 to 2.64
	Sample Size	0.99	0.95 to 1.03

Table12. Results of regression models for effect size, patient and practitioner satisfaction.

Discussion

This study aimed to explore the proportion of studies reporting patient and practitioner satisfaction with software support tools used in the management of knee pain. The proportion of reporting of patient satisfaction was relatively low, with just over a quarter capturing this engagement; the practitioner satisfaction was poorly represented with a single study reporting this item. There was no statistical significance seen with regard to association of reporting satisfaction and effect size with the size of sample or journal impact factor as indicators of article quality.

The scope of knee-related conditions covered was reportedly dominated by OA, but no studies explored ACR; this had been highlighted in Chapter 2 as an area potentially lacking coverage and knowledge transfer. With current advocacy for ACR procedures being endorsed (NICE, 2017b), potentially as prophylactic for OA (Shimomura et al., 2015), these interventions implicating knee pain management may require further translation into the ACR population. As comparisons around ACR rehabilitation have been made with ACL repair (Hambly et al., 2006), the proprioceptive and neuromuscular interventions reviewed may well have applicability across differing knee pain populations (Baltaci et al., 2013; Howells et al., 2013; Senanayake et al., 2013)

Patient satisfaction is generally reported in other areas of healthcare and with the adoption of eHealth initiatives this is regarded as a key criteria

(Jackson and McClean, 2012). One proposed benefit of eHealth may be the cost saving it makes to the delivery of care which has been explored with teleHealth and particularly remote outpatient scenarios (Bergmo, 2015; Dávalos et al., 2009). Cost-effectiveness may offset the need for shared patient decision which is also an agenda in clinical engagement and is reported to lead to improved outcomes and consequently satisfaction (Lé Garé and Thompson-Leduc, 2014). This review excluded studies conducted purely to assess cost-effectiveness but one single study that include a cost measure also reported patient satisfaction (Marsh et al., 2014b); the web-based resource reportedly saved almost 50% on standard care with moderate to high satisfaction levels (ibid.). The study did not report explicitly how satisfaction ratings were achieved *a priori* suggesting the lack of attention to this measure.

Practitioner satisfaction may be implicit within the augmented reality of eHealth but can be implicated in multidimensional models of practice that can account for variation between clinician and patient experience (Salisbury, 2010). Study design may be the influence here, in that single case, validation or cohort studies may be delivered by the developer of the initiative in these reviewed articles (Bisson et al., 2014; Brooks et al., 2014a; Hawamdeh et al., 2012b; Reeve and Williams, 2016; Taylor and Williams, 2015). This is akin to a pharmaceutical manufacturer not only paying for the research but also administering the drug to the patient which implicates further bias (Schulz et al., 2010). The randomised trials within this review fared no better than lower quality designs in terms of reporting, although the single incidence of patient and practitioner satisfaction was an RCT of small sample size in a journal of low impact (Tousignant et al., 2011b).

Study design may have the additional impact in terms of reporting of effect size,the related sample size and clinical importance (Zwarenstein et al., 2008). Lower quality evidence will not support suitable statistical power to detect required effect; there may be an assumption that when an effect size is generated it supports suitability as well as effectiveness of the outcome (Sullivan and Feinn, 2012). Despite recommendations to reliably report effect size in a range of study designs alongside RCTs (Eldridge et al., 2016; Vohra et al., 2016), only a quarter of the 12 trials in this review demonstrated this requirement (Rini et al. 2015; Bossen, Veenhof, et al. 2013; Fung et al. 2012).

The studies in this review looked to address function and perspectives around knee pain and associated conditions and measures. Effect was explored with these outcomes in mind, but the suitability of administering the intervention is not evidently reported and patient experience does not inform these effects. Patient satisfaction and treatment acceptance have been qualitatively described as being influenced by shared decision making with practitioners (Quaschning et al., 2013). Qualitative investigation may elicit the experiential viewpoint more readily than the satisfaction measures or ratings reported in this review (Heijne et al., 2008; Pearson et al., 2016), while Rasch analysis may be a more sensitive statistical tool to use with satisfaction scales beyond reporting effect size (Küçükdeveci et al., 2011). Feasibility study designs may offer a suitable framework to initially explore patients' and health professionals' perspectives (Lancaster, 2015); these accounted for only 2 of the studies reviewed, and arguably this approach should be extended into full trial stage.

Satisfaction is generally high with regards to physical therapy in Western culture (Hush et al., 2011), and it would be appropriate to contextualise satisfaction data on knee eHealth as an ongoing process within MSK. Patient experience has to be taken into account in order to demonstrate the satisfaction with using the measure itself alongside the measure's outcome; the so-called Fit between Individuals, Task and Technology (FITT) (Ammenwerth et al., 2006). This is further informed by the Technology Acceptance Model (now in its third iteration) that supports perceived usefulness, and ease of use, of software systems as aspects of satisfaction that would potentiate adoption of those systems (Venkatesh and Bala, 2008). This model has general applicability for employees in the workplace, but would require further extension to multiple end-user populations, with differing core beliefs or perspectives, in the context covered by this review.

Online communities may provide the forum for capturing a range of perspectives that facilitate patient and practitioner satisfaction or acceptance (Gruzd and Haythornthwaite, 2013). The burgeoning growth of vehicles to garner patient participation in research and decision-making can encompass the development, trial, suitability and acceptance of software interventions (Clayman et al., 2016; Domecq et al., 2014).

The assumption that all technological change is an improvement on healthcare has to be better qualified and supported by meta-evidence of satisfaction. Exploration of satisfaction measures such as the After-Scenario Questionnaire (ASQ), Post Study System Usability Questionnaire (PSSUQ) and the TeleHealth Usability Questionnaire (TUQ) (Schutte et al., 2012) should be routinely included in eHealth studies into knee-related pain management. The TUQ would be particularly pertinent due to combination of existing computer-based usability questionnaires, as a comprehensive questionnaire that covers all usability factors such as usefulness, ease of use, effectiveness, reliability, and satisfaction. Further adaptation would be likely to allow face-to-face interactions to be considered explicitly when the clinical situation demands it (Parmanto et al., 2016). Platform dependency would also warrant further delineation and is currently under review around access to software through mobile devices (Zhou et al., 2017). The recent proposal of using the standardised Enlight measure (Baumel et al., 2017) to rate eHealth interventions is welcome but further consideration of tempering usability criteria with satisfaction outcomes is warranted. This could facilitate therapists' understanding, critical clinical reasoning and competencies to readily engage in patient and population-centred healthcare (Frenk et al., 2010).

Limitations within this review are the heterogeneity of the studies in terms of design and intervention. Qualitative synthesis of thematic analysis may allow for a more refined understanding to overcome this, with the advent of sufficient published, experiential material. The reporting standards scrutinised may not have been deemed appropriate or a necessity by all study authors due to the novel interventions involved. The inclusivity adopted was determined by an attempt to define the scope of eHealth initiatives within the context of knee pain sufferers; this is the first review of its kind to address patient and practitioner satisfaction in this population. Future studies engaging with the varied forms of eHealth in the management of knee-related pain and interventions should look to apply the capture of satisfaction with all interested parties as standard best practice.

Conclusion

Patient and practitioner satisfaction with the use of eHealth measures in the management and rehabilitation of knee pain is not routinely reported. This may have implications for the suitability of administering technology in this population; a medium for capturing this meta evidence needs to be established and used as best practice for studies involving eHealth and knee pain in the future. Reporting standards around the use of technology in clinical and domiciliary scenarios should be revisited in the light of this review.

PHASE I

Modelling: Establishing the profile and motivations of users of an online health community for knee pain sufferers; validating a biofeedback process to complement home-based exercises for the knee.

CHAPTER 4: What is the profile of individuals joining the KNEEguru online health community?

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Published in:

Bright, P., Hambly, K. and Tamakloe, S., 2016. What is the Profile of Individuals Joining the KNEEguru Online Health Community? A Cross-Sectional Mixed-Methods Study. *Journal of medical Internet research*, *18*(4). https://kar.kent.ac.uk/id/eprint/57547

Introduction

The use of the internet for seekers of health-related information provides convenience and accessibility to diverse sources of variable quality (Atkinson et al., 2009). There is a suggestion that patients may find empowerment by engaging with internet healthcare strategies (Samoocha et al., 2010). There is also some perceived scepticism in seeking medical information online due to doubts about accuracy, reliability and bias (Khazaal et al., 2012); this is further compounded with the potential danger that internet health provision medicalises the trivial and engenders the ‘sick’ role (Clark, 2014). Despite concerns regarding potential misinformation, online health communities continue to thrive with growing clinician moderation (Huh and Pratt, 2014) to add credibility to the health related information generated via social media (Hajli et al., 2015). This clinician-validated approach alongside adherence to the Health on the Net Foundation code of conduct (HONF, 2014) and online assessment tools such as the DISCERN instrument (DISCERN, 1999) are establishing quality benchmarks for online healthcare information (Khazaal et al., 2012).

The online health communities (OHC) are now as varied as the specific conditions they deal with (Chumber et al., 2015; Nassiri et al., 2014; Stienen et al., 2015; Wong et al., 2013) and the multi-media aspects of the internet are also being explored and assessed (Gabarron et al., 2013). There are a number of joint-replacement and osteoarthritis (OA) resources online (Nassiri et al., 2014; Pietrzak et al., 2012) which are purported to have a beneficial impact on patient shared-decision making. Knee-related internet resources and attitudes of the online communities of knee pain sufferers are not widely reported; this is despite self-care programmes demonstrating efficacy for controlling pain and maintaining function (Mazzuca et al., 1999). Fifty percent of people aged 50 and over will report knee pain during any one year with one quarter describing this joint pain as severe and disabling(Blagojevic et al., 2010). Increasing age, gender and obesity are identified as risk factors for progression of knee OA in the over 50’s, contributing to OA as the sixth most disabling condition globally (Silverwood et al., 2014); younger individuals are more likely to suffer knee pain as a result of acute injury, repetitive strain or rare juvenile onset of OA (Arden and Nevitt, 2006).

KNEEguru (KG) is an online health community started in 1997, with over 33,000 members, and approximately 74 new registrations a month. KG is stated as a resource for the general public with knee problems, particularly those who have had or are contemplating knee surgery. The community’s mission statement is to, “provide quality information about knee problems, their evaluation and their management to our readers from the global general public”, with access to expert advice and moderated content (KNEEguru, 2015). Previous studies have investigated activity levels of consumers on the KG website with regard to ACR procedures and suitability of specific knee outcome measures to this population of patients (Hambly, 2011; Hambly and Griva, 2008). Main findings from these studies suggest functional change is of more concern than knee pain alone, and this should be reflected in the relevant domain ratings of IKDC and KOOS instruments. This suggests the findings of the initial three chapters of this thesis, in respect to focused rehabilitation, suitably equipped practitioners and patient satisfaction may be important to patients in these OHCs. While the profile of general online healthcare consumers has been reported in adult populations (Bianco et al., 2013; Klemenc-Ketis and Kersnik, 2013; Powell et al., 2011), the profile and experiences of individuals who would selectively engage with a knee specific OHC is not known.

Aims & Objectives

This study sought to explore the expressed motivations for participants seeking specific online health information regarding the knee. The extent to which the perceived benefits and quantifiable motives were related to characteristics of respondents was also assessed. This was with a view to address an overarching research question as to the profile of KG consumers, relating this to theorised benefits and challenges of internet health that potentiated perspectives on knee-pain sufferers and how their profile compared with other OHC users.

Method

Design: Mixed methods, cross-sectional questionnaire, following a pragmatic, additional coverage approach, to combine quantitative and qualitative research as complementary processes (Morgan, 2014).

Procedure

A self-administered, cross-sectional survey of individuals registering on the KG website was undertaken from June to July 2012. Participants were self-selecting and opportunity sampling was deployed; invitation was via a ‘pop-up’ window that appeared upon navigating to the KG registration page. The sole exclusion criterion was participants under 18 years old. Informed consent was given by participants explicitly indicating agreement to complete the survey and no incentive for participation was offered.

The questionnaire was hosted on the Bristol Online Survey (BOS) software platform and initially piloted for face validity. The instrument was designed to identify the characteristic profile, and motivations of users of the website both quantitatively (with attitudinal ratings), and qualitatively (as additional coverage). The survey consisted of 30 main questions (74 items including sub-questions): three open response and the remainder, closed or Likert scale questions. Anonymised participants' demographic and health status characteristics, extent of knee pain, reasons for registering on the website, and questions related to health information-seeking behaviour were captured. The questionnaire development was informed by previous surveys conducted using the OHC (Hambly, 2011; Hambly and Griva, 2010a), drawing on patient motivations to engage around knee pain. There was no adaptive or conditional logic in the response processing; the open qualitative questioning allowed respondents to directly elaborate on their experiences and motivations for engaging with KG as a reflection on the quantitative response (see Appendix III for full questionnaire that includes patient information and consent capture). The procedures for handling, processing, storage and destruction of the data were compliant with the Data Protection Act 1998. The University of Kent ethics committee provided approval for this study.

Analysis

A mix of open and closed questions was used to facilitate inductive enquiry. Summary statistics were calculated to report sociodemographic data, reasons and motivations for joining KG, internet and social media usage, knee problem demographics and participants' perception of health and quality of life. Cross-tabulations for quantitative responses were analysed using a Chi^2 , odds ratios (binary values), and Fisher's Exact test (multi-factorial values) to examine differences in proportions by demographic characteristics; age, gender and educational status were compared to symptoms, motivation, health status, quality of life, surgical intervention, internet use and reasons for joining the OHC. This patient profiling, through capturing a range of characteristics that support patient-centred attitudes, is considered to allow for informed decisions to be made around patient management (Rodriguez-Merchan, 2012). Significance levels were set at $p < .05$ for the Pearson chi-square and Fisher's exact tests; for all odds ratio calculations, a 95% confidence interval was calculated.

Qualitative thematic analysis of the open response questions was completed using a framework approach and iterative open coding (Ritchie et al., 2014). The responses to the following questions were appraised: "Why have you decided to join KNEEguru?" (Qual 1) ;"Why have you now decided to register with KNEEguru?" (Qual 2) ; "Describe what information you want to find and why you want to find it" (Qual 3). This was with a view to create an initial descriptive representation of themes and sub-themes encountered in the participants' narrative, following an additional coverage approach to further inform quantitative data (Morgan, 2014). Triangulation was completed with two additional independent researchers; they each reviewed a randomly allocated 10% of open text, applying thematic codes and any disagreements were moderated between the two individuals and primary researcher (PB). Further refinement of thematic content engendered a conceptual model of how participants rationalised engagement to add contextualisation to quantitative findings. This model was presented as a preliminary finding at a range of seminars to ensure comprehension and depiction of relationships was appropriate.

Results of the study were analysed in a mixed-methods approach using Excel version 14 (Microsoft Corporation, Redmond, WA, USA), SPSS version 20 (SPSS Inc., Chicago, IL, USA) and Analyse-it version 3.76 (Analyse-it Software, Ltd., Leeds, UK). Excel was used to store and analyse transcripts, facilitating the coding framework and thematic analysis. Summary and inferential statistics were calculated using a combination of Excel, Analyse-it and SPSS.

Results

Qualitative questionnaire responses

One-hundred and fifty two respondents took part (11.6 % response rate from 1315 registrants approached) with a mean age of 40.2 years. Sixty-three percent were female, 68.7% were in domestic partnerships, 57.3% were employed, 74% had higher education qualifications and 80% were of white/Caucasian ethnicity. The US was the most represented domicile (55%) followed by the UK (22%) alongside a global selection of other nations. The highest proportion of responders (58%) reported the sharing of experience as the important motivation for engaging with KG (see Table13).

Question of motivation for engagement	Percentage rating as important*
To get emotional support from others	38
To vent out emotions related to the knee problem	31
To validate my experience	43
To seek recognition	12
To offer emotional support to others	42
To share my experience with others	58

Table13. Responses to reasons for engagement questions. *'Important' and 'Very Important' grouped together compared to 'Neither important or non important','Not important at all','Not relevant','Not very important'.

Gender was not typically statistically significant as a determinant of response; females were associated with joining KG in order to get emotional support from other users (odds ratio (OR= 2.11, 95% CI= 1.04-4.27, P= .04) but no difference existed when looking for information about health or use of social media ($p > 0.05$). Respondents' self-perception of health was significantly associated with reported quality of life (OR= 10.86 (95% CI 3.85-30.43, $p < .0001$). Facebook users demonstrated an association with joining KG to share experiences (OR= 2.34, 95% CI= 1.04-5.56, P= .029). Post-surgery respondents were associated with joining KG to compare symptoms with other users (OR= 7.31, 95% CI= 2.06-39.82, P= .0004) rather than compare recovery (OR= 2.34, 95% CI= 0.75-8.72, P= .14). Education to a minimum of graduate level was seen as an indicator of high daily internet usage when compared to secondary level attainment only (OR= 13.29, 95% CI= 1.26-674.28, P= .013).

Thematic Analysis of Qualitative Response

Four themes and 43 sub-themes were initially derived from all 152 responses to the mandatory question, Qual 1. The 4 responses to Qual 2 and the 109 responses to Qual 3 (both non-mandatory questions) were also included. These were rarefied into three overarching themes and 24 sub-themes: condition (8 sub-themes), emotion (9 sub-themes) and support (7 sub-themes) as reported in Table14. Thematic coding assignment was agreed for 100% of a random 10% sample of open text by the 3 independent researchers. The thematic content will be discussed in turn.

1. Condition - relating to reported situation and extenuating circumstances	
a.	Progression/prognosis
b.	Procedure/treatment
c.	Symptom
d.	Diagnosis
e.	Resolution/recovery
f.	Cost
g.	Quality of life/debilitation
h.	Quality of practitionership
2. Emotion - relating to emotional impact on the lives of the responders	
a.	Confusion
b.	Anxiety/frustration
c.	Pragmatism/stoicism
d.	Altruistic
e.	Empathy
f.	Empowerment/inspiration
g.	Trust/confidence
h.	Validation
i.	Expectation
3. Support - relating to perceived merit of engaging with the OHC	
a.	Shared experience
b.	Surrogate
c.	Guidance/contextualisation/informed-decision making
d.	Proactivity/self-management/locus of control
e.	Voyeuristic
f.	Future of healthcare
g.	Beneficence

Table14. Major themes and grouped sub-themes.

Condition

Participants were compelled to describe their predisposing, knee-related issues as a rationale for engagement. A major motivational factor reported was the issue surrounding prognosis or progression; individuals were either concerned at potential outcomes of their condition or recounted the prognostic information gained from medics or their own research. Sequelae of traumatic events alternated between positive and negative experiences: *“After severing all 4 quads off my kneecap the doctor told me I'd be able to play hockey again.”* [Participant (P) 4, a 51-year-old male] Potentially distressing outcomes were also described: *“The doctors have given me an extremely bleak prognosis, telling me that articular cartilage lacks the ability to heal and regenerate.“*[P102, a 28-year-old female] The rate of progression was closely monitored by some individuals and posted as a potential measure for comparison: *“I had a femoral osteotomy 16 weeks ago and it has not healed.”*[P70, a 31-year-old female] Limitation of individual procedures was reported within the context of resolution: *“I had a lateral release and arthroscopy on left knee in 2005. It only helped for approx (sic) 8 months.”*[P93, a 39-year-old female]

Perceptions of condition effect and progress were intimately bound with an underlying causative incident or procedure often aligned to a specific diagnosis. Participants were erudite and well-versed in medical terminology from an informed and critical stance: *“…I suffered from a large horizontal oblique tear involving the posterior horn and body of the medial meniscus.”* [P15, a 52-year-old male] Further context was provided by individual description of symptoms both prior to intervention and in chronic situations. A rich thread of narrative illustrated participants’ perspective on perceived effects of their complaint: *“My symptoms include: popping, grinding, extreme swelling from knee cap to foot (which now had seemed to make my leg numb) knee locking while I sleep and extreme pain.”*[P10, a 36-year-old female] These physical manifestations were often cited as a primary reason for seeking guidance: *“I have had a total knee replacement on both my knees. I am having some post-operative pain and thought I would see if any others could offer some suggestions for "self-help".”*[P137, a 64-year-old female]

Resolution and recovery of participants' knee issues were key motivations for engagement with the KG forum. Many expressed a strong desire to expedite a return to full function or had regained appropriate functional status: *"It (KG interaction) makes me feel more normal and like my knee may actually return to a semi-normal state. I wanted to see how some of the people who post turned out, and therefore signed up to join the site."*[P47, a 29-year-old female] Some individuals presented positive outcomes potentially related to their prior standing: *"I tore my PCL three years ago and was luckily able to resume all sporting activities on a fairly high level as I was used to."* [P51, a 31-year-old male]

The overarching cost, both financially and in terms of the quality of life, for the participants was emphasised. Individuals depicted insidious, limiting effects of their condition and resultant distress: *"I recently injured my knee, I don't know what I did and due to the fact that I do not have health insurance I cannot afford to go to the hospital or any doctor until I have an idea of what may be wrong."*[P142, a 29-year-old male] Feelings of distress, despondency and isolation were described: *"With all my hobbies taken away from me, and all sense of hope gone, I feel that my life is truly over."*[P102, a 28-year-old female]; "*I feel as though I am the youngest person with this severe of an injury (which feels debilitating)."*[P21, a 21-year-old male]

The final concept informing perception around participants' knee conditions was the quality of practitioner and consistency of patient-handling. The reported standard of care was highly variable relative to individual experience: *"Now I am going to try and locate my Physical Therapist from first injury - he was outstanding; professional, knowledgeable, exceedingly competent and provided me the means to help myself heal and regain my lifestyle. I don't have that confidence in my present therapist."*[P5, a 57-year-old female] Others stated satisfaction with the level of guidance around treatment: *"I've spoken with my surgeon, and know what to expect from a medical point of view....and my GP has been very informative as well."*[P26, a 39-year-old female] Competency was seen as an issue around surgery, rehabilitation and expectation; *"I'm told that my surgeon used an unorthodox* *size pin in my knee and it snapped off inside, so now I have shrapnel in my knee."* [P18, a 28-year-old male]; *"The physiotherapy from the National Health Service is patchy and vague…….I don't feel that the physiotherapist or the doctors appreciate that I am a dancer and want to get back into training as soon as possible."*[P6, a 34-year-old female]

Emotion

A strong emotional response to injury, treatment and follow-up care was professed by most participants with varying degrees of impact. The sub-themes embodied were: confusion around conflicting advice; anxiety and frustration at uncertainty of their situation which was occasionally offset by pragmatism and stoicism. A strong altruistic tendency with empathetic reciprocation of experience was regularly articulated. The experience of engaging with the OHC was seen as empowering and inspirational, feeding off the legitimate shared experience of participants. This engendered trust and confidence which led to validation of the experience. The management of their expectations were also then informed by this validation.

Participants expressed confusion with regard to their situation and the guidance provided from healthcare resources with *"too many conflicting tips from my doctors and from elsewhere on the Internet."*[P8, a 41-year-old male] This was compounded by the lack of support material found elsewhere on the internet*:" The general web searches provide mostly sales products and not information"* [P12, a 50-year-old female]. The issue of uncertainty of diagnosis when compounded by conflicting information was also voiced: *"The official diagnosis is patella femoral syndrome, but…….my symptoms seem to be more consistent with chondromalacia patella."*[P90, a 57-year-old male] This confusion was seen to underpin anxiety and frustration which prompted engagement with the community. Standards of care and lack of progress incited further exasperation: *"I am getting frustrated with the level of therapy I am getting with the health service in my country. The recovery is taking longer than I would have thought - of course I have realised that it is a gradual process that won't happen overnight - but my physio seems disinterested."*[P6, a 34-year-old female]

Specific technical issues around medical procedures were cited as cause of distress and concern by a number of participants: *"I joined because I'm unhappy with the USA not allowing surgical repair of damaged ligaments………I've had the surgery-in 1983-and I know it works"*[P88, a 49-year-old female]. The general uncertainty or lack of clarity around impending procedures and their outcomes motivated individuals: *"Am scheduled for TTT in a month and have many questions and concerns I'd like answered."*[P116, a 32-year-old female] Similarly individual response to surgery prompted further need for counsel: *"The scheduled op is next week and I have heard that there may be an allergic reaction to the metal implant currently installed. Is this so? And what material is the new prosthesis?"*[P114, a 75-year-old male]

Individuals offset these issues of anxiety and uncertainty with a pragmatic and stoic response. Experience provided a resigned attitude to outcome on one hand: *"Facing knee replacement, imminent on one side and inevitable on the other."* [P121, a 65-year-old male] While others were keen to avoid surgery with a reserved approach: *"Taking conservative route with PT twice weekly plus daily at home."*[P94, a 56-year-old female] Pragmatism and resignation were described with a sense of personal responsibility regarding knee health: *"In the long term I have been concerned about my knees anyway as they take a lot of wear and tear seeing as I am a cyclist and a dancer, and I'm not getting any younger."*[P6, a 34-year-old female] The resultant psychological impact was expressed: *"I went through a period of depression but eventually worked through it and found happiness without sport or any real physical activity, because engaging in it was more painful (emotionally) than not."*[P21, a 21-year-old male]

A strong desire to inform and support other community members was stated with reciprocation of ideas and perspective. The altruistic desire to help others as a result of sharing the benefit of individual experience was expressed: *"I have learnt quite an amount already but I would like to think that posting in this forum and reading others posts will help to motivate me* *and others.’*[P24, a 34-year-old male] Reciprocation of experience was expected: *“Learn from the folks here and also to help others out with the little that I know.’*[P66, a 25-year-old male] This altruism is seen as a determinant of empowerment and inspiration. Participants described the motivation derived from engaging in the OHC as mitigating the effects of their knee problems*: “I like to read them, it makes me feel more normal and like my knee may actually return to a semi-normal state.’*[P47, a 29-year-old female]

This was framed by issues of trust and confidence influenced by internal and external factors. Internal factors were expressed as the uncertainty of the medical prognosis or rationalisation of participants’ condition: *“I'm nervous about the surgery ..’*[P148, a 42-year-old female]; *“Called my insurance carrier to find out my Dx (sic); osteoarthritis, tear of medial cartilage, effusion of leg joint, disorder of bone and cartilage. Am unsure of the long-term ramifications of this. “*[P5, a 57-year-old female] External influences were felt to be the direct consequences of medical staff and, as previously stated, variable standard of care: *“…I feel let down by the doctors and physiotherapist.’*[P111, a 41-year-old female]; *“I feel like my orthopaedic (sic) doctor is treating me like a number and is not giving me enough information or being open with me about my injury.’*[P80, a 35-year-old female]

Participants entrusted the authenticity of experiences described often in counterpoint to their mistrust of practitioners. A common outcome described was validation of experience based around exposure to the OHC. The community mentality facilitated sharing and rationalisation of experiences of knee pain via a self-determined process: *“…also to be in contact with people who can listen and totally relate and may have helpful ideas.’*[P64, a 43-year-old female]; *“It's comforting knowing that I am not the only person on earth going through this.’*[P45, a 32-year-old female] This validation was explicit in terms of palliation of fear: *“I feel I would like to have some support and reading other people's experience has given me that. I am less frightened because I see that others are experiencing the same problems...’*[P57, a 56-year-old female] Others saw a direct need for affirmation of their predicament: *“Because my experience seems unique so thought I would validate.”*[P147, a 38-year-old male]

Many described their expectations of outcomes from KG interaction or previously unmet expectations. Generally increasing awareness and achieving an informed perspective were described: *“to find out more information from people who have had plc(sic) reconstruction, so I have an idea of what I am to look forward to as I am most likely going to have the same surgery…”*[P134, a 42-year-old male] The participants anticipated management of their own expectations via the actions of KG users*: “Hoping to learn more about my knee injury and the experiences of others, so that I can better expect what might happen for my own knee.”*[P103, an 18-year-old female] Issues of unexpected changes in situation were cause for concern: *“…facing total knee replacement ….It is a shock that this has happened because I expected I would be able to control the osteoarthritis...”*[P38, a *78-year-old male*]

Support

The emotional response to individuals’ knee conditions engendered various concepts of support. This was commonly manifested as descriptions of shared experience with the outcome of validation and awareness; *“To find more information for people with similar conditions as myself. I realize this will be mostly just other peoples(sic) experiences.”* [P12, a 50-year-old female] Sharing information was seen as a pathway to substantiate participants’ experience: *“Mainly to share and be encouraged/educated with others who have undergone similar situations with their legs.”*[P26, a 39-year-old female] Exchanging information on KG was seen as a vital interaction: *“I would like to post my story and hopefully hear back from others that can relate to me.”* [P149, a 41-year-old female]

Engagement was often undertaken by surrogates demonstrating concern and exploring outcomes for close relatives; the individual’s enquiries were often necessitated as a primary carer: *“My 15 year old daughter has severe pain and severe rotation in her femur.”*[P53, a 46-year-old female] The

process of support and guidance was emphasised in respect to trauma: *“My daughter dislocated her kneecap and is due to fly in two days. I want information about the wisdom of flying so soon after an injury*.”[P79, a 59-year-old male] These complications of events around others were often the cause for concern that prompted action: *“My husband had a knee replacement op in Jan 2010. He fell 5 weeks later and had to have a revision, and got an MRSA infection.”*[P114, a 75-year-old male]
The sub-theme of guidance and contextualisation was readily expressed as part of the information-seeking behaviour. Participants were avid consumers of knee healthcare: *“To find as much information as I can on a current knee injury.”* [P25, a 44-year-old male] Others were motivated by existing discussion material and suitably consoled to pursue further support: *“I have been reading the questions/answers on your site and I am interested in getting more information concerning my knee injury.”*[P30, a 60-year-old female] Guidance sought was often tempered by the progress reported by others: *”To find answers to some questions regarding my care and how it compares to others in the same situation.”*[P75, a 55-year-old female] The expectation expressed was that the process of guidance would lead to informed-decision making around procedures or prognosis: *“…..the main reason I wish to join to look up more information, experiences, recovery, advice, and whatever else I can find on distal realignment surgery because that is what I am getting in the near future.”*[P52, an 18-year-old female] The participants rationalised this advice and guidance as a means for reassurance: *“I have decided to join KNEEGuru as I have had many, many problems with my knees. It is nice to read other people’s ideas and thoughts about what they went through and what I am about to go through.”*[P13, an 18-year-old female]

A key element of support was seen as facilitating proactivity via a forum for self-management and autonomy: *“I have a displaced, fractured TP - after 4 weeks of lying around I am looking for some like-minded people!”*[P87, a 37-year-old female]; *“I'm no longer happy being inactive, and I'm again seeking answers.”*[P22, a 21-year-old male] People declared a growing need for establishing locus of control through the community: *“I have gathered that* *there is a lot more I could be doing so I am doing my own research. It seems like comparing notes with people who may have had similar injuries is a good place to start."*[P6, a 34-year-old female] The need to achieve a sense of authority over their knee condition was important to some participants: *"I also have also been some kind of anatomy geek and really have to know everything going on with my body. So I read up on everything I can find….."*[P51, a 31-year-old male]

Certain individuals adopted a voyeuristic approach to engagement and chose to peruse material without full access to the OHC: *"..have knee probs and wanted to view some content that is member only... otherwise would have viewed info but not joined or posted."*[P14, a 50-year-old female] Participants declared a history of observation with burgeoning extenuating circumstances dictating a course of action: *"I have "lurked" on the website for over a year, when I was desperate to find information about complications with my knee ROM."*[P128, a 44-year-old female] While others simply declared a curiosity around fellow OHC consumers, stating the sole reason for engagement was; *"to check out other peoples' profiles."* [P83, an 18-year-old male]

The interaction with web-based technology was identified as the future of healthcare by some: *"I would like to join a community where there is joint discussion because I believe in future, the landscape for individual health care will change with the advance of technology and access to information."*[P53, a 43-year-old female] The OHC information was seen as being vital and trail-blazing: *"Best practice - cutting edge info. Upcoming modalities. Staving off additional damage."*[P5, a 57-year-old female] The general perception of an accessible, informed and knowledgeable community underpinned with expert advice was seen as highly beneficial. This sub-theme of beneficence was described in terms of assistance and well-being: *"I am having a meniscal transplant in 2 days and find this site incredibly helpful."*[P55, a 37-year-old female] Mitigation of fear, distress and symptom-response was also volunteered: *"I am less frightened because I see that others are experiencing the same problems I am having, such as* *using the stairs, swelling, shin pain, stiffness, cannot sit cross-legged anymore, etc. now I know my experiences are not unique and I feel better knowing this information."*[P57, a 56-year-old female] The immersion within the OHC is seen to establish a true community spirit: *"I have read through the posts, and believe that I am in a state similar to many of the folks posting on the forum. I believe that knowing about such people, and learning from their experiences might be helpful to me"*[P7, a 34-year-old male]

The interlinked themes of condition, emotion and support were seen to be related within the context of KG. Participants declared a condition-based knee issue and their consequent emotional response which demanded support. This led to the development of the following conceptual model (Figure7):

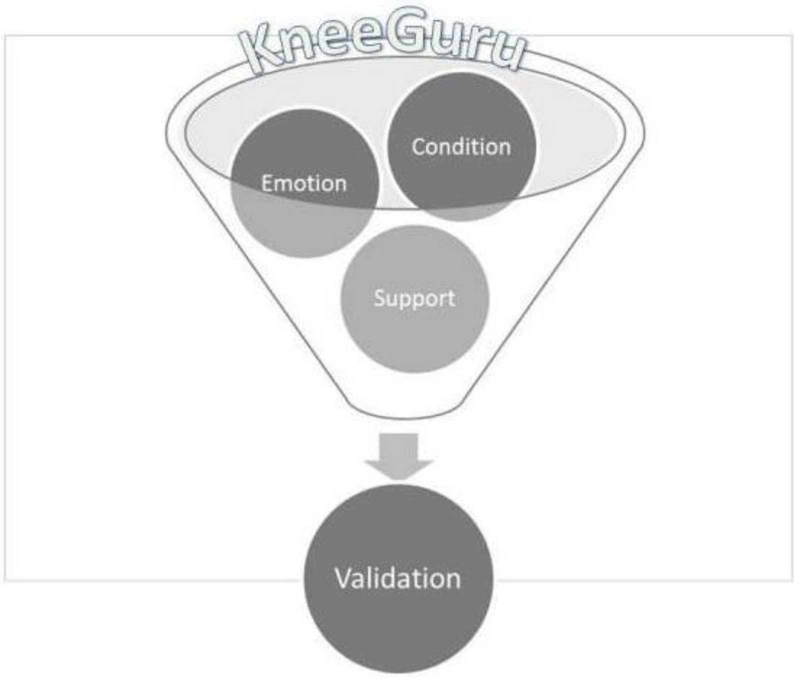

Figure7. Conceptual model of engagement with OHC.

The personal experience of engagement with the OHC is viewed with KG as a filter that takes an individual's condition and emotional response to that condition that drives the need for support. Processing through this filter facilitates validation as the outcome of engagement. This validation is established through the community nature of KG and is perceived to have a major beneficial effect for participants.

Discussion

This study sought to explore the characteristics and expressed motivations for participants seeking specific online health information regarding complaints of the knee. The extent to which the perceived benefits and quantifiable motives were related to characteristics of respondents was also established. The participants were seen to have an emotional response to their knee condition that prompted support through KG; this engagement proved to be a validatory experience.

The response from 152 registrants reflects a mid-point between the levels achieved in other studies conducted in this OHC (Hambly, 2011; Hambly and Griva, 2010a). These studies recruited across six (58 respondents) and twelve months (201 respondents) which, along with an ACR/ACL focus, may account for differences with the inclusive approach adopted in this study during the month of recruitment. While females were more represented in the responders, in line with other reports of OHC participants (Powell et al., 2011), gender was not always typically significant as a determinant of responses. Female participants were associated with joining KG in order to get emotional support from other users. A higher incident of females has been seen to engage with online support communities for combating depression (Houston et al., 2002). This gender-related tendency is seemingly supported in anxiety-inducing behaviour reported across various physical conditions such as cancer, flu and respiratory disorders (Brooks-Pollock et al., 2011; Haggerty et al., 2014; Hvidberg et al., 2015; Uddin et al., 2014). Qualitative emotional responses were described in detail by both our male and female respondents.

Our study respondents also demonstrated that no differences existed between genders when searching directly for information about health. This may be down to the specificity of the OHC and musculoskeletal focus offered by KG. Musculoskeletal pain frequency is reportedly higher in females (Fillingim et al., 2009) alongside incidence of knee OA (Srikanth et al., 2005). This is mirrored by severity of knee pain reported for certain female populations (Han et al., 2016) potentially mediated by biomechanics and progressive decline in oestrogen (Karsdal et al., 2014). Females have less functionality and activity following knee replacement in the West (Cherian et al., 2015) while Asian populations seemingly have less gender-specific outcomes post-surgery (Gen et al., 2015). Our demographic did not describe explicit issues experienced around gender as a motivational factor for engaging with KG. Community support for their presenting condition was highly regarded and accessible but seemingly lacked recognition of latest evidence describing the characteristics that influence knee pathology (Stubbs et al., 2015).

There may be a perceived inevitability about the condition of OA that marks this as a particularly nuanced area of healthcare (Collier, 2012; Gignac et al., 2006). The descriptions of being resigned to the outcome of the disease process reported by our participants may be indication of awareness and expectations being influenced by wide-ranging sources (Vance et al., 2009). Specific patient decision aids, akin to OHC, have been seen to have positive effects on patient choice and awareness but have not led to significant differences in surgical outcomes (Stacey et al., 2016). Long-term patient expectations for OA may contemplate surgery but pain management and functional outcomes are more revered; generalised optimism for long-term outcomes prevail over short-term response (Dwek et al., 2015).

Potential conflicts between informed patients and clinicians expectations, where the former value symptom relief and the latter prioritise safety (Cordero-Ampuero et al., 2012), may also account for our study’s dissonant theme of dissatisfaction with variable standards of healthcare. This finding of criticality around clinical health encounters may be further supported by our finding of association of higher education with greater internet usage and wider implications of health-seeking information (AlGhamdi and Moussa, 2012). Further studies reporting on online behaviour demographics show mixed issues regarding influences and participation with social media and subsequent outcomes (Bolton et al., 2013; Koteyko et al., 2015). The context and necessity of engagement would seem to be crucial with uptake of technology and social networking demonstrably related to age and generational cohort. The perceived ubiquity of technology in developed cultures is presented as both beneficent and maleficent in equal measure (Lober and Flowers, 2011; Vance et al., 2009). The disenfranchised, technologically-challenged individual may adopt a deterministic view that has no locus of control (Surry and Baker, 2016). Our study's indication around education and online activity within Generation X (mean age 40 years) suggests a utilitarian adaption to keep pace with the digital natives of Generation Y (ibid.).

Facebook users demonstrated an association with joining KG to share experiences; previous studies demonstrate the frequency of social networking site use was not a significant predictor of supportive interaction (H. J. Oh et al., 2014). Facebook users have previously been shown to be more willing to engage with student and community activities (Junco, 2012; Tufekci, 2008). The platform has also been successfully explored as a potential medium to disseminate knowledge transfer of healthcare information around OA (Brosseau et al., 2014). As Facebook has developed as an 'intranet' within the internet, it is quickly facilitating information exchange through selective sharing, interaction and self-monitoring of activities (Abell and Brewer, 2014). The implications for general healthcare are still to be fully understood or widely adopted (Hawn, 2009; Maher et al., 2014) but the facilitation of patient empowerment is a major development (Greene et al., 2011). Arguably, as supported in our study, social networks acting as introducers for secure OHCs is a model that can authenticate patient experience, and mitigate concerns surrounding privacy and social anxiety (Pedersen and Kurz, 2016; Shaw et al., 2015).

The participants' emotional response was well-described although this was not directly supported in our quantitative findings. Emotional support (ES) is reported across a range of conditions with the various blogging platforms and communities specifically created for provision of guidance and advice (Ploderer et al., 2014). ES is seen as more valuable and likely to engender and prolong engagement than informational support (Wang et al., 2012). The outpouring of emotion in our thematic content suggested a catharsis borne out by the validatory statements. Online communities would seem to provide an outlet for greater unfettered expression, and exchange of sympathy, unrivalled by the clinical encounter alone (Yao et al., 2015). The ideas of relatedness, mutual respect and engendering competency that are purported to underpin OHC (Zhang, 2016) can be seen as antecedents of shared-decision making (SDM), influencing primary healthcare and challenging paternalism (Barry and Edgman-Levitan, 2012). The burgeoning OHC are informing patients' decisions and their impact is being felt across multiple conditions and scenarios (Hageman et al., 2015; Kehl et al., 2015; Rood et al., 2015).

Respondents' self-perception of health was significantly associated with reported quality of life (QOL). While seemingly obvious, concepts of health between patients and practitioners are rarely reported; it would appear that there is congruence but patients describe how they value the professional over the profession they represent (Papp et al., 2014). This attitude was reported within our respondents with stated predilection for supporting clinicians based on personal preference. With relation to knee and hip OA, QOL has been seen to be influenced by attitudes to health and social support transactions outside of clinical encounters (Ethgen et al., 2004). Our study's findings of the validatory experience offered by OHC participation elucidates the wider finding of social support components mitigating effects of OA and the negative impact on QOL (French et al., 2016; J. Oh et al., 2014).

Post-surgery respondents were associated with joining KG to compare symptoms with other users rather than compare recovery. This may be supported by psychological impact of symptoms on post-surgical knee outcomes (Sullivan et al., 2009). The implications of anxiety and pain catastrophisation around surgical procedures can spur further self-motivated desire to engage in social activity (Somers et al., 2009). The descriptions of validating experience from our study potentiate the mitigation of postoperative pain predicted by catastrophising (Khan et al., 2011). Wider quantitative findings suggest the level of education, tangible support, problem-solving coping and internal locus of control reported in our study are predictive of functional outcome following knee surgery (Lopez-Olivo et al., 2011).

The qualitative responses provide further evidence of surgical outcome, denoting condition, as a motivation for engagement. The emotional impact of this was well-documented in our study and reflects wider reports of pre-surgical anxiety (Pouli et al., 2014). Self-efficacy measures are indicated as vital to postoperative psychological and functional outcomes (Magklara et al., 2014); the use of OHC as part of this self-determination demands greater scrutiny. It is reported that OHCs, as a component of eHealth, facilitate an environment that provides optimum circumstances for improving and strengthening patient participation and satisfaction (Dedding et al., 2011). The conceptual model described in the current study has parallels with Dedding et al.'s finding that the Internet stimulates patient engagement in the clinical setting in three ways: acting as a mitigating mechanism (emotion and condition information shared sensitively); offering a safe training ground for patients (support through enriched consultations); causing a lever effect (validation stimulating change). The full package of care around knee conditions has scope to be further developed to integrate the use of validated online communities that are proving to be viable resources to complement clinical rehabilitation and patient autonomy.

Strengths and limitations

Only 11.6 percent of the total number of registrants agreed to take part in the survey which may limit generalisation of the quantitative findings. The richness of the qualitative responses may be subject to a Pygmalion Effect (Dauvrin and Lorant, 2015); individuals believing that appeasing expectations of the researcher would provide them with greater subsequent consideration.

The low response rate may indicate bias but closer scrutiny suggests the respondent characteristics are representative of samples reported in similar studies.

Conclusion

This study, in line with wider literature, suggests that the profile of users of an online knee-specific community is typically female, middle-aged, white/Caucasian, married, employed and attained a level of higher education. They demonstrate a pragmatic approach to healthcare information with altruistic motivations and desire to share experiences as a means of validation. This emphasises ways of promoting efficient and appropriate online, knee-related healthcare and demonstrates the benefits of the Internet as a viable complement to clinical engagement supported by wider perspectives on eHealth. Consideration of integrated packages of care around knee health should include recommendation of online health community support in future to assist in reporting of applicable measures or experiences.

CHAPTER 5: What is the agreement between electromyography and dynamometry measures of quadriceps and gluteal muscles in short-arc quadriceps and seated clamshell exercises?

Introduction

Electromyography (EMG) of the quadriceps, hamstrings and gluteals facilitate epidemiological studies that determine electrical activity profiles in a range of scenarios (Camic et al., 2015; Semciw et al., 2014). Quadriceps and hamstrings muscle activation during isometric and ballistic movements have been reliably established via EMG (Fauth et al., 2010). The active ratio of vastus lateralis and vastus medialis obliquus in squat positions has been determined to be independent of gender, knee position and leg dominance but influenced by squat depth (Jaberzadeh et al., 2016). EMG profiles suggest the best exercise for activation of the gluteus medius is modified hip abduction (side-lying clamshell position); single-leg squat and deadlift exercises provoke greatest activation of the gluteus maximus (Distefano et al., 2009). There is evidence that a neutral pelvis position optimises recruitment of the gluteus maximus and medius during the clamshell exercise; increasing the hip flexion angle further increases gluteus medius activation (Willcox and Burden, 2013).

Muscle weakness and imbalance is a common feature of lower extremity dysfunction: knee and hip OA, patellofemoral pain syndrome (PFPS), joint instability and hypermobility syndromes are associated with impaired muscular activation (Abhishek and Doherty, 2013; Lankhorst et al., 2012; Marreiros et al., 2016; Nevitt et al., 2016). Home rehabilitation exercises are widely used in physical therapy to compliment treatment and mitigate or stabilise degenerative and functional change (Henriksen et al., 2016). Home rehabilitation is typically considered to be patient-driven, practitioner-initiated activities that form part of a larger package of related care, and may be facilitated by technology that guides or informs exercise (Borghese et al., 2014). Domiciliary exercises are recommended in a range of conditions such as osteoarthritis (OA), chronic joint instability and PFPS (Fransen et al., 2015). Exercise interventions also reduce pain and improve physical function for people awaiting knee and hip replacement surgery (Gill and McBurney, 2013; Wallis and Taylor, 2011). The engagement of patients with domiciliary knee and hip pain exercise and management programmes suggests these initiatives demonstrate clinical and cost effectiveness (Hurley et al., 2012). Use of home-based, exercise feedback measures provide a potential complement to reported outcome measures on knee pain and function (Ferber et al., 2015). Visual stimulus in using prime movers of the knee has also been seen to influence a higher response in resultant EMG profiles, suggesting potential to facilitate progressive functional gains in patients (Silva et al., 2013). The option for patients to report objective, measured progress during prescribed exercise programmes may engender compliance, in addition to recounting frequency of engagement (Tagesson et al., 2008).

A major aim of any exercise programme is to address strength and function of impaired structure; prescribed exercises depend on identifying the structures implicated in dysfunction within the population of interest (Mayer et al., 2011). For knee pain sufferers, muscle strengthening exercises focus mainly on the quadriceps, hamstrings and gluteal muscles alongside proprioceptive training (Knoop et al., 2013; Messier et al., 2013; Roos et al., 2011). Targeted isometric quadriceps exercise programmes have demonstrated beneficial effects on thigh muscle strength, pain and functional disability in patients with knee and hip OA (Jansen et al., 2011; Knoop et al., 2015). In generic lower extremity rehabilitation, the clamshell exercise has been shown as a preferential exercise for the activation of gluteus medius (Bolgla and Uhl, 2005), stabilising hip and knee movement.

Maximising compliance is key in dictating success with exercise therapy, particularly in a domiciliary setting (Chapter 1; Foster et al., 2014). It has been suggested that adherence and progression measures could be improved if patients had options for feedback and self-reporting (Bollen et al., 2014). Preliminary evidence suggests that biofeedback may be used to reinforce exercise technique and outcomes (Giggins et al., 2013). Biofeedback is defined as: “A process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance. Precise instruments measure physiological activity such as brainwaves, heart function, breathing, muscle activity and skin temperature. These instruments rapidly and accurately "feed back" information to the user. The presentation of this information — often in conjunction with changes in thinking, emotions and behaviour — supports desired physiological changes. Over time, these changes can endure without continued use of an instrument” (Schwartz, 2010, p.90).

This has been further interpreted in a more pragmatic, patient-centred, perspective; using a range of data (signals or measures), patient education and explanations, biofeedback can provide missing, or deficient information relative to the intervention, and outcome, back to the patient (Schwartz and Andrasik, 2017, p.16). Biofeedback from physical rehabilitation exercises may have potential to induce faster recovery, increased patient engagement and motivation (Gamecho et al., 2015). The complexity of interaction and potential for technology failure in using animatronic or visual instruction, combined with muscle and motion monitoring (ibid.), may lead to diminishing patient adherence once these usability studies are explored with larger scale designs. Biofeedback has been explored in the context of eHealth with respect to knee arthrokinematics and emerging bio-sensor technology (Chapter 3; Sundemo et al., 2016); there is a suggestion that simpler strategies using ubiquitous technology may be necessary to extend scope of patient engagement (Gamecho et al., 2016).

The use of bathroom scales has been validated to provide indication of graded weight-bearing, with repeated user accuracy seen to be within 1.5% of achieving a desired ground reaction force of 25% body-weight (Malviya et al., 2005). Further application of this readily available household item could be within the context of biofeedback, providing indicative strength readings during domiciliary exercise, adding ‘missing’ information in accordance with

Schwartz and Andrasik (2017, p.16). Exercises for hip and knee such as clamshell (Distefano et al., 2009) and short-arc quadriceps extension (Kushion et al., 2012) have already been shown to be effective in targeting the thigh and buttock muscles. EMG signals for gluteus medius in the clamshell position range from 27 to 36 percentage maximum voluntary isometric contraction (%MVIC) (Selkowitz et al., 2013; Sidorkewicz et al., 2014). The activity profile of the vastus medialis (VMED) is shown to range between 55 and 66 %MVIC across a set of 5 weight bearing exercises (Ayotte et al., 2007). It is not known if the introduction of a biofeedback system in the form of the bathroom scales would affect the EMG profile for the gluteus medius and the quadriceps muscles during rehabilitation exercises.

Aims and objectives

The aim of this study was to investigate agreement between myoelectric activity, in terms of %MVIC, when using bathroom scales during the seated clamshell exercise and short-arc quad extension (SAQE) exercise. The primary objective was to determine the %MVIC of vastus medialis (VMED) and gluteus medius (GMED) muscles during SAQE and clamshell exercise derivatives. This reliability approach was explored using electromyography (EMG) with a view to address the following research question:

What is the agreement between %MVIC when performing the seated clamshell exercise and short-arc quadriceps extension exercise with or without biofeedback?

A secondary outcome was to explore the agreement between generated force measures reported via dynamometry and the bathroom scales for the quadriceps and gluteal exercises.

Method

Design

Prospective single-group repeated-measures study; this followed an approach using elements for reporting reliability and agreement studies (GRRAS) where appropriate (Kottner et al., 2011).

Participants

Volunteers were recruited from the student population of the European School of Osteopathy (ESO). Participants were excluded from taking part if they were suffering with bilateral knee or hip pain or were diagnosed with an underlying metabolic disorder or neuromuscular condition such as myaesthenia gravis or chronic fatigue syndrome.

Equipment

Bipolar (10-mm center-to-center) wireless surface electrode sensors and receiver (Trigno™ Wireless EMG, Delsys Inc., Natick, MA, USA) were deployed with Delsys EMGworks Acquisition software running on Windows 7 on a Hewlett Packard ProBook 6545 laptop. Quadriceps and gluteal muscle strength was measured with PCE-CS 300 dynamometer (PCE Instruments UK Ltd, Southampton, UK) and Bluetooth-connected Konig KN-PS800B digital bathroom scales. The study was conducted in the research and clinic facilities at the ESO and University of Kent's School of Sport and Exercise Sciences.

Outcome measures

The primary outcome measure was the %MVIC of the VMED and GMED captured during the exercise protocol; readings were also taken for vastus lateralis (VLAT) and gluteus maximus (GMAX) to contextualise the primary outcome. Control sets for each exercise acted as the 'Gold Standard' for the EMG data (Kottner et al., 2011). The secondary outcome was the force measurements recorded from the dynamometer (the 'Gold Standard' comparison) and bathroom scales, initially captured in kilograms.

Procedure

Anthropomorphic data was recorded from each participant; age (years), height (metres via stadiometer reading) and weight (kilograms via Konig bathroom scales).

Sensor placement

Wireless Trigno™ surface electrode sensors were placed on the right thigh. The skin contact area for the sensor was shaved and cleansed using an isopropyl alcohol wipe. Surface electrodes were then attached for each of the muscles following Distefano et al. (2009). The sensor for the VMED was positioned a fifth of the distance from the medial joint line of the knee to the anterior superior iliac spine. A hand-held goniometer was used to identify the 55° angle of fibres of the VMED in medial relation to the quadriceps tendon to place the sensor accordingly.

The fibres of the VLAT run 12 to 15° lateral to the quadriceps tendon and the electrode was orientated at this angle, fixed at the midpoint between the head of the greater trochanter and the joint line at the lateral femoral epicondyle. The placement for electrode for the GMAX was 33% of the distance between the second sacral vertebral level and the greater trochanter. The GMED placement was 33% of the distance between the greater trochanter and the iliac crest (Distefano et al., 2009; Rainoldi et al., 2004).

Exercise protocol

After an initial timed 60 second static walking warm-up, five exercises were performed by each participant; seated clamshell, side-lying clamshell, seated clamshell with biofeedback, SAQE and SAQE with biofeedback. The SAQE was performed in a seated position on the floor, with a bolster under the flexed right knee, with the foot laterally rotated at a 20-degree angle; participants were asked to contract the quadriceps bringing the leg into a straightened position (Figure8). The contraction was held for 2 seconds, prompted by the instruction to squeeze as hard as possible during that timeframe, followed by a 2 second rest period. This was repeated 5 times;

recording of the EMG signal was 20 seconds for each exercise. This process was subsequently repeated with the Konig bathroom scales placed underneath the bolster, resting on a solid supporting couch, to facilitate viewing of the scales digital reading.

Figure8. Execution of the short-arc quadriceps extension: start and end position.

The seated clamshell exercise was performed in a self-supported seated position, hip at 45°, knee bent at a 90° and positioned against a wall. Participants were instructed to push their right knee into the wall as an isometric contraction. This was again repeated 5 times, 2 second contraction followed by 2 second rest. As with the SAQE, bathroom scales were introduced, held in position between the participant’s right knee and the wall (Figure9); clamshell exercise protocol was then repeated.

Figure9. Execution of the seated clamshell exercise.

The side-lying clamshell exercise was performed with the participant on their left side, knees bent at 90º, hips 30º, with their feet parallel to the posterior aspect of the pelvis (Figure10). Participants were instructed to lift their right knee towards the ceiling while keeping their feet together, performing a maximal contraction at the end of range. The EMG signal was again recorded for 20 seconds, 2 second contraction followed by 2 second rest, for 5 repetitions. Each of these continuous, 20-second EMG amplitude values were then normalized to a control set; this was identified as the EMG data from the standard or dependent version of the exercise in each case (Halaki and Ginn, 2012). This also allowed for any fatigue effects to be potentially identified over time.

Figure10. Side-lying clamshell exercise: start and end position.

Further exploration of the isometric force applied for the quadriceps and gluteals was undertaken using a mobile PCE-CS 300 dynamometer (PCE Instruments UK Ltd, Southampton, UK) and Konig digital bathroom scales. Measures were captured in accordance to the procedure adopted in Chapter 6; isometric hip abduction for seated clamshell and seated isometric quadriceps extension were performed by each participant. Three maximum voluntary isometric contractions (MVIC) were elicited for each exercise on the two pieces of equipment to provide an average measure. Fatigue levels were monitored across all exercises by gaining verbal reassurance of recovery between sets, ensuring participants felt suitably recovered to continue. Participants were made aware that they may experience minor to moderate discomfort such as soreness and tiredness up to 48 hours after participation in the form of delayed onset muscle soreness.

Ethics

The study protocol was approved by the Research Ethics Committees of the European School of Osteopathy and the School of Sport and Exercise Sciences, University of Kent. Informed consent was captured prior to study engagement where participants were informed of the benefits and risks involved in the study (see Appendix IV for The Patient Information Sheet and Consent Form).

Sample size

The intended sample size required for this study was calculated using G*Power (Faul et al., 2007), software version 3.1 (Heinrich-Heine-Universität Düsseldorf, Germany) . The *a priori* calculation was based on linear multiple regression tests and suggested 40 individuals were required. This was determined using an anticipated effect size of 0.35 with power set at 80%, 5% α probability and number of maximum predictors set to 4 (Faul et al., 2009; Kottner et al., 2011).

Statistical analysis

Summary statistics, regression and correlation analysis were calculated using Excel version 14 (Microsoft Corporation, Redmond, WA, USA), Analyse-it version 3.76 (Analyse-it Software, Ltd., Leeds, UK) and SPSS version 24 (SPSS Inc., Chicago, IL, USA). Distribution was assessed using Shapiro-Wilks and visual inspection of Q-Q plots. EMGworks Acquisition v4.3 (Delsys Inc., Natick, MA, USA) was used for recording and capture of the EMG signal. The signal data generated was normalised to baseline amplitude of a control exercise to obtain %MVIC for each muscle group using the EMGworks Analysis v4.2 programme.

These data were then exported to an Excel spreadsheet for subsequent analyses. Linear regression was run with the dependent and predictor variables set *a priori* as presented in Table15 using a backward selection process to achieve best fit within the model. Investigation of predictors was undertaken with a view to inform imputation analysis in future research (Vittinghoff, 2011). Collinearity was assessed using the reported variance inflation factor (VIF) produced from the statistical software. This was anticipated to be higher than the acceptable thresholds for independent effect (5 and 10) due to the potential for strong linear relationships in the measures (Robinson and Schumacker, 2009; Yu et al., 2015).

Variable	Muscle	Position	Biofeedback	Exercise
Dependent	Gluteus Maximus, Gluteus Medius, Vastus Lateralis	Side-lying	N	CLAM
Predictor	Gluteus Maximus, Gluteus Medius, Vastus Lateralis	Seated	N	CLAM
Predictor	Gluteus Maximus, Gluteus Medius, Vastus Lateralis	Seated	Y	CLAM
Dependent	Vastus Medialis, Vastus Lateralis, Gluteus Medius, Gluteus Maximus	Seated	N	SAQE
Predictor	Vastus Medialis, Vastus Lateralis, Gluteus Medius, Gluteus Maximus	Seated	Y	SAQE

Table15. Regression variable assignment.

Amplitude readings for VMED and GMED muscles were further analysed using Intraclass Correlation Coefficient in order to further inform collinearity and dependent variable effects, exploring aspects of reliability (Kottner et al., 2011; Weir, 2005). Kilogram strength values from the dynamometer and bathroom scales were tested for distribution (Shapiro-Wilks test) and equality of variance (Levene's Test) to determine the appropriate correlation analysis; Pearson's or Spearman's test with accompanying 95% confidence intervals (CI). Significance threshold was set as $P<.05$ in all testing. Kilogram data was further converted to newtons (kg * m/s) then normalised for torque values (newton metres per kilogram) to allow for comparison to wider literature. Participant height data was used to calculate necessary torque moment arm lengths using a standard regression formula for estimation of tibia/height ratio (Duyar and Pelin, 2003).

Results

Thirty five participants were recruited but only 17 proceeded to data capture stage; their characteristics were shown to conform to normal distribution (continuous data, $P>0.05$). The 18 withdrawn individuals cited time commitment as their main reason to decline. The group was 47% female (8/17); age ranged from 18 to 51 years (mean 36.2, SD 10.1 years) and average body mass index (BMI) exceeded the threshold of guideline recommendation (<25 kg/m^2) (Winter et al., 2016), (mean 25.43, SD 4.45 kg/m2). Mean height was 1.73 (SD 0.08) m, and mean weight was 76.53 (SD 17.6) kg.

Table16 & 17 show the %MVIC for each muscle group during the clamshell and SAQE exercises including measures of central tendency and dispersion. Biofeedback (BIO) outcomes related to the exercise conducted with the bathroom scales. The standard exercise (NONBIO) was performed without the scales.

EMG Source	BIO ST GMED	NONBIO ST GMED	NONBIO SL GMED	BIO ST VLAT	NONBIO ST VLAT	NONBIO SL VLAT	BIO ST GMAX	NONBIO ST GMAX	NONBIO SL GMAX
Mean	64.47	63.50	67.70	88.23	87.83	87.64	34.13	36.35	43.09
SD	23.64	22.56	18.27	21.58	21.41	21.02	25.66	25.35	19.53
Median	63.05	62.69	65.96	95.90	96.27	95.49	26.78	24.59	40.21
IQR	42.84	41.51	32.54	2.92	2.67	4.57	28.30	44.14	19.61

Table16. Muscle group summary %MVIC data for clamshell exercise. *ST-seated, SL-side-lying*

EMG Source	BIO VMED	NONBIO VMED	BIO VLAT	NONBIO VLAT	BIO GMED	NONBIO GMED	BIO GMAX	NONBIO GMAX
Mean	47.24	44.57	35.61	34.76	95.64	93.23	81.99	84.11
SD	22.96	18.20	15.59	6.30	5.05	9.95	22.27	22.00
Median	45.46	41.17	29.86	34.47	97.81	97.12	89.18	92.40
IQR	28.39	25.24	23.64	8.84	3.65	3.22	7.00	5.72

Table17. Muscle group summary %MVIC data for SAQE exercise.

Regression analysis

The clamshell exercise provided highly predictive EMG activity outcomes (>90%) across the range of execution. GMED activity profiles for the seated position contributed significantly to prediction of the outcome in the side-lying position but VIF values of 173 indicate the high collinearity of the two derivatives of the seated version. Only the VLAT activity from the clamshell in seated position performed without biofeedback was predictive of the side-lying variant (VIF=1). Combined GMAX data demonstrated no significant association (see Table18 for details) (VIF=2.3), but model adjustment indicated both isolated seated versions were equally, moderately predictive (R^2 adjusted=0.53, *P*<.0001, CI 0.29-0.85, VIF 1).

Predictor	**Dependent variable CI**	**R² adjusted**
	nonbio SL GMED	
bio ST GMED	1.26 to 1.77	0.91*
nonbio ST GMED	-0.96 to -0.69	
	nonbio SL VLAT	
bio ST VLAT	-0.43 to 0.23	
nonbio ST VLAT	0.74 to 1.41	0.998*
	nonbio SL GMAX	
bio ST GMAX	-0.07 to 0.72	0.589
nonbio ST GMAX	-0.07 to 0.73	

Table18. Clamshell exercise regression variable analysis.* *P<.0001*

Variably predictive data was elicited from the EMG activity during the standard and biofeedback execution of the SAQE exercise (VIF=1 in all cases indicating low collinearity). VMED profiles were significantly related with 74% of variance accounted for (between the exercises). GMAX demonstrated the strongest significant association (99%) between two modes of SAQE execution while VLAT and GMED showed low, but significant relationship (see Table19).

Predictor	Dependent variable CI	R² adjusted	P-value
	nonbio VMED		
bio VMED	0.47 to 0.9	0.741	<.0001
	nonbio VLAT		
bio VLAT	0.11 to 0.44	0.423	.003
	nonbio GMED		
bio GMED	0.05 to 1.98	0.213	.041
	nonbio GMAX		
bio GMAX	0.94 to 1.03	0.992	<.0001

Table19. SAQE exercise regression variable analysis.

Intraclass Correlation Coefficient (ICC)

The data for %MVIC GMED demonstrated a high ICC for the seated and side-lying execution of the clamshell exercise. The seated versions with and without biofeedback produced the highest significant correlation (>90%). The SAQE exercise had similarly high ICC for the VMED muscle (see Table20 for details).

Exercise	Muscle	Position	ICC	CI	P-Value
Clamshell	GMED	ST* & SL	0.67	0.26 to 0.87	.004
		ST*	0.91	0.75 to 0.97	<.0001
SAQE	VMED	ST*	0.92	0.77 to 0.97	<.0001

Table20. Clamshell and SAQE exercise ICC analysis.

Dynamometry correlation

The force measures did not conform to a normal distribution across the range of outcomes captured. Corresponding summary data for newton and newton metres per kilogram is depicted in Table21.

	SAQE-Dyn	SAQE-Sc	CLAM-Dyn	CLAM-Sc
Median - N	404.69	196.13	178.81	121.60
IQR	250.23	163.12	133.11	135.01
Median - Nm/kg	1.87	1.09	0.99	0.79
IQR	1.03	0.52	0.64	0.63

Table21. Summary of clamshell and SAQE force values. *(IQR – interquartile range)*

Spearman's Rank Correlation demonstrated significant linear relationships across the dynamometry and biofeedback data for the 17 participants. The clamshell exercises were approaching 80% of variance explained by proportional change in the two exercise procedures. The SAQE values were closer to 60% with both clamshell and SAQE demonstrating statistical significance (see Table22).

Exercise	R^2	CI	P-Value
Clamshell	0.78	0.59 to 0.88	<.0001
SAQE	0.57	0.11 to 0.83	.017

Table22. Clamshell and SAQE exercise force correlation.

Discussion

The main aim of this study was to explore agreement of measures validating the use of biofeedback, in the form of bathroom scales, complementing two recognised exercises recommended for rehabilitation of the lower extremity. Principal findings of this research were statistically significant correlation between the EMG profiles for specific muscles engaged during the range of clamshell and SAQE exercises undertaken. Force outcomes were also correlated between dynamometry and biofeedback measures.

EMG analysis of the GMED during execution of the clamshell exercise provided indication of consistent activity. The seated version of the clamshell with and without biofeedback was highly indicated as collinear. The ICC for GMED in the two positions indicated good (side-lying vs seated derivatives) to excellent reliability (seated bio vs nonbio derivatives) (Fleiss, 1999). This high correlation for the seated clamshell could be attributable to the consistency in positioning, pressure, timing and stabilisation afforded to the method of execution (Cuthbert et al., 2007). This could be further influenced by the asymptomatic sample, ignoring any gender-specific traits (Carcia and Martin, 2007; Nyland et al., 2004); there is evidence that GMED strength is compromised in low back pain sufferers assessed using subjective manual muscle testing (Cooper et al., 2016). The deployment of simple objective physical measures in these type of epidemiological studies could establish higher confidence in providing management strategies for at-risk populations (Cooper et al., 2010); bathroom scales could facilitate this.

The level of correlation between seated and side-lying clamshell GMED EMG activity within this study indicates some slight variance in execution. The %MVIC ranged from 63.5 to 67.7 across three positions, improving favourably against the reported 38-40 %MVIC of Distefano et al. (2009) and 27-36 %MVIC of Selkowitz et al. (2013) and Sidorkewicz et al. (2014). This may be attributed to the change in range of movement and muscle recruitment between various positions for hip abduction (Bolgla and Uhl, 2007; Thorborg et al., 2009; Youdas et al., 2014). This variance has also been considered in relation to standing compared to side-lying capture of hip abduction measures (Brent et al., 2013); this study advocated the use of targeted abduction exercises that the current findings would also support. The maturational differences in sex and age detailed by Brent (ibid.) were not considered due to the maturity of this current sample.

The VLAT activity profile was also consistent within two variants of clamshell exercise; side-lying and seated without biofeedback. VLAT activity has been reported as active during counter-adduction stabilisation in reciprocity with VMED while performing leg press (Peng et al., 2013); the %MVIC of 31.28 to 39.34 was comparative to the 35-36 readings from VLAT during SAQE but less than the 88 %MVIC during the clamshell exercise of the current study. VLAT EMG profiling across 24 hours shows generally low activation (Klein et al., 2010) (>1 minute above 80 %MVIC) but may support a short-lived intensity demonstrated in the current sample. VLAT activity has been explored in the role of leg extension exercises (Chang et al., 2014; Irish et al., 2010; Peng et al., 2013) and the reported %MVIC ranges of 55-98 cover the VLAT outcomes in the current findings. Combined leg extension and hip abduction has also been seen to produce diminished EMG VMED and VLAT activity (Hertel et al., 2004); a uniplanar approach to VLAT is supported by the higher EMG profiles indicated with this study's clamshell exercise, regardless of variant performed.

The VMED myoelectric activity showed excellent reliability and strong correlation between SAQE exercise variants. Percentage MVIC was 44.57 and 47.24 for standard and biofeedback myoelectric responses. This is less than previously reported values for VMED during open and closed-chain sling extension exercises; 86.30 and 85.67 respectively (Chang et al., 2014). Comparison to this earlier study may be limited by its normalisation of the MVIC which entailed the use of a maximum resistance rather than a control exercise set. EMG datum for a standard open-chain knee extension has been reported as 65 %MVIC (Irish et al., 2010); while comparable to reports for closed-chain activation (55-66 %MVIC) (Ayotte et al., 2007), there are broad ranges described within these studies (squat and lunge exercises incorporate 60 to 99 %MVIC) (Irish et al., 2010). Nuanced heterogeneity in the samples may be a potential influence, reinforcing variability considered in EMG studies of leg musculature (Staudenmann et al., 2009); typically low sample and asymptomatic participants limit generalisation to other populations across the related EMG literature.

Reviewing the GMAX outcomes in this study indicates strong correlation between standard and biofeedback SAQE exercise which exceeds activation during clamshell. The biofeedback modification to SAQE within this study suggests that GMAX is the dominant producer of force within the execution of the exercise for this sample. While VMED still produces comparable signals, the added downward force to register pressure on the scales implicates hip extension, and would invoke signal activity in the prime extensor within this mechanism. This suggests that gluteal activation may be a further benefit of this modified knee extension exercise. The 82-84 %MVIC for GMAX is substantially raised compared to the 27-59 range across twelve exercises reported by Distefano et al. (2009). The values approximate to 64-94 %MVIC described across a 0-90° range of hip positions (Worrell et al., 2001) and the 20-88 %MVIC for bridging, step-up and squat exercises (Youdas et al., 2017). The closest parallel to the current data is seen with resistance to prone trunk extension (with lower extremity stabilised) stimulating 88 %MVIC for GMAX (Ekstrom et al., 2008). This stabilisation between knee and pelvis seemingly proffers similar activity to the fixed position of pelvis and thigh with the SAQE. This suggests potential use of the SAQE to target GMAX in suitable patient populations, demonstrating very high-level activation (>60 %MVIC) (Reiman et al., 2012).

Force measures demonstrated moderate (SAQE) and high (clamshell) positive correlation (Mukaka, 2012). The GMAX dominance in the biofeedback version of the SAQE may account for the moderate level seen along with positional changes in obtaining the two measures of force. The median knee extension force generated (41kg) placed this sample 10 units above an elderly cohort measured using a spring gauge for quadriceps assessment (Hsu et al., 2014). Such differences would seem commensurate with reports of age-related strength loss (Cadore et al., 2014; Landi et al., 2017) and this population would benefit from the muscle power training offered by these SAQE and clamshell variants. Hip muscle strengthening in respect of PFPS demonstrates seemingly congruent values with the current study (Santos et al., 2015; Thomson et al., 2016); their reported follow-up values are in the range of 2.1 to 2.4 nm/kg for abduction and 3.88 to 3.93 for knee extension.

The variety of force and strength measures implicated across reviews shows heterogeneous properties, with torque, mass, weight and BMI being used arbitrarily and limiting generalisation. This further supports the need for standardisation of methodology around strength measures highlighted by other authors (ibid.). The dynamometry measures for SAQE were potentially prone to additional variance due to differences in the positions and method of muscle testing (Garcia et al., 2016; Tabard et al., 2015). All corresponding %MVIC values, however, were in the region of activation levels (>40 %MVIC) promoting strength gains (Reiman et al., 2012). The approximation between these strength values suggest further scope for complementing manual muscle testing within the clinical and domiciliary settings. The accuracy of different commercial bathroom scales may be equivocal; this is offset by use of a single, consistent repeatable measure as the primary concern in standardising any home-based knee programme (Ravaud et al., 2009).

Strengths and limitations

The strengths of this study were the reliability of the repeated measures due to ease of execution, uniplanar positioning and consistent duration. This validation substantiates the use of bathroom scales to facilitate muscle testing and strength training in a domiciliary setting. Limiting factors were in accordance with those described in the wider literature; the homogenous, small sample size lacked nuanced characteristics to fully determine the boundaries of participant engagement given the failing to achieve *a priori* sample size estimate. The substantiation of strength measures is also subject to the vagaries of multiple outcomes explored in the literature; repeating within a conventional lab setting with floor-standing dynamometry may be optimal for further validation. Further work in relation to exploration of predictive models, with other physical outcome measures, could inform how the use of these data could be used in imputation analysis around clinical assessment. There may be potential to accrue population data for normative values, exploring variances in patient presentation and nuances of different equipment given the ubiquity of bathroom scales. The adoption of the pragmatic approach demonstrated in this study allows for exploration of factors such as repeatability and suitability. The order and dosage of exercises requires further investigation in respect to applicability to symptomatic individuals. Future research should also determine the suitability of deploying this form of biofeedback within a home-based rehabilitation exercise programme.

Conclusion

This study sought to validate the agreement between measures of quadriceps and gluteal muscle activity in short arc quadriceps extension and seated clamshell exercises, when augmented by the use of bathroom scales. The major findings provided evidence that electromyography data was consistent and predictable when comparing the exercises with and without the scales. Biofeedback force reporting was also significantly associated with dynamometry readings. Further research should be undertaken to explore the suitability of this form of biofeedback, within a domiciliary rehabilitation exercise programme, compared to an appropriate alternative.

PHASE II

Exploratory trial: A novel rehabilitation intervention using a bespoke online health community, biofeedback and eHealth.

CHAPTER 6: What is the effect of biofeedback on quadriceps and gluteal generated force when used as an adjunct to short arc quad and seated clamshell exercises?

Introduction

Knee pain is reported as inevitable with aging and contributes to the comorbidity of chronic musculoskeletal pain in the global population (Jordan et al., 2010). As previously described, conditions such as OA and PFPS are seen to benefit directly from exercise interventions with clinically important pain reduction (Chapter 4; Chapter 5; Fransen et al., 2015; van der Heijden et al., 2015). Deficit in muscle strength and power have been shown to alter biomechanics and perpetuate changes in arthrokinematics of the knee (Murray et al., 2015). This can be the precursor of significant pain, stiffness and reduced function and mobility as articular cartilage degrades (Bhatia et al., 2013). While prophylactic procedures to offset articular cartilage defect degradation are now recommended (Chapter 1; NICE, 2017b), appropriate, activity and compliant exercise, commensurate with the characteristics of the individual, may ensure optimal knee health (Dedinsky et al., 2017; Marks and Allegrante, 2005).

The National Institute for Health and Care Excellence guidelines for the core treatment of knee pain are muscle-strengthening exercises, with the adjunct of manual therapy and raised activity levels (NICE, 2011). This combination, when employed pre-operatively, has had mixed results; improvement in function and reduced pain levels are seen in hip patients but not those awaiting knee replacements (Gill and McBurney, 2013; McKay et al., 2012). Partial or complete joint replacements can improve quality of life, and enable a return to daily activity by reducing pain and improving function (Bijlsma and Knahr, 2007). Highly implicated in this process is guided patient recovery and rehabilitation, either face-to-face or via eHealth measures with appropriate activity dosage (Chapter 1; Chapter 3; Chapter 4;Marsh et al., 2014b; Zech et al., 2015). Muscle strengthening exercises have also been found to improve post-operative recovery rates, and reduce falls and further injury when combined with manual therapy (Gokeler et al., 2015; Piva et al., 2017; Taniguchi et al., 2016).

Clinical guidelines advise that care plans be individualised with the end goal of ensuring participation (Bennell et al., 2014). These guidelines highlight the importance of participant motivation and accessible facilities as key considerations to be taken into account; supervised exercise programmes facilitated by healthcare practitioners may be the ideal but the expense can be prohibitive (Bennell and Hinman, 2011). Home exercise programmes eliminate these financial and accessibility issues and have been found to be as effective as hospital and rehabilitation centre led programmes (Galea et al., 2008; López-Liria et al., 2015). Improved adherence to exercise programmes for hip and knee demonstrate better outcomes in pain levels, physical function and self-perceived effect; stimulating and maintaining adherence in the long term is a challenge (Marks, 2012; Pisters et al., 2010).

Two muscle groups generally recognised as having pre-eminent roles in optimal knee health are the quadriceps and gluteals (Thompson et al., 2013). There is a suggestion that vastus medialis oblique (VMED) and vastus lateralis (VLAT) imbalance is a contributing factor in knee pain (Miao et al., 2015) but targeted exercise strategies show equivocal results in PFPS (Alrshood et al., 2017; Thomson et al., 2016). Studies have demonstrated that performing isometric exercises to strengthen VMED elicit discernible morphological change in the muscle (Khoshkhoo et al., 2016). A typical open-chain, isometric exercise for the quadriceps, including VMED, is the short arc quadriceps extension exercise (SAQE) (Chapter 5; Chen et al., 2015; Kushion et al., 2012).

The clamshell exercise is a further open-chain, non-weight bearing, strengthening exercise used in pain management and rehabilitation programmes for hip and knee arthroplasty (Chapter 5; Sidorkewicz et al., 2014). The GMED is described as having the most influence on hip and knee loading (Valente et al., 2013) and the clamshell exercise can be an effective resistance training exercise for this muscle. Guided, home-based, exercise as rehabilitation is seemingly safe and effective but further quality trial data is required (Kim et al., 2016a).

There is growing use of biofeedback within exercise and rehabilitation with suggestion of associated post-operative functional recovery (Akkaya et al., 2012; Inan et al., 2018) and increased muscle strength (Kirnap et al., 2005). Dynamometry and electromyography (EMG) are stated as the most widely researched biofeedback tool (Chapter 5; van Melick et al., 2016; Wasielewski et al., 2011) but these systems can be expensive to implement or require a high level of technical mastery (Chen et al., 2015; Levinger et al., 2016; Senanayake et al., 2013). Cheap and simple options, such as sphygmomanometer cuffs and bathroom scales, have been explored in physical therapy with respect to assessing adductor strength and grading weight-bearing during rehabilitation (Delahunt et al., 2011; Malviya et al., 2005). The findings described in Chapter 5 suggest that, inclusion of biofeedback in clamshell and SAQE has a direct linear agreement with a standard version of both exercises, in terms of muscle activity and generated force. It is not known how this inclusion of biofeedback would influence force outcomes over the course of an exercise programme. The use of bathroom scales as a cost-effective and readily available form of biomechanical biofeedback, providing a quantitative realisation of patients' muscle-generated force has not been explored.

Aims and Objectives

The primary aim of this study was to investigate the effectiveness of biofeedback at improving generated force of the quadriceps and gluteal muscles during two knee exercises compared to no feedback. The objective was to specifically compare short arc quadriceps extension and seated clamshell exercises with or without the use of bathroom scales as biofeedback in respect to generated force, in kilograms. The following research question was addressed:

Is there a difference in gluteal and quadriceps generated force subsequent to a home exercise programme for the knee with or without the augmentation of biofeedback?

Method

Design

Randomised feasibility study

Participants

Participants were recruited from current year 1 to 4 undergraduate students on the Osteopathy programme at the European School of Osteopathy and Year 2 undergraduates on the Sports Therapy programme at the University of Kent. Recruitment took place from August 2016 to January 2017 and student participants were invited to take part in the study via email and notices placed around campus. The following criteria were applied:

Inclusion Criteria

Male and female adult students were engaged to participate if they could commit to performing regular exercise, undergo fortnightly assessments, receive reminders via text message and had Internet access.

Exclusion Criteria

Participants were excluded from taking part if they were suffering with bilateral knee or hip pain, engaging in high intensity physical training or were diagnosed with an underlying metabolic disorder or neuromuscular condition.

Equipment

Participant baseline characteristics measures were captured via an online SurveyGizmo (SurveyGizmo Co., Boulder, CO, USA) form transferred to a spreadsheet. Anthropometric data was gathered using Bluetooth-connected Konig KN-PS800B digital bathroom scales, free-standing stadiometer and tape measure. Quadriceps and gluteal muscle strength was measured with

PCE-CS 300 dynamometer (PCE Instruments UK Ltd, Southampton, UK) and the Konig bathroom scales (Figure11).

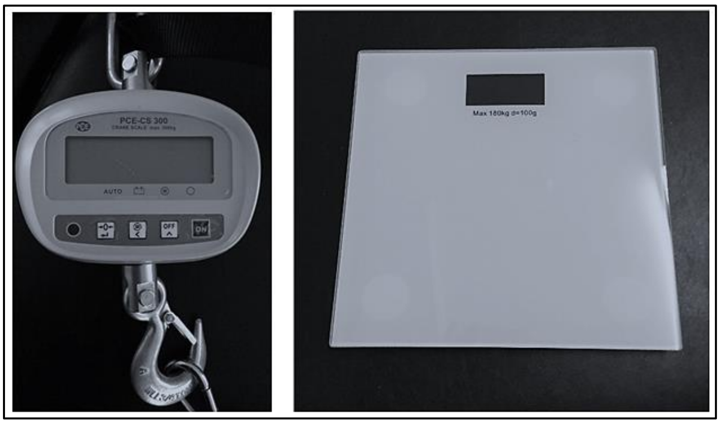

Figure11. Equipment to measure pre- and post- intervention gluteal strength.

Procedure

Following initial recruitment by two research assistants, online and paper patient information was provided with appropriate capture of consent details in accordance with the ethics procedure. After initial screening and baseline data capture, participants meeting the inclusion criteria were randomized into two groups using a software generated list for random allocation. The following characteristic data were collected at baseline: Height (cm), weight (kg), waist circumference (cm), musculoskeletal pain and activity levels (both 11-point (0-10) numeric rating scales), age, gender and dominant leg (leading in gait cycle). Circumferential measures were taken at three points; pelvis (taken at the level of the anterior superior iliac spine or ASIS), mid-thigh (mid-point between the superior surface of the greater trochanter and the lateral inferior border of the femoral condyle) and pre-patella (superior to the base of the patella).

Pre-intervention measurements of quadriceps and gluteal muscle strength in the dominant leg in each participant were then measured in two ways; dynamometry and bathroom scales. The quadriceps extension strength was assessed with the participant sat on a fixed treatment couch; the portable dynamometer fixed via its hook connector to a wall-mounted eye shield anchor positioned below the seated participant. The dominant knee was supported by the edge of the couch running parallel to the posterior joint line at the popliteal crease, the leg at 90° to the thigh (adapted from Amano et al. (2016)). The participant was instructed to push with their ankle restrained against the strap of the dynamometer with a maximum contraction for 3-5 seconds. The assessment involving the bathroom scales employed an adapted version of the short-arc quadriceps extension exercise using a foam-roller as a support under the knee (adapted from Kushion et al. (2012)). The roller was positioned on the bathroom scales to facilitate the viewing of readings as the participant contracted the quadriceps (Figure12).

Figure12. Dynamometer and bathroom scale recordings for extension exercises.

The gluteal abduction required the participants to sit on a couch with their non-dominant leg outstretched and their dominant leg flexed at the hip and knee, with zero degrees abduction of the hip (see Figure13). The dynamometer strap was placed around their distal femur and proximal tibia, and they were instructed to abduct the hip against the resistance of the strap with maximal effort. The contraction timings followed the quadriceps instruction and for both exercises the participants were instructed to hold either side of the couch for stabilisation. The maximum force generated with each effort was recorded and the process was repeated 3 times for each exercise and the average calculated for each participant.

Figure13. Dynamometer and bathroom scale recordings for seated clamshell.

To record hip abduction force using the bathroom scales, participants were sat on the floor, with their dominant leg positioned next to a wall and performed a seated version of the clamshell exercise (an adaption from Distefano et al. (2009)). They were instructed to keep their non-dominant leg outstretched and their dominant knee and hip flexed with zero degrees hip abduction. The scales were positioned between the participant's dominant knee and the wall; participants were instructed to push into abduction, while supporting themselves with both hands on the floor. This process, with maximum force captured with each effort, was repeated 3 times to create an average for each individual.

Allocation and study progression

Participants were randomised into two groups via a computer-generated random number listing. Both groups were instructed to repeat the baseline exercises with one group (bio) using the bathroom scales as biofeedback to complement the programme. Each exercise required a timed 5 second contraction and 2 second relaxation phase and was initially repeated in sets of 12 and on both legs with a 60 second relaxation phase between sets. The progression phases for the groups across the six weeks, modified from studies into progressive exercise for knee OA (O'Reilly et al., 1999; Scopaz et al., 2009), are depicted in Table23. Volume change was staged by increasing sets with consistent repetitions; intensity was to be determined by the individual based on force readings elicited by maximum pressure exerted on the scales (anticipated to increase over time).

Exercise staging	Intensity (Sets x Repetition)	Between Sets Rest Period
Short arc quadricep extension		
Week 1-2	2 x 12	20 secs
Week 3-4	3 x 12	20 secs
Week 5	4 x 12	20 secs
Week 6	5 x 12	20 secs
Modified (seated) clamshell		
Week 1-2	2 x 12	20 secs
Week 3-4	3 x 12	20 secs
Week 5	4 x 12	20 secs
Week 6	5 x 12	20 secs

Table23. Main principles of the qod 6-week strength exercise programme.

Each group was given paper instructions detailing the first 2 weeks of their programme and were sent standard short message service (SMS) text reminders every other day when they were due to perform the exercises. Participants in the bio group were each given a set of bathroom scales, and a link to online bespoke video instructions detailing their exercise progression, and how to use the scales to assess resistance. Participants in this group were also asked to post readings of their maximum effort achieved onto an online forum after each exercise session (see Chapter 7). Participants in the standard exercise group (non-bio) were requested to return every 2 weeks to review performance and initiate the next progression. These participants were also requested to keep a diary of their engagement in order to provide evidence of compliance.

Primary and secondary outcome measure

The primary outcome measure was the strength related to kilogram force of hip abduction and knee extension of the dominant leg measured by bathroom scales and dynamometer at week six. Secondary outcomes were circumferential changes in the mid-thigh, pre-patella and pelvis circumference at week six.

Blinding

Randomization, treatment allocation and statistical analyses were performed blindly. Two research assistants measured all participants at baseline and follow-up and managed the allocation, progression and reminder procedures. The primary investigator (PB) was blinded to participants' treatment allocation and analysed the anonymised data independently of the data gathering. Due to the nature of the interventions, neither the patients nor the research assistants could be blinded; no details were provided to participants on perceived beneficial group allocation.

Sample size

Strict adherence to *a priori* sample size requirement was not possible. The outcomes were captured using a mobile dynamometer to facilitate location-independent data gathering; as such no minimally important change data were available from studies using either kilogram units or normalised values as an indicator of muscle strength or force. Strength changes are reported across heterogeneous samples and this study aspired to replicate the findings of Stensrud et al. (2015), using 32 patients in each group to detect a statistically significant difference of 10% between the group means in knee extension strength. The intended sample size required for this current study was calculated using G*Power (Faul et al., 2007), software version 3.1 (Heinrich-Heine-Universität Düsseldorf, Germany) . The *a priori* calculation was based on testing for mean difference, with 32 individuals required in each group. This was determined using an anticipated effect size of 0.71 with power set at 80%, 5% α probability. The novel nature of the data capture determined that the feasibility be explored in order to qualify the replicable intervention, identify efficacy measures and post-hoc power across appropriate comparators (Craig et al., 2008; Lancaster, 2015). Recruitment was halted once sampling was exhausted from the available population. (Tyler et al. 2006).

Ethics

The study protocol was approved by the Research Ethics Committees of the European School of Osteopathy and the School of Sport and Exercise

Sciences, University of Kent. Participants were advised to report any adverse events encountered while engaged on the study to the primary investigator (see Appendix V for The Patient Information Sheet and Consent Form).

Data analysis

Results of the study were calculated and analysed using Excel version 16 (Microsoft Corporation, Redmond, WA, USA), SPSS version 24 (SPSS Inc., Chicago, IL, USA) and Analyse-it version 3.76 (Analyse-it Software, Ltd., Leeds, UK). Summary statistics from participants, including body mass index (BMI, kg/m^2) and waist-to-height ratio (WTH-R), were reported. Non-normalised strength measures were used to normalise values for strength outcomes, calculated using the formula $S_n = S/m$ (where S is the non-normalised strength measure, m is mass and S_n is the normalised value independent of body size) (Bazett-Jones et al., 2011). This was performed to allow comparison of findings to the wider literature.

Intention to treat (ITT) analysis was adopted; any missing outcome data at follow-up were imputed via multiple linear regression modelling, using populous continuous variables as predictors for values that were omitted. Nominal variables were assessed for proportionality using Chi^2 and Fisher's exact test. Baseline continuous data were analysed for homogeneity (Shapiro-Wilks and Levene's test) and assertion of comparable randomised allocation between the groups. Pre- and post-intervention quadriceps and gluteal strength and volumetric measures were tested for shifts in location of mean or median differences, dependent on ratified parametric test assumptions (student's t-test or Wilcoxon Mann Whitney U with 95% confidence intervals (CI)); significance threshold was set as $P<.05$. Effect sizes (> 0.8 large effect, 0.5 moderate effect, <0.3 small effect) and post-hoc power were calculated in relation to mean differences using G*Power (Faul et al., 2007), software version 3.1 (Heinrich-Heine-Universität Düsseldorf, Germany).

Results

Participant data

Forty two students were randomised into two groups with five participants (12%) lost to follow up. One individual was counselled to withdraw following allocation due to high performance training commitments. Eight participants (22% of ITT analysis) discontinued the exercises between weeks 3 and 4; final outcome measures were imputed for these 8 individuals (3 clamshell outcomes, 5 quadriceps outcomes). See Figure14 for participant allocation and flow through the study including group numbers lost to attrition.

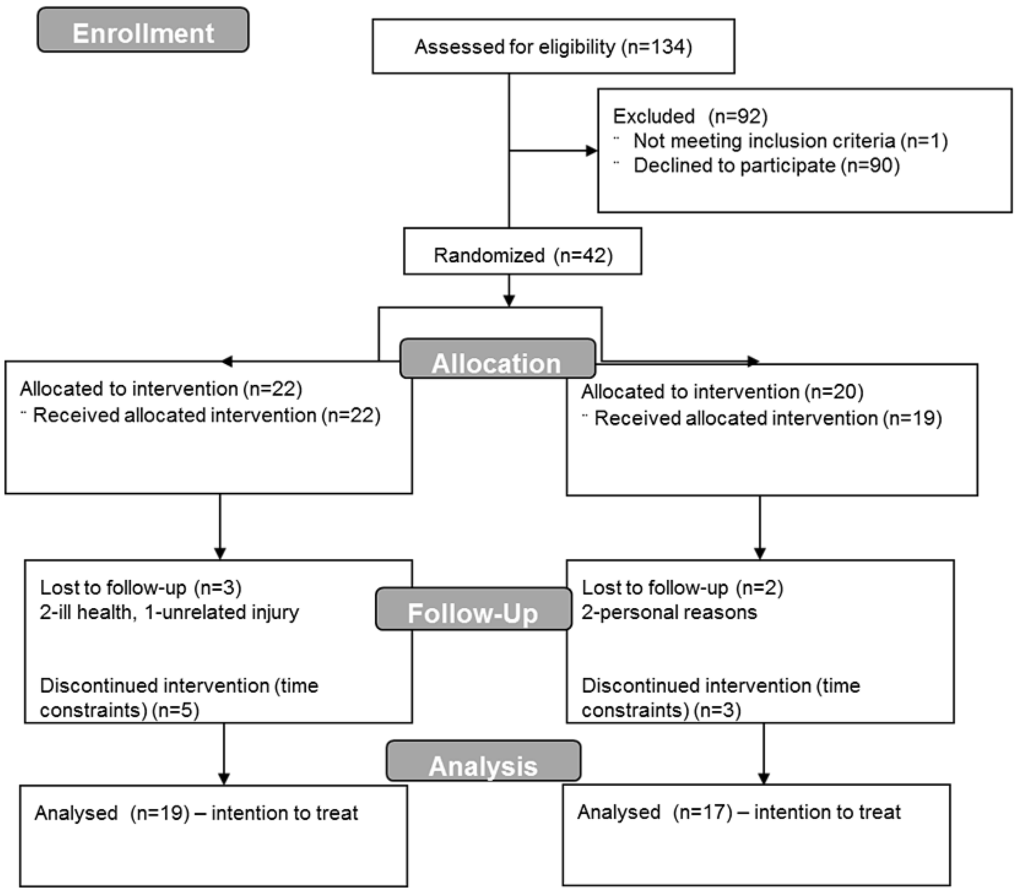

Figure14. CONSORT flow diagram of participant engagement.

Baseline characteristics

The groups were comparable across the range of baseline data and conformed to parametric test assumptions for continuous data (*P*>.05);

gender was reported as 47% female in the bio group and 64% female in the non-bio group. BMI and WTH-R were at the healthy threshold measure (25 and 0.5 respectively) and moderate activity levels were reported in both groups with low levels of musculoskeletal pain. Two participants attempted to maintain a diary of their exercise from the non-bio group; all 19 participants engaged with reporting progress online in the bio arm of the study (detailed in Chapter 7). Full baseline characteristics are presented in Table24.

Group	Bio	Non-bio
Gender F/M	9/10	11/6
Age	32.8 (10.8)	27.5 (10)
Dominant Leg L/R	2/17	1/16
Height(cm)	173.5 (10.1)	171.1 (10.2)
Weight(kg)	75.65 (16.2)	75.45 (15.12)
BMI(kg/m$^{2)}$	25.01 (4.39)	25.77 (4.83)
Waist(cm)	87 (12.9)	88.4 (11.3)
WTH-R	0.5 (0.7)	0.5 (0.7)
NRS-Pain-MSK	2.0 (3)*	1.0 (3)*
NRS-activity	4.4 (1.3)	4.7 (2)

Table24. Summary of baseline characteristics between groups – continuous data mean (SD). **Median and inter-quartile range (IQR)*

Primary and secondary outcome measures

The primary and secondary baseline outcome measures all demonstrated comparable characteristics (*P*>.05) but clam dynamometry (both groups), pre-patella (bio) and pelvis circumference values were skewed. The summary values for these measures are reported in Table25.

Group	Bio	Non-bio
SAQE-Dyn(kg)	42.91 (17.52)	39.37 (13.45)
CLAM-Dyn(kg)	21.62 (13.5)*	18.23 (15.33)*
SAQE-Sc(kg)	24.59 (10.91)	19.59 (7.57)
CLAM-Sc(kg)	20.58 (9.52)	16.20 (7.76)
Pre-patella(cm)	40 (9.3)*	37.4 (8.3)
Mid-thigh(cm)	53.8 (8.4)	55 (6.3)
Pelvis(cm)	94.5 (13.5)	92 (10.3)*

Table25. Summary of baseline outcome measures between groups – mean (SD). **Median (IQR), SAQE- short arc quadriceps extension; Dyn –dynamometer; Sc - scales*

With the exception of one outcome, normalised data for generated force demonstrated consistent but non-significant improvement at final follow-up. The pre and post-intervention values are depicted in Table26. The between-group differences for each normalised outcome were: 0.09 (SAQE-Dyn), 0.03 (CLAM-Dyn), 0.12 (SAQE-Sc) and 0.05 (CLAM-Sc).

Outcome		Group	
		Bio	**Non-bio**
Pre-programme	**SAQE-Dyn**	0.56 (0.21)	0.53 (0.17)
	CLAM-Dyn	0.28 (0.16)*	0.26 (0.17)*
	SAQE-Sc	0.32 (0.13)	0.27 (0.11)
	CLAM-Sc	0.23 (0.11)*	0.19 (0.11)*
Post-programme	**SAQE-Dyn**	0.59 (0.33)	0.65 (0.36)
	CLAM-Dyn	0.33 (0.11)	0.34 (0.14)
	SAQE-Sc	0.36 (0.08)	0.43 (0.13)**
	CLAM-Sc	0.26 (0.13)*	0.27 (0.13)*

Table26. Summary of normalised force outcome measures (kg^1/kg^2) between groups – mean (SD). **Median (IQR), **P<0.05 Wilcoxon Mann Whitney U,1-strength,2-bodymass*

The differences within and between groups' outcomes at six weeks were comparable with the exception of the short arc quadriceps extension using scales (both normalised and non-normalised); this demonstrated a statistically significant shift in means (non-bio; 61% increase, student t-test: P=.01). The effect size in this instance was large (0.87) with achieved power of 72%. There was a general improvement in force generated for all measures with the non-bio group demonstrating a greater increase.

Outcome Measure	Group	Within Group Difference (mean (SD))	Mean Difference (CI)	Effect Size	Power
SAQE-Dyn(kg)	Bio	3.83 (21.31)			
	Non-bio	7.99 (24.05)	4.16 (-11.2 to 19.52)	0.18	0.08
CLAM-Dyn(kg)	Bio	1.44 (8.20)*			
	Non-bio	4.17 (6.23)*	2.55 (-1.8 to 6.75)**	0.18	0.08
SAQE-Sc(kg)[1]	Bio	2.82 (9.29)			
	Non-bio	12.03 (11.79)	9.21 (2.06 to 16.36)	0.87	0.72
CLAM-Sc(kg)	Bio	3.67 (13.83)*			
	Non-bio	5.1 (6)*	1.43 (-3.47 to 7.83)**	0.2	0.09
Pre-patella(cm)	Bio	-1 (6.8)*			
	Non-bio	0 (7)*	3 (-1 to 9)**	0.64	0.45
Mid-thigh(cm)	Bio	-1 (4.8)*			
	Non-bio	-2 (5.7)*	-2 (-5 to 2)**	0.01	0.05
Pelvis(cm)	Bio	-1 (5.5)*			
	Non-bio	1 (3.3)*	3 (0 to 6)**	0.31	0.14

Table27. Summary of differences and between groups' effect sizes with achieved power. **Median (IQR), **Hodges-Lehmann shift, 1*-P=.01

Both groups reported minor changes and a trend of reduction in the circumferential measures. Full details of within and between groups' difference are detailed in Table27 and percentage change is depicted in Figure15. Greater percentage change was evident for all outcome measures within the non-bio group, apart from the pre-patella circumference, which demonstrated no difference at follow up in terms of median shift. Mean SAQE force increase was 26% across all measures with all groups demonstrating an increase in excess of 8%.

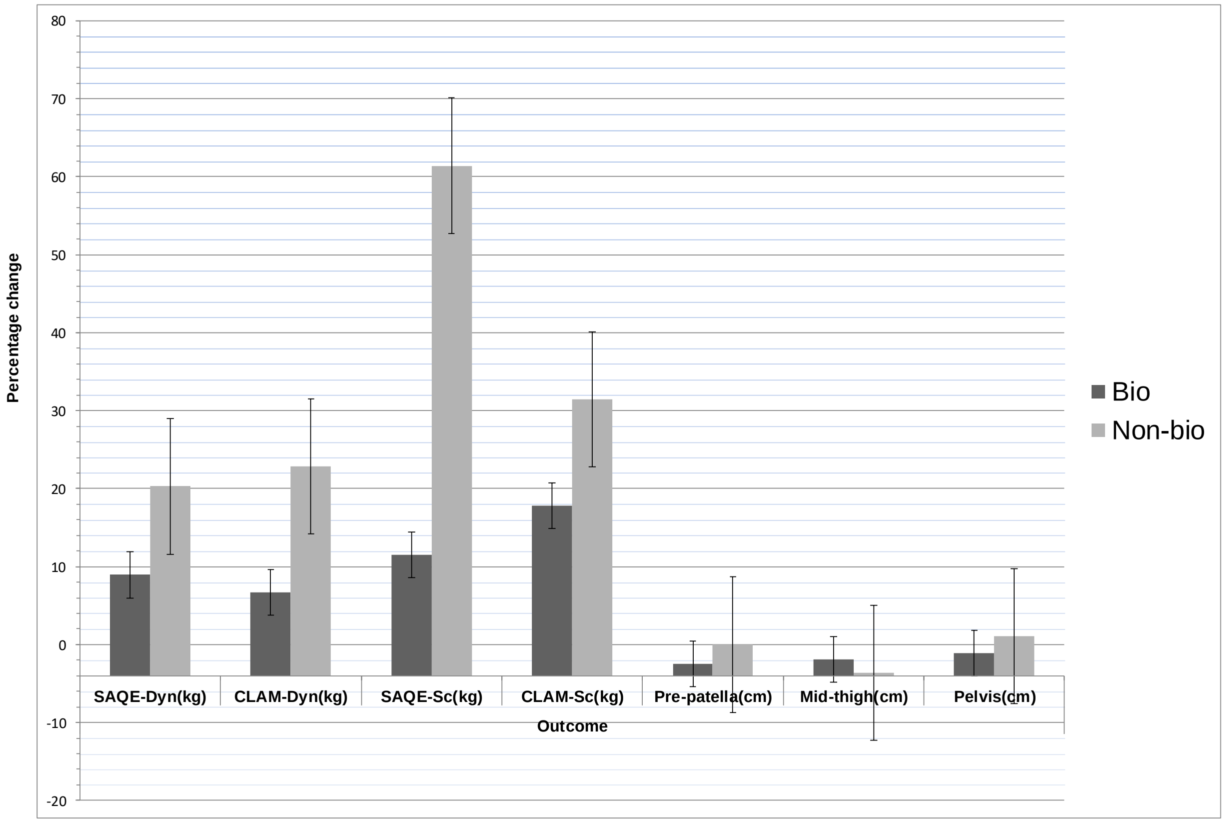

Figure15. Comparative percentage change within groups.

Adverse events

There were no exercise-attributable adverse events reported during the study that contributed to the withdrawal of participants. Only individuals in the bio group (n=4) reported any mitigating factors affecting strength: two of these described feeling weak as a consequence of a viral infection; one felt generalised pain as a consequence of a non-related injury and one described an increase in hypermobility. All these individuals reporting subsidiary effects completed the full six-week exercise programme.

Discussion

The primary aim of this study was to determine if a difference in gluteal and quadriceps strength was apparent when undertaking a home exercise programme for the knee with or without the augmentation of biofeedback. The secondary aim was to determine if changes in strength also contributed to a change in circumferential measures of the thigh and pelvis. While both groups improved in generated force, only one outcome showed statistical significance (the non-bio group). This was in relation to the short-arc quadriceps measure recorded on the bathroom scales, indicating a large effect (0.87). Minor, statistically insignificant changes were seen in terms of thigh and pelvic dimensions; moderate attrition (22%) was encountered, suggesting reasonable compliance to the exercise programme. Compliance reporting was lower in the non-bio group; 12% compared to 100% engagement in bio group.

Improvements in muscular strength are commonly reported in studies involving exercise, conditioning and training (Williams et al., 2017). Applying resistance exercise across all major muscle groups is a public health initiative (Garber et al. 2011) and is a major factor in addressing sarcopaenia and dynapaenia in the aging population (Aagaard et al., 2010; Arnold and Bautmans, 2014). Within the scope of musculoskeletal conditions with applicability for manual therapy, adjunctive exercise has a demonstrable effect (Clar et al., 2014). Changes in musculature governing knee and hip and their arthrokinematics are reported across a range of interventions or programmes (Houglum, 2016). An 8-week strengthening and proprioception programme for managing PFPS was seen to improve hip abduction strength in female patients (Earl and Hoch, 2011). The effect size reported of 0.8 related to a strength change of 0.04 in kilograms normalised to body mass for hip abduction; this falls within the normalised changes of 0.03 and 0.05 for the two abduction outcomes in this current study.

Open chain, maximum repetition extension exercises have been shown to reduce ligamentous laxity across 12 weeks with progressive protocols for anterior cruciate injury (Barcellona et al., 2015); six week checks illustrated improvements in knee stability at this interval. In the current study, the 6-week programme induced strength changes in line with reports in the literature but the groups only differed significantly with the outcomes captured from the bathroom scales as an adjunct to knee extension exercises and not hip-related measures. The percentage increase in all group's knee extension strength was comparable or exceeded the 10% required for symptomatic participants by Stensrud et al. (2015). The lack of meniscal deficits in the current sample and reported moderate activity levels may explain this high percentage difference.

The non-bio group demonstrated major improvement in SAQE scale outcome but comparable findings were evident in all other generated force and physical dimension outcomes between groups. Hypertrophy is not necessarily a coincidental effect with progressive strength changes (Delmonico et al., 2009; Wernbom et al., 2007) and can be dependent on extended training beyond the 6 weeks deployed in the current study (Knight and Kamen, 2001). While exercise is regarded as a key lifestyle component, studies around knee pain can vary in terms of programme length; ranges are seen from 6 weeks up to 5 years of extended activity (Creasey et al., 2017; Pedersen and Saltin, 2006; Thomas et al., 2002).

Gluteal strength changes have been demonstrated in acute response to Grade IV mobilisations synonymous with high velocity, low amplitude thrusts (HVLAT) (Yerys et al., 2002). Similarly to the current study, 40 asymptomatic students were sampled and the immediacy of the 3-minute post-test position suggested that volumetric change was highly unlikely. The lack of explicit reporting of effect size and power limit contextualisation; the significance of .002 is actually indicative of a mean torque difference between mobilisation groups of 2.65. While the outcome measures may reflect different strength outcomes, the standardised effect would provide a clear comparison (Colquhoun, 2014). Reported data for the Yerys et al. (2002) study facilitate post-hoc power to be calculated that are comparable to this study; an effect size of 0.9 with achieved statistical power of 0.79 (likely 0.07 increase in power over this study due to balanced, larger sample size). Yerys et al.'s acute change is a moot point as the extended duration of exercise and long-term maintenance is vital in managing knee function (Brosseau et al., 2017).

The significant SAQE finding raises several implications; dosage and compliance within the bio group and potential motivation provided by visual biofeedback as an outcome measure (Silva et al., 2013). The exercise effort, dose and duration potentially influenced the group responses; maximal effort can be problematic to determine based on individual perception purported to lead to large muscle unit activation to maintain effort (Henneman and Mendell, 2011). The role of stabiliser muscles and the extent of their involvement may have been implicated in the strategies of participants in this current study. General requirements around exercise interventions around OA suggest a focus on improving cardiovascular fitness with emphasis on increasing quadriceps strength but also include lower extremity strength conditioning through land-based activity (Fransen et al. 2015). This is suggestive of a more holistic strategy which has some contradictions in the literature that indicate specificity in approach, particularly in using individualised one repetition maximum as basis for improvement (Creasey et al., 2017).

The current study's use of bathroom scales suggests potential to provide a home-based assessment of a single exercise, repetitive strength measure, mirroring the finding of a recent meta-analysis on knee OA (Juhl et al., 2014). Conversely, the maximal resistance and compliance reported for the bio group may have affected progress with potential over-training inducing reported adverse effects and non-significant difference in strength at follow-up (Kreher and Schwartz, 2012). The novelty of the resistance biofeedback and self-determination within the non-bio group may account for the 61% increase in this group for this SAQE strength measure; pressure to conform may have facilitated an overly compliant attitude in the bio group, aligned with reported attitudes seen within weight management exercise programmes (Teixeira et al., 2012) and given the student demographic of the sample.

Exercise adherence has been identified as influential in establishing efficacy in related outcomes (Pisters et al., 2010). The participants that reported on their individual progress within this study maintained 100% compliance to the exercise programme. This may have been further enhanced by the bio group's access to online video instructions which is suggested to improve exercise adherence in managing knee pain (Kim et al., 2016b). Exploring the nuances of these influences surrounding technology use and satisfaction with related outcomes is necessary as suitable online access to materials may be deemed as important as the materials themselves (de Vries et al. 2017; Chapter 3). It should be noted that symptomatic knee patients have different psychological profiles to asymptomatic volunteers, and that specific online forums can provide the validation, support, and resources to meet the former's greater need (Chapter 4). NRS pain levels reported within the current sample was below 3 (median) and, while pain was reported as a side-effect, this may well have been highly subjective, influenced by the artifice of the study engagement (Morley, 2016). Exploration of packages incorporating pain and motivational psychology, physical activity and nutrition as eHealth, technology-based interventions is warranted; this may further inform adherence profiles, engender autonomy and mitigate lifestyle distractions within non-pharmacological maintenance of knee function (Murphy et al., 2016).

Strengths and limitations

The strengths of this study were the reported compliance over the six weeks of the exercise programme augmented by biofeedback. The implications for lack of significant difference between groups may be limited by the activity profile of the sample. Selection bias within the convenience sample of undergraduate students and their evident commitment to the exercise programme, both in reported compliance and improvement in outcomes prevent generalisation. Further exploration with symptomatic individuals from a range of socioeconomic backgrounds is suggested as vital in order to establish greater response profiles (Rolfson et al., 2016).

The use of bathroom scales suggest a suitable assessment of muscle strength as a biofeedback mechanism that could enable long term monitoring, identified as a key factor for exercise adherence (Marks, 2012). Individualized strength differences in this current study arose from motivation, self-monitoring and efficacy that informed progression data; this may have further implications for reducing therapeutic costs in a clinical setting in terms of patient autonomy (Leardini et al., 2004). Key within this is determining appropriate dosage to ensure progression beyond the current 6-week programme. This would have to be explored within the particular knee condition of interest; compliance would then be contextualised to the appropriate dosage with conditions such as OA, PFPS, TKR, ACL repair or ACR (Chapter 1; Chapter 3; Chapter 4).

The variation in the use of differing sets of bathroom scales in the domiciliary setting may be a limitation. Consistency of equipment use within this setting would be key in ensuring ongoing resistance progression is maintained. The same equipment was used for all baseline and follow-up measures within this study, and assessment reliability, could be attributable to stability of participants' position during measurement. This has previously been reported as an issue with other mobile or hand-held dynamometers (Martin et al., 2006). Research into the stability of execution in the domiciliary setting is warranted with extended capture of exercise execution through mobile video and motion capture technology (Calyam et al., 2016; Levinger et al., 2016). Qualitative exploration with symptomatic patients and their experiences in undertaking these exercises with biofeedback measures is also warranted, particularly exploring aspects of satisfaction in the process (Chapter 3).

Conclusion

This study aimed to investigate if the inclusion of a biofeedback mechanism alongside domiciliary exercises for the quadriceps and gluteal muscles resulted in a difference in hip abductor and knee extension generated force. Main findings suggest that no difference is apparent in force or circumferential measurements of the implicated musculature. There is scope that the use of bathroom scales may facilitate compliance and autonomy in the area of maintaining knee health. Extended research into the use of home-based and eHealth technology as a means to provide suitable biofeedback for exercise efficacy is warranted, with a view to increasing exercise motivation and adherence in symptomatic populations. The clinical and cost-effectiveness of this rehabilitation approach would need to be further viewed through the lens of patient experience.

CHAPTER 7: What is the feasibility of patients using an online forum for reporting progress when engaging with a six-week exercise programme for knee rehabilitation?

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Published in:

Bright, P. and Hambly, K., 2018. Patients Using an Online Forum for Reporting Progress When Engaging With a Six-Week Exercise Program for Knee Conditioning: Feasibility Study. JMIR Rehabilitation and Assistive Technologies. https://kar.kent.ac.uk/id/eprint/66865

Introduction

The use of web-based resources and eHealth applications for patients with knee pain is an area of expansion (Hussain et al., 2017; Pearson et al., 2016). EHealth is considered to encompass technology delivered through computer, hand-held tablet or smartphone that support patients and practitioners in decision making, coping strategies or functional improvement (Chapter 3; Eysenbach, 2001). There are a range of knee conditions such as OA, arthroplasty and cruciate ligament tears that are being informed by patient decision aids, electronic patient reported outcomes and biofeedback software (Chapter 3; Hambly and Griva, 2010a; Pua et al., 2015; Rini et al., 2015). Positive effects are noted across a range of conditions including knee

OA but further work is required on determining suitable interactions between patients and these eHealth measures (Stacey et al., 2014b).

The cost of developing and delivering eHealth resources is considered to be offset by the ease of patient accessibility (Vedder et al., 2014). The lack of quality studies and the heterogeneous nature of conditions supported by eHealth prevent full unequivocal endorsement of the cost-effectiveness of technology driven approaches (Darkins et al., 2015; de la Torre-Díez et al., 2015). The expedient delivery and low cost development afforded by Web 2.0 applications may facilitate further access to eHealth (Noor et al., 2014). The Web 2.0 platform has been seen to increase participation through social media and the sharing of experience due to the ease of posting materials such as video files and online forums (Chou et al., 2013). This latest generation of internet development is seen as providing a collaborative medium for knowledge generation and dissemination (Li, 2010). This underpins the potential interactive nature of eHealth programmes that has been reported to facilitate healthcare engagement (Algeo et al., 2015).

Educational research and pedagogic practice have been fruitful areas of exploration around Web 2.0 applications (Conole et al., 2010). The option to motivate learners in ever more expansive ways of engagement adds to the wider participation aspirations of higher education (Burke, 2012). There are a range of tools that allow for students to engage in learning and feedback in the Web 2.0 toolset that may have applicability in eHealth (Bennett et al., 2012; Brown, 2010; Conole et al., 2010). These tools have also been deployed to support chronic conditions in older adults with regards to education and self-management; the pedagogue/student relationship transformed to clinician/patient with the shared aim of empowerment (Stellefson et al., 2013).

The exposure to the range of eHealth has been seen to bridge gender and age differences but there is a suggestion that gender influences engagement with Web 2.0 applications (Huang et al., 2013). Online social interaction has also been explored with respect to weight management facilitated through discussion boards; attrition rates are reportedly high in this area and little change is noted in body mass index (BMI) as a common outcome measure (Williams et al., 2014). High BMI was seen to be associated with higher attrition rates.

Padlet is a Web 2.0 online noticeboard that can be used to facilitate participant interaction by posting of multimedia files as virtual ‘‘sticky notes’’ with mediation by an administrator (Fuchs, 2014). The scope for using this resource as an eHealth application has been investigated with some success in terms of engaging surgeons or clinicians to discuss cases in a forum setting (Noor et al., 2014). The initial disadvantages described around mobile access have been addressed with the latest software release (Padlet, 2017). There is potential that this platform could facilitate an OHC; OHCs can be used to share patient and clinical experiences while disseminating expert-moderated knowledge (van der Eijk et al., 2013).

These communities have the potential to allow patients to report progress and responses that are normally qualitative in nature (Chapter 4). With the range of biofeedback devices now available, the sharing of quantitative data to monitor patient progress and motivation via Web 2.0 applications has potential to influence compliance (Giggins et al., 2013). The use of the Padlet Web 2.0 platform to facilitate a patient-led, clinician-moderated, online forum around knee rehabilitation exercises with biofeedback data has not been explored. The potential to use this type of forum for participant-specific primary data gathering is also an area requiring further investigation.

Aims and Objectives

The primary aim of this study was to determine the feasibility of patients using an online forum for reporting progress when engaging with a six-week exercise programme for knee rehabilitation.

The objective was to facilitate a moderated, online community and explore the participant characteristics that reportedly influence engagement, with a view to answer the following research question:

Is there a difference in reporting progress in an online forum based on gender, age and BMI?

A secondary objective was to ascertain if sufficient individual data were reported in order to complete a multiple baseline case study for participants in the study. A tertiary objective was to establish if sufficient qualitative data were posted to allow induction of descriptive themes.

Method

Design

Mixed-methods: Quasi-experimental feasibility study with an integrated single case, multiple baseline, ABCD analysis and descriptive thematic summary.

Participants

As part of a parallel study into the effects of biofeedback on knee rehabilitation (Chapter 6), participants were recruited from current year 1 to 4 undergraduate students on the Osteopathy programme at the European School of Osteopathy and Year 2 undergraduates on the Sports Therapy programme at the University of Kent. Recruitment took place from August 2016 to January 2017 and student participants were invited to take part in the study via email and notices placed around campus. The following criteria were applied:

Inclusion Criteria: Male and female adult students were able to take part in this study if they had daily access to bathroom scales, permitted receipt of reminders via text message and had online access via any suitable device.

Exclusion Criteria: Participants were excluded from taking part if they were suffering with bilateral knee or hip pain, had recurrent high intensity physical training or an underlying metabolic disorder or neuromuscular condition.

Online Forum

The Padlet Web 2.0 application (Padlet Co, Sunnyvale, CA, USA) was used to develop the forum for posting of patient data. From the main site page (https://padlet.com), accessed via a personalised user and password, the '+make a Padlet' option was selected and a freeform option for the forum was selected (Figure16).

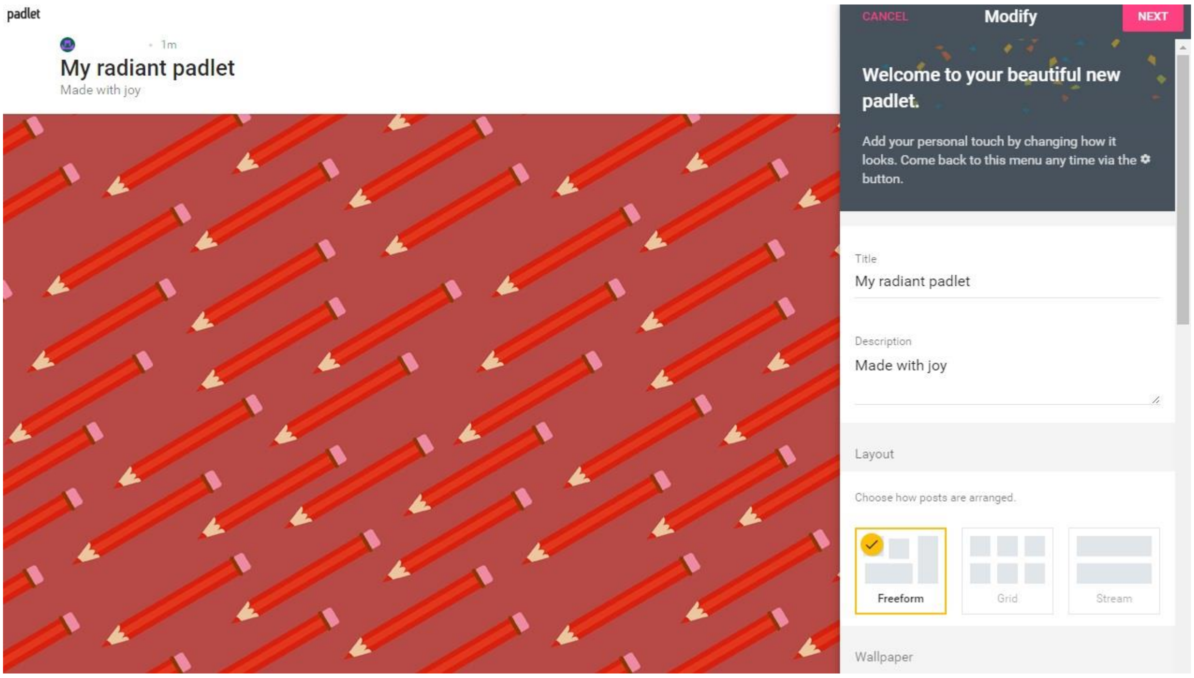

Figure16. Creation page for Padlet.**Wallpaper is indicative and themes can be customised.*

As users were encouraged to share information and experience, the posts were not anonymised but oversight of the activity was conducted by the lead researchers on the study (PB, KH). A code of conduct was posted on the webpage in order to ensure acceptable standards of behaviour were adopted. The details of this can be viewed in Textbox1. Padlet also operates its own policy for reporting and removing inappropriate content in addition to user-defined practice available on their web-site.

The use of this moderated forum is to: provide information to study participants; allow a medium for recording progress; facilitate sharing of experiences during the course of the study. The exchanges should remain respectful and courteous at all times. Banter is encouraged but the study moderators policing activity will ensure any offensive or inappropriate comments or images are removed. Participants that persist in posting such material will be asked to withdraw from the study.

Textbox1. Code of conduct displayed on Padlet.

Procedure

This study was conducted in line with guidelines to assess feasibility of a novel intervention in terms of process, qualitative assessment and variable components (Craig et al., 2008; Lancaster, 2015). The following characteristic data was collected at baseline: Height (cm), weight (kg), waist circumference (cm), body mass index (BMI, kg/m^2), activity levels (11-point NRS), age and gender. Participants were inducted into a programme consisting of staged repetitions of a seated clamshell exercise (an adaption from Distefano et al. (2009)) and short-arc quadriceps extension (Chapter 5; Chapter 6).

Both exercises were repeated in sets of 12 and on both legs with a 60 second relaxation phase between sets. The progression phases were as depicted in Table28.

Weeks 1 and 2	Maintain 2 sets of 12 repetitions every other day	Phase A
Weeks 3 and 4	Maintain 3 sets of 12 repetitions every other day	Phase B
Week 5	Maintain 4 sets of 12 repetitions every other day	Phase C
Week 6	Maintain 5 sets of 12 repetitions every other day	Phase D

Table28**.** Exercise progression details for participants.

Participants in both groups were sent text reminders on days they were required to perform the exercises. The text messages included a hyperlink to the bespoke Padlet forum with instructions detailing their exercise and video guidance materials. Participants were also requested to post readings of their maximum effort obtained from the bathroom scales onto the online forum after each exercise. Additional bespoke commentary took place during the study to elicit responses or offer encouragement; these can be viewed through the forum link and seen in Figure17.

Outcome measures

The primary outcome measure was the number of recorded entries detailing progression with the exercise schedule. A secondary outcome measure was the maximum voluntary contraction (MVIC) reading provided by the participants over the stages of engagement within the study.

Ethics

The study protocol was submitted to and approved by the Research Ethics Committees of the European School of Osteopathy and the School of Sport and Exercise Sciences, University of Kent as part of a larger study exploring the use of biofeedback in knee rehabilitation (Chapter 6).

Data analysis

The Padlet postings were exported to a spreadsheet and aligned to participant baseline data. Summary and inferential statistics were calculated using Excel version 16 (Microsoft Corporation, Redmond, WA, USA) and Analyse-it version 4.65.3 (Analyse-it Software, Ltd., Leeds, UK). The numbers of recorded entries and BMI were assessed for distribution and equality of variance; gender group relationships and differences in reporting were explored using odds ratios (OR) (with 95% confidence intervals (CI)) and the Mann-Whitney *U* test. Physical characteristics (BMI) and reporting differences were also explored using Student's t-test. Correlation between age and recording of entries was explored using Spearman's test; statistical significance was set at $P<.05$. Entries entered against one date were considered a single entry so multiple data added under a single date were only counted once. Discrete nominal values were derived from this in terms of binary (Y/N) indication of engagement with the forum to allow proportional analysis of association.

The staged recordings of maximum voluntary isometric contractions were extracted from the forum-recorded entries and three consistent datasets were analysed using a multiple baseline, ABCD case study approach aligned to stages of exercise baseline and progression (Gast and Ledford, 2014; Romeiser-Logan et al., 2017). A statistical process control (SPC) visual analysis was applied to the resultant line graphs with means and standard deviations (SD) calculated from Phase A baseline data. Statistical significance was regarded as two consecutive data points outside +/- 2 SD in Phases B, C or D (Box et al., 2015). Linear trend lines were added to indicate direction of individual progress. Finally, open forum comments were analysed within a descriptive thematic framework (Ritchie et al., 2014), and summarised in relation to the source participants.

Results

Baseline characteristics

A total of 19 participants were recruited. The group was 47% female (9/19); age ranged from 19 to 53 years (mean 32.79, SD 10.78 years) and BMI ranged between 16.63 and 33.83 kg/m2 (mean 25.02, SD 4.39 kg/m2); eight individuals (42%) were over the desired 25 kg/m2. Mean height was 173.47 (SD 10.06) cm, mean weight was 75.65 (SD 16.20) kg, and median waist circumference was 84.0 (IQR 12.7) cm. Participant’s mean activity rating was 4.42 (SD 1.30) and the median number of Padlet entries was 8 (IQR 16).

Primary outcome measure

Twelve individuals (63%) opted to engage with the Padlet forum with entry frequency ranging from 4 through to 40. Follow-up on the 7 who did not report outcomes elicited 4 replies; time constraints (n=3) and technophobia (n=1) were cited as reasons for non-response. All individuals that initially reported outcomes went on to complete the exercise programme regardless of dropout from the forum. The depiction of the finalised notice board entries can be viewed in Figure17.

Inferential analysis of the influences on reporting by gender and age showed no statistical significance. The odds for male and female responders demonstrate that gender was not a factor in this sample for engaging with the forum activity (OR 0.761, CI 0.06 to 6.93). There was no significant difference between genders and entry frequency (P=.97) or BMI and engagement (P=.46). Age and entry frequency also showed no significant correlation (R^2=0.054, CI -0.42 to 0.51, P=.83).

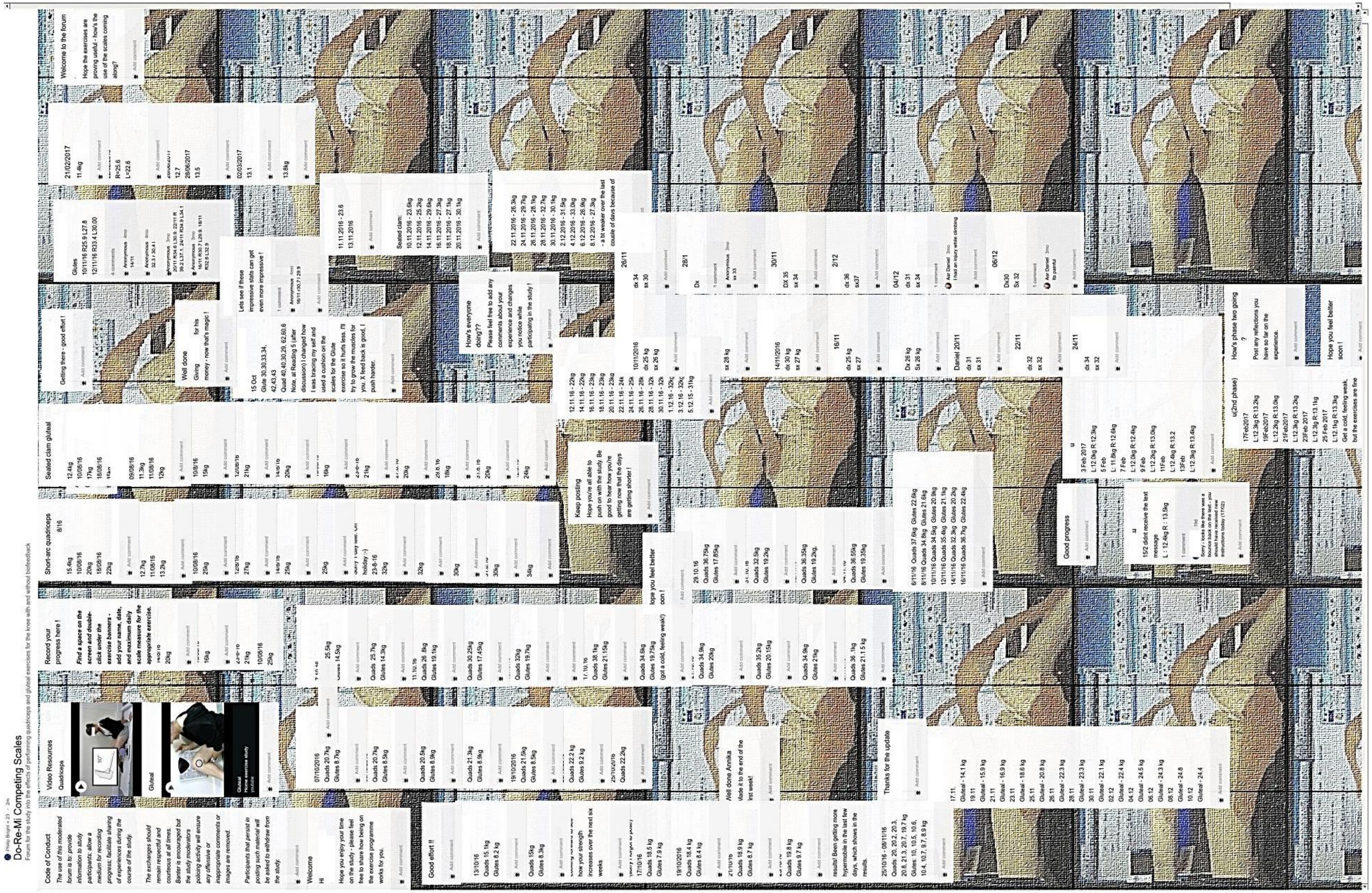

Figure17. Bespoke Padlet forum with participant and moderator posts.

Secondary outcome measure

Consistent data were reported across all six weeks of the study by 5 of the 12 participants that engaged with the forum (58% attrition rate); three were selected for statistical process control analysis due to their staggered recruitment dates (see Figure18). The multiple baseline analysis demonstrates the training effects of participants undertaking the staged exercises and the duration of their engagement with the short arc extension quadriceps exercise.

A progressive conditioning response is demonstrated in the three line graphs with significant events depicted in two of the three SPC analyses. SPC1 incurs two consecutive data points outside the upper 2SD threshold at the end of Phase D; SPC3 demonstrates a range of significant improvements in reported muscle MVIC during Phase B and D of the study.

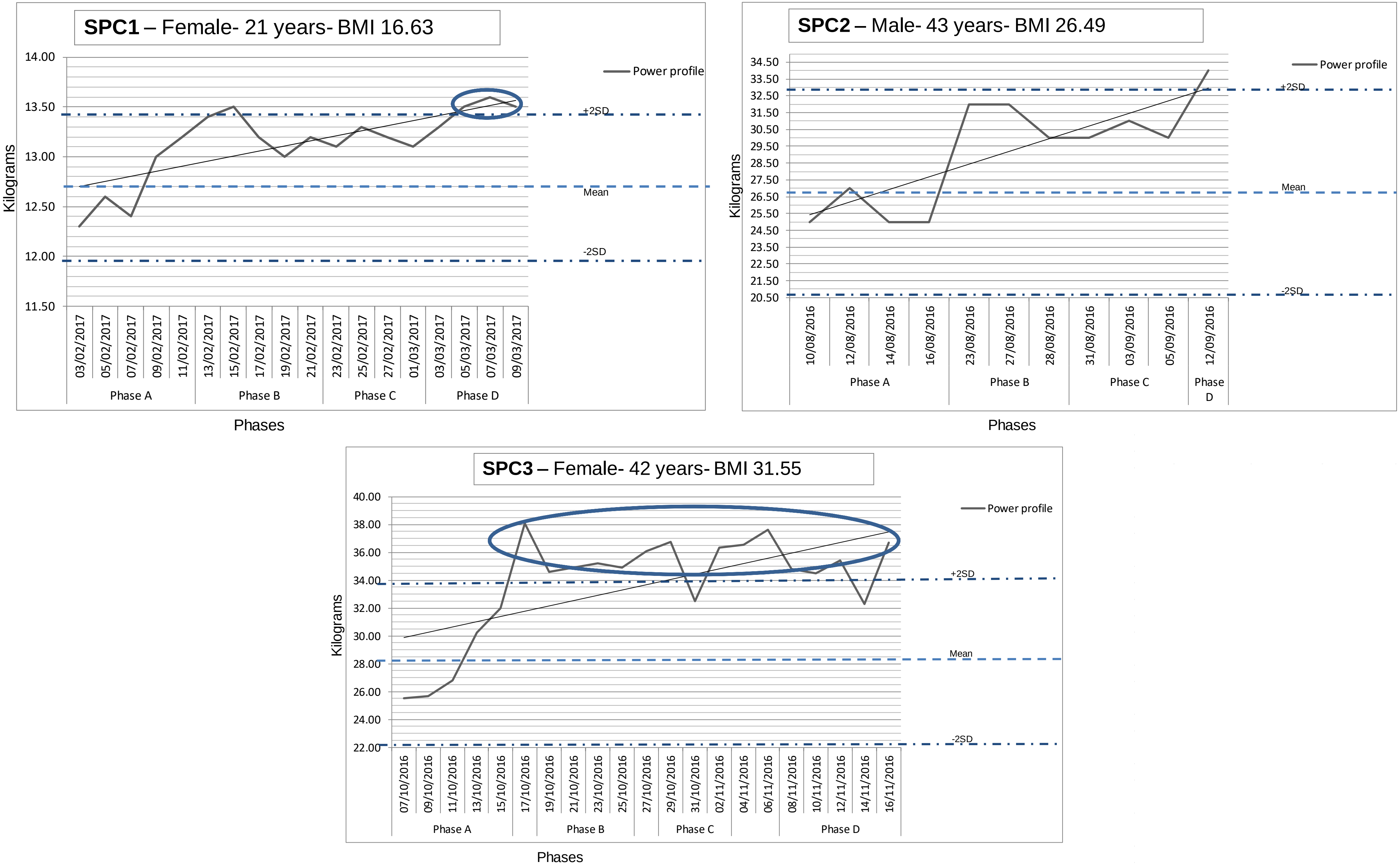

Figure18. Multiple baseline analyses of single participant data with statistical thresholds and linear trend lines.

Qualitative data

Six participants (50%) provided limited commentary during their engagement with the online forum; examples are represented in Table29 that demonstrate themes of pain, mitigation and response . These participants were representative of the gender (40% female) and age (mean 31) of this study's demographic.

Participant	Theme	Quote
Female, age 22	Mitigation	"Been getting more hypermobile in the last few days, which shows in the results"
Male, age 41	Response	"Feedback is good, I push harder"
	Mitigation, pain	"I changed how I was bracing myself and used a cushion on the scales for the glute exercise so it hurts less"
Female, age 21	Mitigation	"Get a cold, feeling weak, but the exercises are fine"
Male, age 42	Mitigation	"A bit weaker over the last couple of days because of flu"
Male, age 29	Pain	"I had an injury while climbing….it's painful"

Table29. Illustrative quotes from online forum.

The individuals provided reflection on their experiences and progress in response to the exercises (Female, age 22). The mitigating effects of pain were commonly reported in response to perceived decline in performance and reporting (Male, age 29). A stoic sense of perseverance was interpreted from the commentary with an adaptation of technical approach where required (Female, age 21; Male, age 41).

Discussion

The primary aim of this study was to determine the feasibility of patients using an online forum for reporting progress when engaging with a six-week exercise programme for managing knee pain. No statistically significant difference was found in reporting progress based on gender, age or BMI. It was possible to use individuals' posted progress data to complete a multiple baseline case study for a selection of participants in the study. Participants were willing to engage in limited discussion posts during their progression on the programme.

Posting to the forum was initially at a moderate level and attrition rates were comparable with other studies exploring engagement with online discussion boards. The 58% reported in this current study is in the range of the 12 studies exceeding the 20% attrition rate within the review of Williams et al. (2014). Within the scope of behavioural change in eHealth, the range of 41-84% attrition is reported in large randomised control trials (Maher et al., 2014). The consistency of participants' reports within the current study, facilitating generation of individualised progression data, may be indicative of the stable core user remnant that prevails after initial early dropouts (Eysenbach, 2005). Further exploration of the benefits of self-reporting with the incentive of producing individual activity profiles is warranted, particularly within the scope of affordable technology and activity tracking (Hassett et al., 2016).

Exercise adherence has been identified as a major contributor to exercise efficacy (Pisters et al., 2010). Participants that made initial engagement with recording their outcomes online committed to the six week programme irrespective of report attrition. The access to the video instructions through the forum may have influenced this behaviour as these media have been seen to improve exercise adherence (Kim et al., 2016a; Tohyama et al., 2010). The growth in 'Big Data' and interactive technology may facilitate this further; real-time remote video capture of patients, tracking and analysing movement, with feedback relayed direct from a therapist may be the panacea in this field (Calyam et al., 2016). There are implications for these type of systems in terms of sensitivity of personal data (Antheunis et al., 2013) and developing suitably secure software architecture is an ongoing challenge within the Web 2.0 milieu (Premarathne et al., 2016; Shrestha et al., 2016). The integration of body sensor network information into this Cloud-Computing platform, and the volume of wearable devices (e.g., FitBit, MOOV, Nike+) that can contribute to these biofeedback networks elicits a complex array of data (Gravina et al., 2016). This potentially lacks meaning or context for patients; the findings of this current study demonstrate a simple solution to this complexity.

Age and social media engagement have been reported as conflicting characteristics in studies engaging eHealth with usage mediated by generation. While engagement activity profiles may differ, the Over-65s are comparable to the Under-30s in terms of the proportions reporting the use of the Internet for health-related information (53 and 56% respectively) (Korda and Itani, 2013). The age range in this current study crossed Generation X and Y but lacked engagement with Senior Citizens. The Over-65s are motivated to engage with eHealth and increased Internet use as a vital connection with the wider world, offsetting age-related functional changes (Henshaw et al., 2012) and physical inactivity (Konstantinidis et al., 2016). Age was not seen as predictive of engagement in this study but there is a suggestion that socio-economic status is an overt influence on Internet use in relation to subjective health (Wangberg et al., 2008). The sample in this study were drawn from undergraduate cohorts but the 19-53 age range would suggest access to funding and social status could not be directly inferred and was not sought at the time of participation.

The influence of gender in technology-assisted healthcare has conflicting evidence; practitioners' engagement may be more influenced by location although female general practitioners may be less likely to adopt new software (Ward et al., 2008). Gender may be influential as a barrier to information technology use in adolescents (Hanlon et al., 2016) but reported disparities in adoption of internet-based health correspond more with lower income, educational attainment, ethnic background and those for whom English is not their native language (Schickedanz et al., 2013). Gender influence on engagement was equivocal in terms of the odds reported in this current study. As previously stated, socio-economic status was not captured and the student sample here may be more consumer-driven, aligned to recent shifts in UK Higher Education with strong emphasis on student choice and experience (Hemsley-Brown and Oplatka, 2016). The shifting engagement in this study's student participants may be tempered by self-determination and personal preference with willingness to engage influenced by social desirability leading to misreporting or withdrawal (Brenner and DeLamater, 2014); exploration of potentially fabricated information or 'digit preference', comparing the 'objective' MVIC measures captured against normative data , deserves further attention (Al-Marzouki et al., 2005).

The BMI range within this study's sample was broad and did not seemingly influence reporting. Electronic media use has been reported as a risk factor for higher BMI, particularly within the adolescent female population (Melkevik et al., 2015). Conversely, targeted eHealth solutions for weight management in young women suffer from poor uptake and user satisfaction ratings (Hutchesson et al., 2016). Activity and diet modification via specialised applications may offer an improved engagement profile around personal weight-management in adults (Gregoski et al., 2016). This may be adversely affected by work-based pressures and employers strategies to encourage and endorse compliance to these eHealth measures is vital (Bardus et al., 2014).

Similarly perceived pressures reported by other healthcare undergraduates (Heinen et al., 2017) may be applicable to the current study and mitigated engagement. Time availability and pressures of course deadlines are also reported as inhibitors to activity related eHealth (Quintiliani et al., 2013). The potential addictive impact of technology and reduced academic performance reported in other studies (Samaha and Hawi, 2016) may have been seen as prohibitive in this study's sample. Exploration of technology reliance and side-effects on prolonged eHealth use is a conflicting relationship that warrants further exploration.

The provision of individualised single case data fed back to patients contributes to the ideal of personalized, preventive health-care planning (Skinner, 2016). The ability for patients to report on their own progress with clinical home-based outcomes has been reported as vital to integrated electronic medical records (Shameer et al., 2017). The biofeedback information in this study correlates with dynamometry (Chapter 6) and could provide further complementary data to wearable devices (Gravina et al., 2016; Slater et al., 2016a); this potentially negotiates the pathway between consumer mass-adoption and practitioner caution in this developing area (Piwek et al., 2016). This current study demonstrates that patients can have direct access to personal analytics and potentially aid in the management of ongoing conditions. The growing demand to use single case analyses to inform effect size and meta-evidence (Shadish et al., 2014; Vohra et al., 2016; Zucker et al., 2010) demands that 'Big Data' from individual patients be used more constructively, particularly the patient-accessible visual analytics afforded within these designs (Kratochwill and Levin, 2014).

This study's sample reported experiences around pain, mitigation and responsiveness and this was within a recruitment strategy of asymptomatic participants. Subjective and objective pain measures have been widely explored in knee condition sufferers (Mutlu and Ozdincler, 2015; Skou et al., 2015). Qualitative data intimates that patients' outcomes and pain management should be considered on an individual basis (Nyvang et al., 2016), with online forums providing the validation, support and resources as required (Chapter 4). The sample in this current study described mitigating effects of pain in relation to the exercise task-orientation. This contrasts with young symptomatic individuals that report the burden of MSK pain on quality of life and future prospects; the need for digital technologies to provide accessible, evidence-based resources is seen as vital in connecting these people with support from peers and health professionals (Slater et al., 2016b). The individuals in the current study were potentially engaging from a sense of duty and felt compelled to offer mitigation when compliance wavered. There is suggestion that compelling pain management programmes may only arise with a population that perceives the need for individualised care, particularly if that population feels disenfranchised (DeMonte et al., 2015).

Strengths and limitations

Limitations of this study include selection bias with a convenience sample of undergraduate students. Only those prepared to commit to the programme were included indicating that participants had an underlying motivation towards exercise. All participants were asymptomatic implicating the diversity in compliance; attrition could be further mitigated with a motivated symptomatic patient population. The extension to engage with the Over-65s in future studies would allow the development of this type of OHC in condition-specific scenarios. Socio-economic status was not captured by this study and this is seen as a key influence on access and engagement in the field of eHealth; such barriers to engagement have to be explored further. This study was able to demonstrate that a cheap solution to developing an OHC is feasible and that individualised, patient-centric data can be produced from reporting biofeedback data on an online forum. Future research should look to investigate discordance between attitudes to technology-assisted healthcare, the importance of individualised visual data to patients and the role of forums in monitoring patient engagement and progress in symptomatic populations.

Conclusion

Patients can engage with an online forum for reporting progress when complying with exercise programmes for managing knee pain. No significant influence was found on reporting progress in an online forum based on gender, age or BMI. It was possible to use individual posted progress data to complete a multiple baseline case study for a selection of participants in the study. Participants were willing to engage in limited discussion posts during their progression on the programme. The parochial nature of the sample is a limitation; future work in the area should look to address discordance between attitudes to technology assisted healthcare, the importance of individualised visual data to patients and the role of forums in monitoring patient engagement and progress in trials involving symptomatic knee-pain populations. Determining veracity of posted data, socio-economic background and other barriers to accessing these community forums need to be considered in this exploration.

GENERAL DISCUSSION

1. Overall Summary

The implications for rehabilitation and management of knee pain using eHealth, biofeedback and online communities have not been addressed in previous research. The main aim of this thesis was to further inform the options for rehabilitation around the knee, exploring latest generation techniques for addressing progressive joint disease and management strategies in clinical, educational and eHealth settings. This was guided by elements of the MRC framework for the development and evaluation of complex interventions (Craig et al., 2008); theory, modelling and exploratory trial. The Preclinical theory part explored the current state of reporting knee rehabilitation in terms of latest articular repair techniques, UK musculoskeletal-related, physical therapy curriculum providers and technology-assisted interventions. The Phase I modelling part established options for self-assessment and reporting through biofeedback-informed exercises that could be generalised to knee pain sufferers; an approach supported by the exploration of the reported experiences of individuals engaging with an online health community for knee pain. The Phase II exploratory trial compared biofeedback-informed exercise with standard exercise, alongside an eHealth component, to explore the use of simple Web 2.0 solutions, and readily available household equipment, for their suitability of use with knee function and pain management.

Theory: Reporting of Current Knee Rehabilitation Practice

The first part of this thesis comprised three separate Chapters exploring the literature and healthcare curriculum in relation to knee dysfunction. The initial study investigated post-operative approaches following use of cell-based technologies for addressing articular cartilage lesions of the knee. This systematic review focused on the standard of the reporting of rehabilitation in articular cartilage repair studies involving third generation autologous chondrocyte implantation. The scope for improvement since the Jakobsen et al. (2005) pivotal review was contextualised through the quality of reporting of rehabilitation in the surgical studies using the Coleman Methodology Score (CMS). The consistent finding was that, while reporting scores had improved, the presence of a designated rehabilitator as an author was directly associated (*P*=.0029) with a higher CMS for reporting rehabilitation elements; recommendation to include designated rehabilitators in study conduct ensued. This study highlighted the need for greater reporting of compliance in the field of prescribed protocols for knee management strategies and raised the question as to which musculoskeletal therapy the requisite rehabilitators could be drawn from.

To address this question, Chapter 2 went on to investigate the scope of coverage of specific articular cartilage educational content, surveying UK musculoskeletal (MSK) therapy undergraduate course providers. MSK medicine is widely established in UK undergraduate curriculum (Oluwajana et al., 2011) but it is not widely reported as to how mechanisms of articular cartilage injury, repair and rehabilitation are taught at this level across MSK therapies. The aim of this cross-sectional questionnaire study was to determine if final professional award was an influence on the coverage around rehabilitation. While no major differences were observed between therapies, teaching of standard rehabilitation approaches prevailed over specific post-operative care following cartilage repair (*P*<.05). The equivocal evidence around the latest generation of techniques was mooted as a potential reason (Biant et al., 2015). While low response rate (14%) was a critical factor, potential lack of exposure for advances in surgery determined that both patients and practitioners may need to engage with other innovative, technology-driven modes of treatment within non-pharmacological approaches to knee pain (Button et al., 2015).

Chapter 3 sought to determine the scope of technological interventions used in the management of the dysfunctional knee. Satisfaction with this use of clinical software and hardware in the field of knee pain and rehabilitation is not fully understood (Stacey et al., 2011); the extent of the impact on the patient has yet to be established (Hunt et al., 1998; Küçükdeveci et al., 2011). The aim of this systematic review was to explore satisfaction reporting on these technologies and establish if this related to reporting of sample size, effect size and listed journal impact factor. Practitioner and patient satisfaction with the eHealth technology, including telemedicine, biofeedback and clinical decision tools, was poorly reported. No pre-defined predictors were seen to influence the inclusion of satisfaction reporting; implicated studies revolved around function or pain outcome measures. Patient preferences were rarely explored in these eHealth initiatives, suggesting that technical advancement was positively biased. Patient experience has been stated as a requirement to be taken into account in order to demonstrate the satisfaction with using the measure itself alongside the measure's outcome; the so-called Fit between Individuals, Task and Technology (FITT) (Ammenwerth et al., 2006). This raised the question as to what would motivate knee pain sufferers to engage with such technology, the nature of their reporting and how would the experience be rationalised by participants.

Modelling: Online Health Community and Biofeedback

The second part of this thesis encompassed two separate Chapters regarding the exploration and validation of online health communities and biofeedback used within the context of knee pain management. Chapter 4 engaged with individuals joining the KNEEguru online health community to elucidate the role of online initiatives in mitigating response to knee pain. There is a suggestion that patients may find empowerment by engaging with internet healthcare strategies (Samoocha et al., 2010). Despite concerns regarding potential misinformation, online health communities continue to thrive with growing clinician moderation (Huh and Pratt, 2014). This mixed-methods study sought to explore the expressed motivations for participants seeking specific online health information regarding the knee. The extent to which the perceived benefits and quantifiable motives were related to characteristics of respondents was also assessed. Using both quantitative and qualitative approaches, participants' responses to a questionnaire regarding their backgrounds and motivations were analysed. The major finding was that social network use was associated with sharing experiences of knee pain (odds ratio 2.34, 95% CI 1.04 - 5.56, *P*=.03). Individuals were able to rationalise their emotive, knee-related issues through the forum and validate their predicament. Social networks acting as introducers for secure OHCs can authenticate patient experience (Pedersen and Kurz, 2016). This suggested that clinician-moderated, online environments could have a role to play in mitigating the effects of knee pain.

In Chapter 5, a simple and novel solution was conceived to enable patients to report change around their knee condition. Exercises for hip and knee such as clamshell (Distefano et al., 2009) and short-arc quadriceps extension (Kushion et al., 2012) have already been shown to be effective in targeting the thigh and buttock muscles. The use of bathroom scales as an outcome measure has been explored in respect to graded weight bearing (Malviya et al., 2005) but there may be potential use as a biofeedback mechanism. Further exploration was required to establish the reliability of using this equipment as a potential outcome, measuring and reporting strength. This study validated the activation profile of quadriceps and gluteal muscles in short arc quad and seated clamshell exercises augmented by the use of bathroom scales. Intraclass Correlation Coefficient statistics demonstrated significantly high reliability (over 90%) between electromyography (EMG) activity in thigh and buttock musculature. This provided evidence that EMG data was consistent when comparing the exercises with and without the scales. The muscle generated force reporting was also significantly associated with dynamometry readings. The deployment of this simple objective physical measure in further epidemiological studies could facilitate higher confidence in physical activity management strategies for at-risk populations (Cooper et al., 2010). There may be potential to accrue population data for normative values and explore variances in different equipment.

Exploratory Trial: Home-based Exercise and Online Forum

The modelling component findings informed the approach for Chapter 6; a randomised feasibility study into the effect of biofeedback on quadriceps and gluteal generated force when used as an adjunct to the aforementioned hip and knee exercises. Clinical guidelines advise that care plans be individualised with the end goal of ensuring participation (Bennell et al., 2014). These guidelines highlight the importance of engendering participant motivation and access to viable facilities as key considerations to be taken into account. There is growing use of biofeedback within exercise and rehabilitation with suggestion of associated post-operative functional recovery (Akkaya et al., 2012) and increased muscle strength (Kirnap et al., 2005). The primary aim of this study was to investigate if the inclusion of a biofeedback mechanism alongside exercises for the quadriceps and gluteal muscles resulted in a difference in hip abductor and knee extension generated force. In a sample of moderately active students, calculated standardised effect sizes around strength and circumferential change were found to be comparable to other exercise studies (0.01 to 0.31); a large effect (0.87) was seen for force change in the extension outcome for the group exercising without biofeedback. Compliance was well-reported in the biofeedback arm (100%) which suggested a potential issue with dosage over the six weeks of the study. The use of bathroom scales suggest a suitable assessment of muscle-generated force as a biofeedback mechanism that could enable long term monitoring, identified as a key factor for exercise adherence (Marks, 2012). Individualised outcome differences in this study arose from motivation, self-monitoring and efficacy that informed progression data; this may have further implications for reducing therapeutic costs in a clinical setting in terms of patient autonomy (Leardini et al. 2004).

Further elucidation was provided within Chapter 7, the final study, where feasibility of using an online forum was investigated to facilitate community engagement with the biofeedback exercise programme. The use of web-based resources and eHealth applications for patients with knee pain is an area of expansion (Hussain et al., 2017; Pearson et al., 2016). The Web 2.0 platform has been seen to increase participation through social media and the sharing of experience due to the ease of posting materials such as video files and online forums (Chou et al., 2013). Padlet is a Web 2.0 online noticeboard that can be used to facilitate student interaction by posting of multimedia files as virtual ‘sticky notes’ with mediation by a pedagogue (Fuchs 2014). The primary aim of this study was to determine the feasibility of patients using an online Padlet forum for reporting progress when engaging with a six-week exercise programme for knee rehabilitation. This encouraged participants to openly report progress, experiences and adverse effects from exercising irrespective of gender, age or BMI (P>.05). Bathroom scale-derived outcome measures were posted that enabled single subject analysis to be conducted demonstrating individual conditioning responses. Commentaries provided indicated that participants felt the need to rationalise limitations with progression based on mitigating factors such as injury and pain. The online forum provided an effective tool for reporting experience, measuring compliance and facilitating individualised data that has meaning to participants outside of meta-analysis (Kratochwill and Levin, 2014). The findings support the need for digital technologies to provide accessible, evidence-based resources that are vital in connecting patients with support from peers and health professionals (Slater et al., 2016b, 2016a).

Future Phase III: Definitive Randomised Controlled Trial

The findings support further development in terms of the continuum of increasing evidence, following the MRC framework (Blackwood et al., 2010). Exploration into the reporting characteristics in relation to bathroom scales, and a range of underlying conditions, in the form of larger epidemiological studies are warranted. These could be undertaken alongside trials involving a population of interest such as knee arthroplasty, ACL repair, ACR and PFPS. Recently published work using a sphygmomanometer cuff as a strength training aid has reported some success with post-surgical knee patients and may provide a further comparator (Horstmann et al., 2017). This study observed issues with patient deployment of the cuff and self-reporting of outcomes; possible use of a suitably architected, online forum may be appropriate in this scenario. This is indicated by an app-based training routine that supports postoperative rehabilitation (Hardt et al., 2018), but lacks options for social interaction. Both Horstmann et al.’s and Hardt et al.’s findings are supportive of further protocol development from the approach of this thesis and its findings. Further consideration within other healthcare settings facing the burden of knee pain management may be warranted, taking into account the patient experience in that management process. Long-term implementation in terms of replicable results in pragmatic and realistic settings to determine effectiveness can then be further assessed.

2. Conclusion and Perspectives

In conclusion, the original work of this thesis increases the body of knowledge in terms of rehabilitation practice, viable home-based exercise and Web 2.0 eHealth approaches to managing knee pain. The use of online forums and communities has been established within this thesis as a viable complement to standard care in this field. The integration of patient experience within the clinical and domiciliary setting has also been successfully explored with scope for further investigation in condition-specific populations. The findings offer cost-effective, alternative measures for use in the clinical practice of physical therapists, sport rehabilitation professionals and researchers. The use of bathroom scales as an adjunct to strength monitoring in patients has been ratified within this body of work. Further research is now required in terms of applicability to symptomatic knee pain sufferers, pre-operative patients and strength monitoring within clinical trials. The key reporting of important change back to individual patients and the satisfaction of this engagement also demands further exploration in the long-term.

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APPENDICES

Appendix I

Expanded CMS scoring table

Author(s)	Year	Article/paper title	Journal	CMS evaluation score	1. Study size 0-10 points	2. Mean follow-up 0-10 points	3. Number of surgical procedures 0-10 points*	4. Type of study 0-15 points	5. Description of surgical procedure 0-5 points	6. Description of postop rehabilitation 0-5 points	7.Inclusion MRI outcome 0-10 points	8.Inclusion histological outcome 0-10 points	1. Outcome criteria 0-10 points	1. Outcome criteria 0-10 points	1. Outcome criteria 0-10 points	1. Outcome criteria 0-10 points	2. Outcome assessment 0-15 points	2. Outcome assessment 0-15 points	2. Outcome assessment 0-15 points	2. Outcome assessment 0-15 points	3. Description of selection process 0-15 points	3. Description of selection process 0-15 points	3. Description of selection process 0-15 points	3. Description of selection process 0-15 points
Batty, L., S. Dance, et al.	2011	"Autologous chondrocyte implantation: An overview of technique and outcomes."	ANZ Journal of Surgery 81(1-2): 18-25.	71	>60: 10	12-24: 2	>1 but >90 %: 7	RCT: 15	Fair technique without elaboration: 3	Well described with >80% of patients complying: 5	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	Use of outcome with good sensitivity: 3	Subjects recruited (results not taken from surgeons' files): 5	Investigator independent of surgeon: 4	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5
Carey-Smith, R., J. R. Ebert, et al.	2010	"Arthroscopic matrix-induced autologous	Techniques in Knee Surgery 9(3): 170-175.	49	<20/NS: 0	24-60: 5	>1 but >90 %: 7	0	Adequate technic stated with detail: 5	Well described with 60%–80% of patients complying: 2	Reported >80% patients: 10	Reported <50% patients: 5	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliab	Use of outcome with good sensitivity: 3	0	0	0	0	0	0	0	Eligible subjects not included in the study satisfactorily accounted for or

		chondrocyte implantation: A simple surgical technique."													ility: 3									100%: 5
Crawford, D. C., C. M. Heveran, et al.	2009	"An autologous cartilage tissue implant NeoCart for treatment of grade III chondral injury to the distal femur: prospective clinical safety trial at 2	Am J Sports Med 37(7): 1334-1343.	30	<20/NS: 0	24-60: 5	1 only: 10	0	Adequate technic stated with detail: 5	Protocol not reported: 0	Reported >80% patients: 10	Not reported: 0	0	0	0	0	0	0	0	0	0	0	0	0

		years."																						
Crawford, D. C., T. M. DeBerardino, et al.	2012	"NeoCart, an autologous cartilage tissue implant, compared with microfracture for treatment of distal femoral cartilage lesions: an FDA phase-II prospective, ran	J Bone Joint Surg Am 94(11): 979-989.	64	20-40: 4	12-24: 2	1 only: 10	RCT: 15	Adequate technic stated with detail: 5	Protocol not reported: 0	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	Use of outcome with good sensitivity: 3	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	Recruitment rate reported: * <80%: 3	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

		domized clinical trial after two years."																						
Dai, X. S. and Y. Z. Cai	2012	"Matrix-induced autologous chondrocyte implantation addressing focal chondral defect in adolescent knee."	Chinese Medical Journal 125(22): 4130-4133.	46	< 20/NS: 0	12-24: 2	>1 but >90%: 7	0	Adequate technic stated with detail: 5	Protocol not reported: 0	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5
Della Villa, S., E. Kon, et al.	2010	"Does Intensive Rehabilitation Permit Earl	American Journal of Sports Medicine 38(1).	50	< 20/NS: 0	<12/NS: 0	1 only: 10	Prosp Cohort: 10	Adequate technic stated with detail: 5	Protocol not reported: 0	Reported > 80% patients: 10	Not reported: 0	0	0	0	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%:

		y Return to Sport Without Compromising the Clinical Outcome After Arthroscopic Autologous Chondrocyte Implantation in Highly Competitive Athletes?"																						5

Ebert, J. R., D. G. Lloyd, et al.	2010	"Knee biomechanics during walking gait following matrix-induced autologous chondrocyte implantation."	Clin Biomech (Bristol, Avon) 25(10): 1011-1017.	71	20-40: 4	12-24: 2	1 only: 10	Prosp Cohort: 10	Adequate technic stated with detail: 5	Well described with >80% of patients complying: 5	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	Use of outcome with good sensitivity: 3	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Ebert, J. R., D. G. Lloyd, et al.	2012	"Isokinetic knee extensor strength deficit following matrix-induced autologous chondrocyte implantation."	Clinical Biomechanics 27(6): 588-594.	88	> 60: 10	24-60: 5	1 only: 10	RCT: 15	Fair technique without elaboration: 3	Well described with >80% of patients complying: 5	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	Use of outcome with good sensitivity: 3	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	Recruitment rate reported: * >80%: 5	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5
Ebert, J. R., M. Fallon, et al.	2012	"Arthroscopic matrix-induced autologous chondrocyte implantation: 2-year outc	Arthroscopy 28(7): 952-964 e951-952.	63	> 60: 10	12-24: 2	1 only: 10	RCT: 15	Fair technique without elaboration: 3	Well described with >80% of patients complying: 5	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	0	0	Subjects recruited (results not taken from surgeons' files): 5	Investigator independent of surgeon: 4	0	0	Selection criteria reported and unbiased: 5	0	0	0

		omes."																								
Ebert, J. R., M. Fallon, et al.	2012	"A randomized trial comparing accelerated and traditional approaches to postoperative weight bearing rehabilitation after matrix-induced autologous chondrocyt	Am J Sports Med 40(7): 1527-1537.	52	41-60: 7	24-60: 5	1 only: 10	Retro Cohort: 0	Fair technique without elaboration: 3	Well described with >80% of patients complying: 5	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5		

		e implantation: findings at 5 years."																						
Ebert, J. R., W. B. Robertson, et al.	2008	"Traditional vs accelerated approaches to post-operative rehabilitation following matrix-induced autologous chondrocyte implantation (MACI): com	Osteoarthritis Cartilage 16(10): 1131-1140.	72	>60: 10	<12/NS: 0	1 only: 10	RCT: 15	Fair technique without elaboration: 3	Well described with 60%–80% of patients complying: 2	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Gigante, A., D. Enea, et al.	2009	parison of clinical, biomechanical and radiographic outcomes." "Distal realignment and patellar autologous chondrocyte implantation: mid-term results in a selected population."	Knee Surg Sports Traumatol Arthrosc 17(1): 2-10.	47	<20/NS: 0	24-60: 5	>1 but >90%: 7	Prosp Cohort: 10	Fair technique without elaboration: 3	Protocol not reported: 0	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Mithoefer, K., K. Hambly, et al.	2009	"Return to sports participation after articular cartilage repair in the knee: scientific evidence."	American Journal of Sports Medicine 34(6): 1020-1038.	50	20-40: 4	24-60: 5	<10%> 2 of 90%: 4	0	Fair technique without elaboration: 3	Well described with 60%–80% of patients complying: 2	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5
Nehrer, S., R. Dorotka, et al.	2009	"Treatment of full-thickness chondral defects with hyalograft C in the knee: a prospective clinical	Am J Sports Med 37 Suppl 1: 81S-87S.	45	20-40: 4	>60: 10	<10%> 2 of 90%: 4	0	Adequate technic stated with detail: 5	Protocol not reported: 0	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Niemeyer, P., J. M. Pestka, et al.	2008	case series with 2 to 7 years' follow-up." "Characteristic complications after autologous chondrocyte implantation for cartilage defects of the knee joint."	American Journal of Sports Medicine 36(11): 2091-2099.	41	41-60: 7	24-60: 5	<10%> 2 of 90%: 4	0	Adequate technic stated with detail: 5	Protocol not reported: 0	Reported > 80% patients: 10	Not reported: 0	0	0	0	0	0	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Saris, D. B., J. Vanlauwe, et al.	2008	"Characterized chondrocyte implantation results in better structural repair when treating symptomatic cartilage defects of the knee in a randomized controlled trial versus microfracture."		72	> 60: 10	24-60: 5	1 only: 10	RCT: 15	Fair technique without elaboration: 3	Protocol not reported: 0	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	0	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Strauss, E. J., L. E. Fonseca, et al.	2011	"Management of focal cartilage defects in the knee: Is ACI the answer?"	Bulletin of the NYU Hospital for Joint Diseases 69(1): 63-72.	59	20-40: 4	24-60: 5	1 only: 10	Prosp Cohort: 10	Fair technique without elaboration: 3	Well described with >80% of patients complying: 5	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5
Van Assche, D., Caspel, D.V. et al.	2011	"Implementing one standardized rehabilitation protocol following autologous chondrocyte implantation or microfracture in	Physiother Theory Pract.27, 125-136.	74	20-40: 4	24-60: 5	1 only: 10	RCT: 15	Fair technique without elaboration: 3	Well described with >80% of patients complying: 5	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Van Assche, D., F. Staes, et al.	2010	the knee results in comparable physical therapy management." "Autologous chondrocyte implantation versus microfracture for knee cartilage injury: a prospective randomized trial, with 2-yea	Knee Surgery Sports Traumatology Arthroscopy 18(4).	41	>60: 10	12-24: 2	>1 but >90%: 7	Retro Cohort: 0	Inadequate unclear: 0	Well described with >80% of patients complying: 5	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	0	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

		r follow-up."																						
Van Assche, D., Van Caspel, D. et al	2009	"Physical activity levels After characterized chondrocyte implantation versus microfracture in the knee and the relationship to objective functional	Am J Sports Med. 37, 42S-49S.	63	41-60: 7	12-24: 2	>1 but >90%: 7	RCT: 15	Inadequate unclear: 0	Well described with >80% of patients complying: 5	Not reported: 0	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	Recruitment rate reported: * >80%: 5	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

		outcome with 2-year follow-up."																						
Vanlauwe, J. J., T. Claes, et al.	2012	"Characterized Chondrocyte Implantation in the Patellofemoral Joint An Up to 4-Year Foll		63	>60: 10	12-24: 2	<10%> 2 of 90%: 4	RCT: 15	Inadequate unclear: 0	Protocol not reported: 0	Not reported: 0	Reported > 50% patients: 10	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 5

Wondrasch, B., L. Zak, et al.	2009	ow-up of a Prospective Cohort of 38 Patients." "Effect of accelerated weight bearing after matrix-associated autologous chondrocyte implantation on the femoral condyle on radiographic and	Am J Sports Med 37 Suppl 1: 88S-96S.	65	20-40: 4	24-60: 5	1 only: 10	Prosp Cohort: 10	Fair technique without elaboration: 3	Protocol not reported: 0	Reported > 80% patients: 10	Not reported: 0	Outcome measures clearly defined: 2	Timing of outcome assessment clearly stated e.g., at best outcome: 2	Use of outcome criteria that has reported good reliability: 3	0	Subjects recruited (results not taken from surgeons' files): 5	0	0	0	Selection criteria reported and unbiased: 5	0	0	Eligible subjects not included in the study satisfactorily accounted for or 100%: 6

		clinical outcome after 2 years: a prospective, randomized controlled pilot study."																						

Appendix II

Investigating undergraduate manual therapy curriculum with regard to articular cartilage repair

Page 1: Welcome

Thank you for considering taking part in this survey; this will potentially help map a specific aspect of musculoskeletal curriculum to determine if specialist knowledge transfer is required.

The survey is completed anonymously, can be saved part way through and takes around 15 minutes to complete.All data collected in this survey will be held anonymously and securely. No personal data is asked for or retained. Cookies, personal data stored by your Web browser, are not used in this survey.

Your consent to participate is required and you may withdraw at any point without forfeit. By clicking CONTINUE, your consent is implicit - please close your browser window if you do not wish to proceed.

Note that once you have clicked on the CONTINUE button at the bottom of each page you can not return to review or amend that page

Page 2: Main Questionnaire

Note that once you have clicked on the CONTINUE button your answers are submitted and you can not return to review or amend that page.

Articular cartilage

This section deals with your course curricular coverage of articular cartilage in terms of physiology, pathology and surgical repair procedures.

1. With specific regard to articular cartilage (AC) physiology, please indicate if the following elements are covered within the curriculum

	Element covered ?				Please select the HE levels (Ofqual rating) this material is covered at.								
	Yes	No	Not known	Prefer not to answer	N/A	4	5	6	7	Not known	Other	If applicable, please state which course module(s) this is covered in?	
AC Collagen type													
AC layers (structure)													
AC Chondrocyte proliferation													
AC Tissue repair characteristics (including healing times)													

2. With specific regard to AC surgical repair techniques, please indicate if the following are covered within the curriculum.

	Element covered?				Please select the HE levels (Ofqual rating) this material is covered at.							
	Yes	No	Not known	Prefer not to answer	N/A	4	5	6	7	Other	If applicable, please state which course module(s) this is covered in?	
Autologous chondrocyte implantation/transplantation (incl.MACI)												
OATS/Mosaicplasty/plugs												
Microfracture/Pridie drilling												
Platelet rich plasma (PRP)/stem cell therapy												

3. With specific regard to AC arthrokinematics, please indicate if the following elements are covered within the curriculum.

	Element covered?				Please select the HE levels (Ofqual rating) this material is covered at.							
	Yes	No	Not known	Prefer not to answer	N/A	4	5	6	7	Other	If applicable, please state which course module(s) this is covered in?	If you se
AC Load bearing												

AC Stimulus reaction												
Biomechanics predisposing AC injury												
AC defect implications												

4. With specific regard to AC surgical repair rehabilitation, please indicate if the following are covered within the curriculum.

	Element covered?				Please select the HE levels (Ofqual rating) this material is covered at.							
	Yes	No	Not known	Prefer not to answer	N/A	4	5	6	7	Other	If applicable, please state which course module(s) this is covered in?	
Patient characteristics (age,gender,BMI,biomechanics)												
Surgical characteristics (defect size/location, concomittant procedures)												
Rehabilitation protocols												
Outcome measures (patient reported/surgeon reported)												

5. Which level do you consider that the topic of AC rehabilitation should be taught at.

- Undergraduate
- Postgraduate (MSc,PG Cert)
- Continuing professional development
- Other

5.a. If you selected Other, please specify:

6. Are there any additional comments you would like to make regarding curricular content and articular cartilage elements?

Course details

This requires you to provide nominal details for the course offering that you oversee.

7. What is the title of the full-time musculoskeletal undergraduate course you administer?

More info

8. What is the qualification gained on graduation from the course?

8.a. If you selected Other, please specify:

9. Which university validates the undergraduate degree course?

More info

10. What are the A Level entry requirements for the course?

10.a. If you selected Other, please specify:

11. What are the International Baccalaureate entry-level points for the course?

12. What is the standard full-time duration of the course?

- 2 Years
- 3 Years
- 4 Years
- 5 Years
- >5 Years

13. Please select the regulatory standards and professional competencies that the course is validated against?

- Chartered Society for Physiotherapists' Code of Professional Values and Behaviour
- Health and Care Professions Council's Standards of Proficiency
- General Osteopathic Council's Osteopathic Practice Standards
- General Chiropractic Council's Code of Practice and Standard of Proficiency
- The Society of Sports Therapists' Standards of Conduct

Other

13.a. If you selected Other, please specify:

Page 3: Final Page

Thank you for taking the time to complete this questionnaire. Your participation is important and will help inform the direction of knowledge transfer from articular cartilage research.

If you would be interested in seeing the results of this survey, please email the primary investigator; *Philip Bright (pb301@kent.ac.uk)*.

Please follow this link to return to the:

Bristol Online Surveys Homepage

Key for selection options

8 - What is the qualification gained on graduation from the course?

BSc
Integrated Masters
Other

10 - What are the A Level entry requirements for the course?

AAA
AAB
AAC
ABB
ABC
ACC
BBC
BCC
CCC
Other

Jisc Online surveys

KNEEguru Registration Survey

Showing 152 of 152 responses

Showing **all** responses

Showing **all** questions

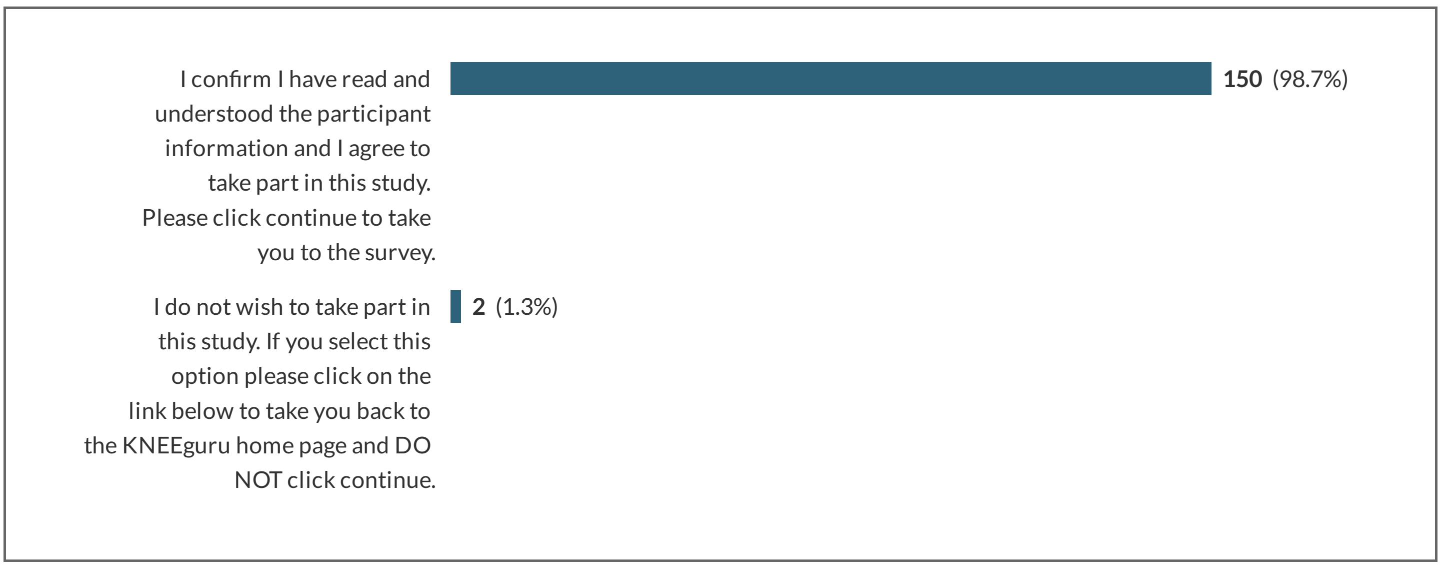
Response rate: 101%

Participant Information Sheet

Data Protection Statement

Informed Consent

1 Are you happy to continue with the survey?



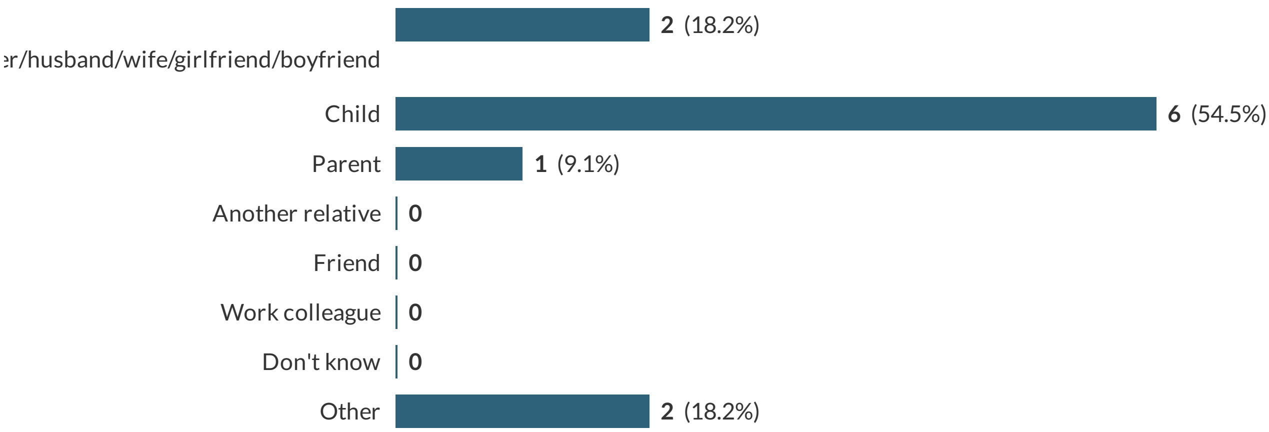
Why are you registering with KNEEguru?

2 Why have you decided to join KNEEguru? Please provide as much detail as you can.

Showing 5 of 152 responses	
Wanted to comment on a post in the forums	110401-110395-6144711
After having a grade 3+ tear of my MCL I wanted to see how other peoples recoveries compared to mine.	110401-110395-6144712
Have knee issues!	110401-110395-6144713
After severing all 4 quads off my kneecap the doctor told me I'd be able to play hockey again. So I went thru the surgery and rehab but I feel like there should be better progress. What I'm really looking to do is gain perspective on whether I'm pushing too hard or expecting too much. It's been 5 months since surgery and things are feeling 60-70%, I just want to know when to realistically expect 100% strength and minimal pain.	110401-110395-6144714
Am obese 57 year old woman with prior torn meniscus/excessive scarring in left knee which necessitated me putting 10 lb weight on my knee, to straighten leg, a few times a day for a number of months. Now - 8 years later - In March 2012, I suffered a left knee injury while twisting/exiting my auto. After one week of ice/Ibuprofen/limping, I went to the head of sports medicine/orthopedist at local hospital who x-rayed my knee, gave me a cortisone shot and told me "No walking" but that I could do pool exercises and a recumbent bike (lowest setting). Expressed surprise that I had no swelling. He also wanted to know "what happened to me?" as I have put on significant weight since my previous injury. Five days after my appointment, I did bike for 15 minutes and experienced a very stiff left knee as soon as I stopped. The next morning while walking downstairs, I heard a "pop" and my left leg collapsed while I experienced excruciating pain. Eventually, continued down the stairs on my butt and clutched the wall to get to a chair where I remained for the next few days. Had an MRI and was told that I have a torn meniscus and arthritis - that I need to lose 50 lbs and I will feel better. I was told that if my knee was operated on, I would return in six months and ask the physician "How could you do this to me?". I was advised to cut back on ibuprofen because that could cause problems. Do pool rehab twice a week but feel it the next day. Provided chair exercises to do during day. Quads are strengthening. That said, I am essentially house-bound. In order to shop, I must utilize motorized cart at store. Come downstairs in morning and don't go up again until retiring for evening. Had my husband bring home an office chair so that I can wheel around the first floor of my house on the wood floors. Can't stand or walk for any length of time without significant pain. Nor can I walk my two Shih Tzu. Definitely feeling incrementally better - progress at glacial speed. Have lost 19 lbs and cut back on the ibuprofen and ice. Now I am going to try and locate my Physical Therapist from first injury - he was outstanding; professional, knowledgeable, exceedingly competent and provided me the means to help myself heal and regain my lifestyle. I don't have that confidence in my present therapist. Called my insurance carrier to find out my Dx; osteoarthritis, tear of medial cartilage, effusion of leg joint, disorder of bone and cartilage. Am unsure of the long-term ramifications of this. Doing continuous online research everyday. Want to avoid surgery. By joining KNEEguru, I thought that I might learn about different treatments I've come across; Tanezumab, Doxycycline, Glucosamine and chondroitin sulphate, autologous conditioned serum, PRP, Tapentadol, Licofelone. Am also exploring alternative remedies; homeopathy, accupressure, energy medicine (meridians), EFT, etc...	110401-110395-6144715

3 Are you looking on the internet about knee problems primarily for yourself or for someone else?

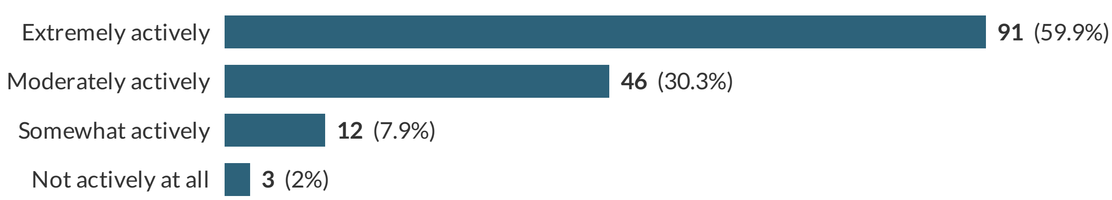
3.a If someone else, what is their relationship to you



3.a.i If you selected Other, please specify:

Showing all 2 responses	
Wife also has knee difficulties; she is learning about treatments for both of us.	110401-110395-6144750
online friend from another website	110401-110395-6144799

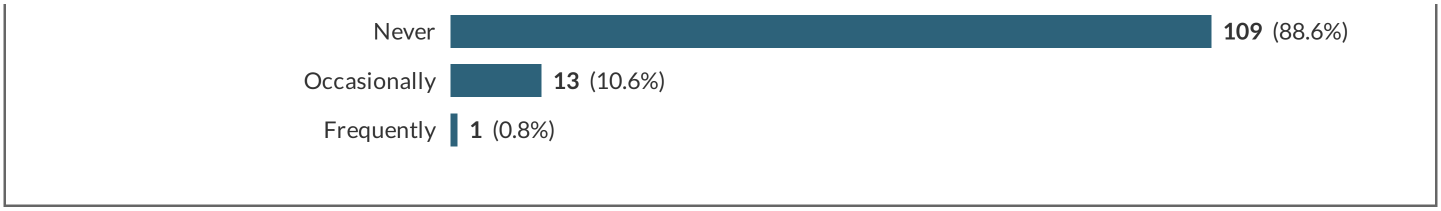
4 How actively are you currently seeking information about knee problems?



5 Where have you sought information about knee problems in the last 6 months?

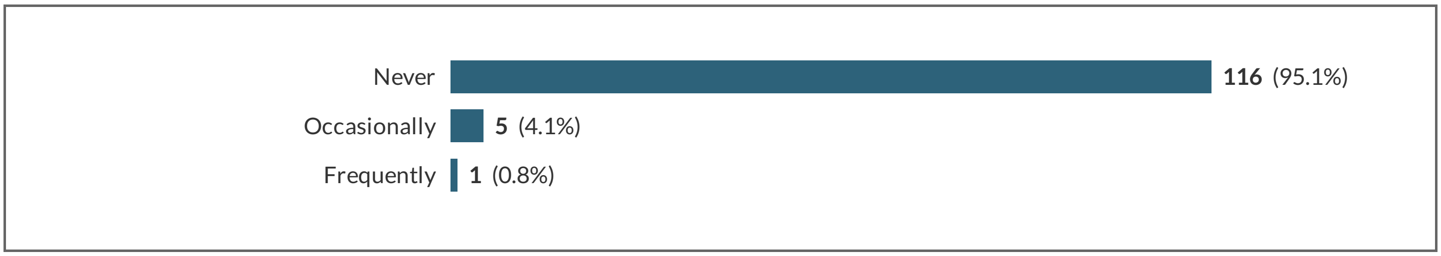
5.1 Television

5.1.a Television - Please indicate which sources of information you use to find out about knee problems.



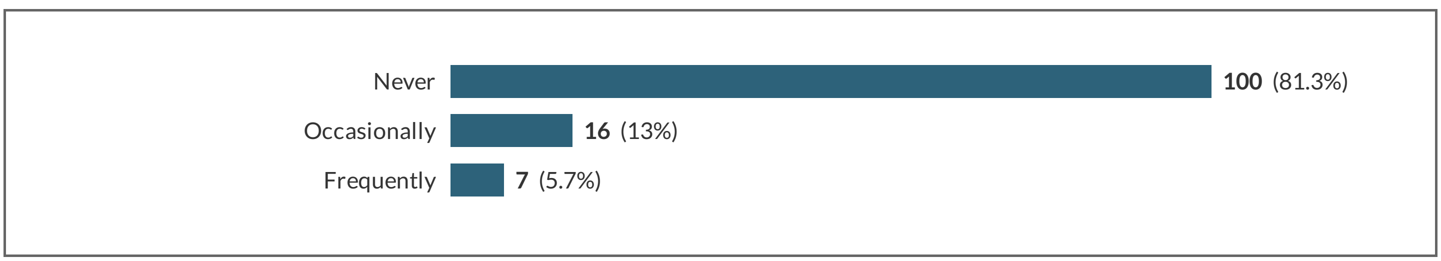
5.2 Radio

5.2.a Radio - Please indicate which sources of information you use to find out about knee problems.



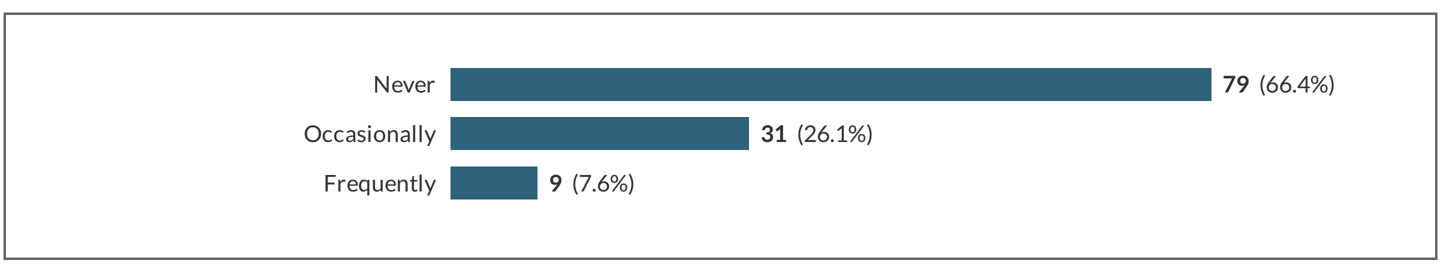
5.3 Newspapers

5.3.a Newspapers - Please indicate which sources of information you use to find out about knee problems.



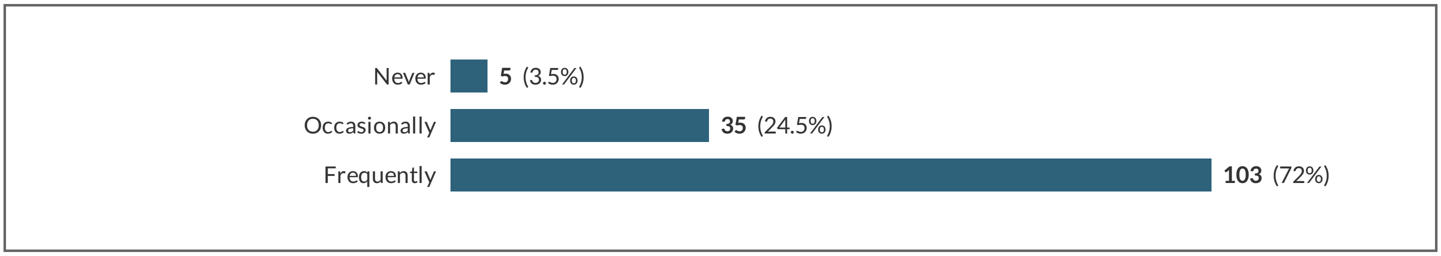
5.4 Magazines

5.4.a Magazines - Please indicate which sources of information you use to find out about knee problems.



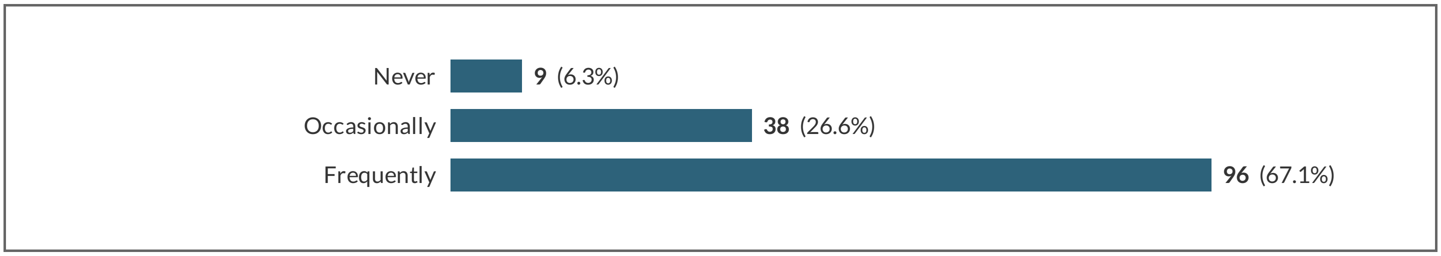
5.5 Internet - medical pages

5.5.a Internet - medical pages - Please indicate which sources of information you use to find out about knee problems.



5.6 Internet - patient forums

5.6.a Internet - patient forums - Please indicate which sources of information you use to find out about knee problems.

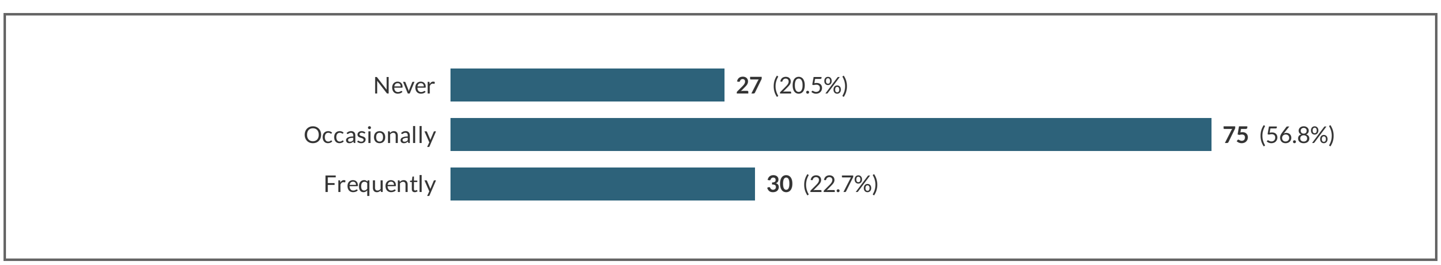


5.7 Medical journals

5.7.a Medical journals - Please indicate which sources of information you use to find out about knee problems.

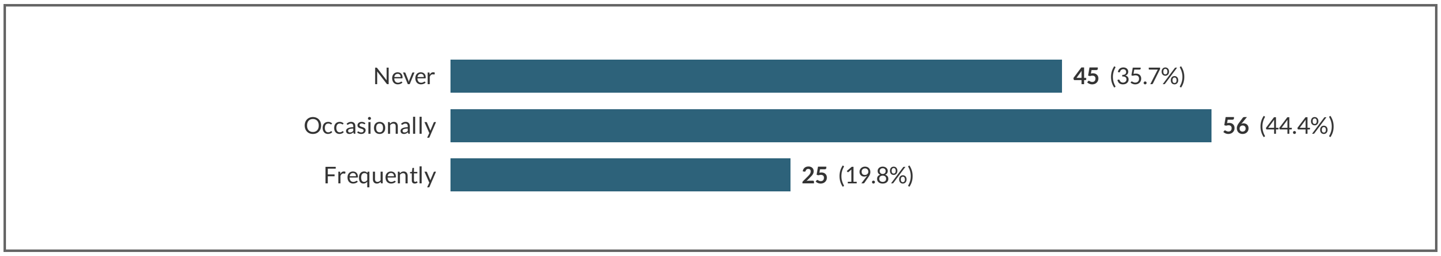
5.8 Friends

5.8.a Friends - Please indicate which sources of information you use to find out about knee problems.



5.9 Family

5.9.a Family - Please indicate which sources of information you use to find out about knee problems.

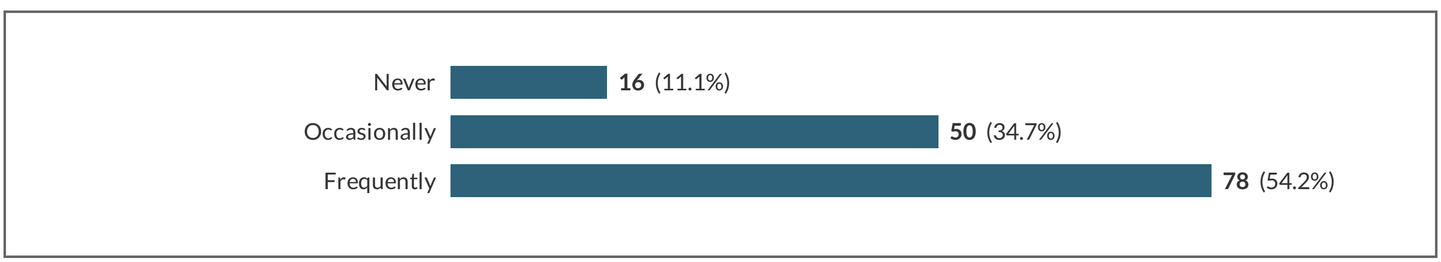


5.10 Primary care physician/GP

5.10.a Primary care physician/GP - Please indicate which sources of information you use to find out about knee problems.

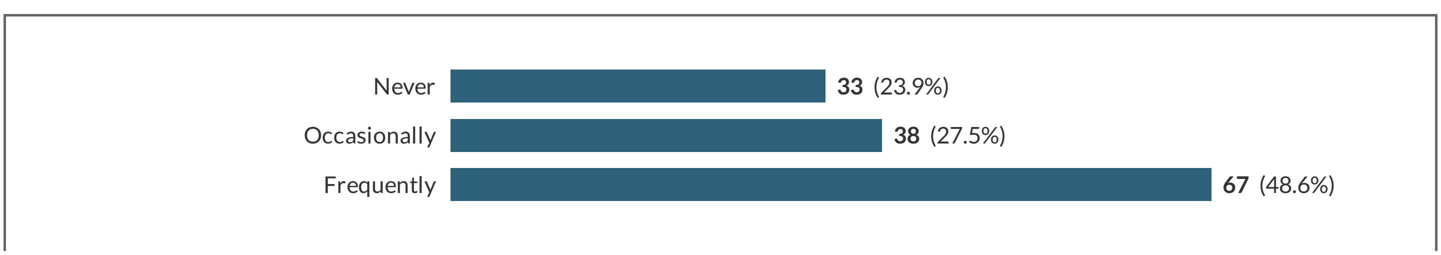
5.11 Knee surgeon/orthopaedic consultant

5.11.a Knee surgeon/orthopaedic consultant - Please indicate which sources of information you use to find out about knee problems.



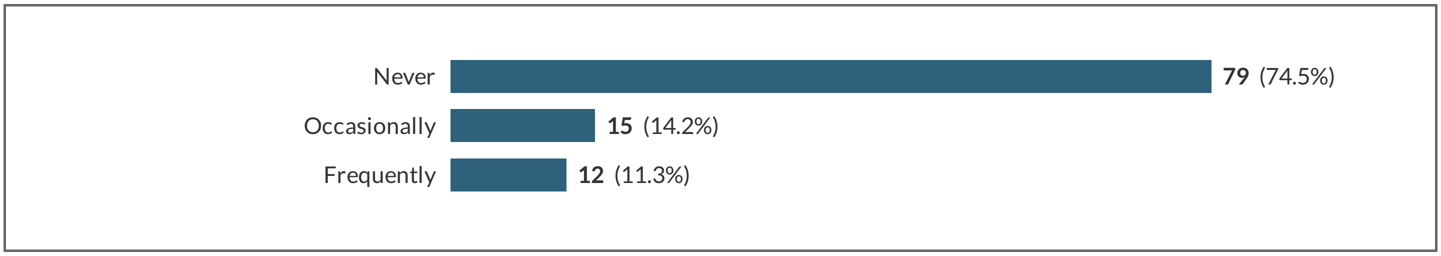
5.12 Physiotherapist/physical therapist/sports therapist

5.12.a Physiotherapist/physical therapist/sports therapist - Please indicate which sources of information you use to find out about knee problems.

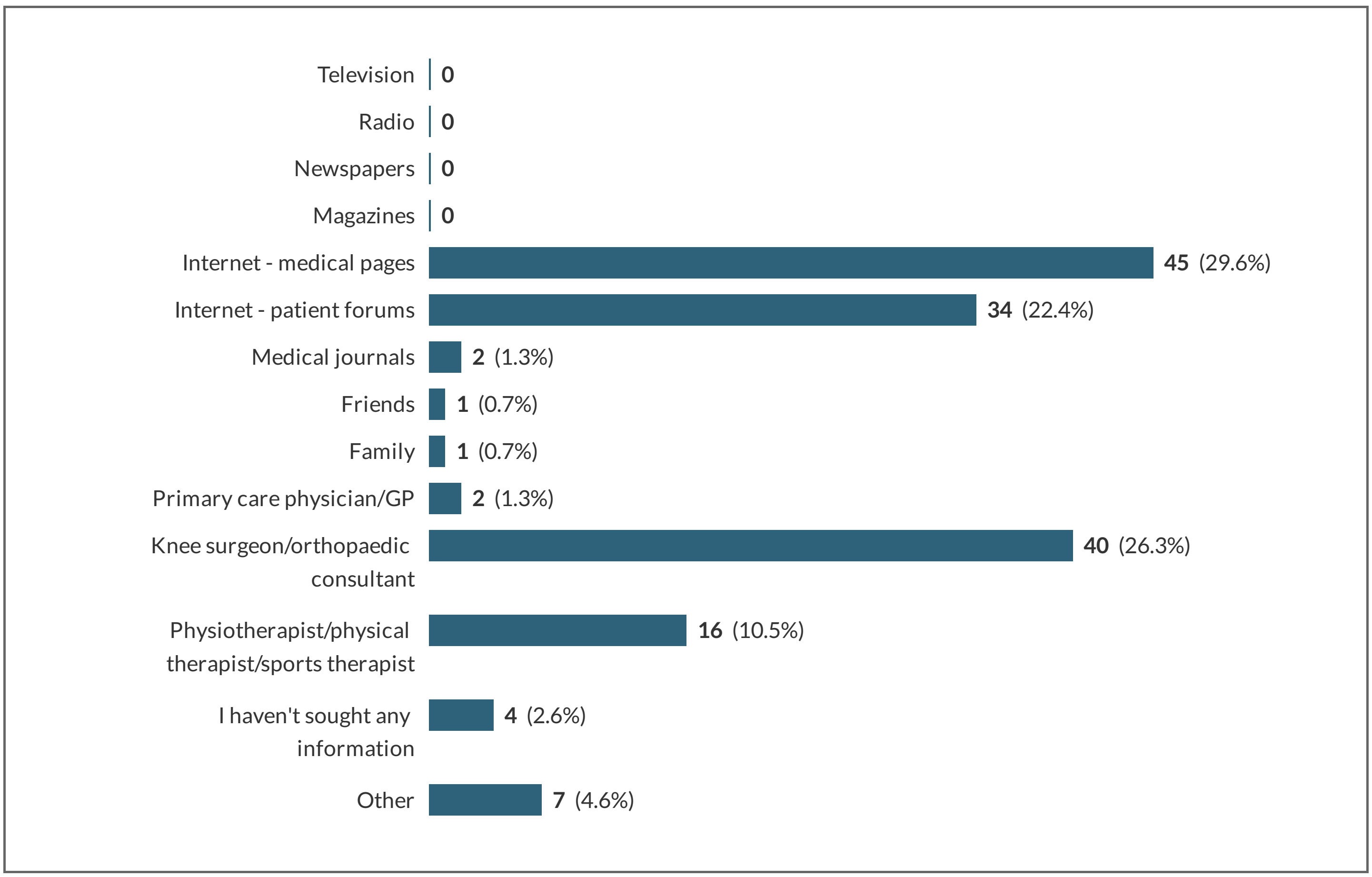


5.13 Other

5.13.a Other - Please indicate which sources of information you use to find out about knee problems.



6 What has been your main source of information about knee problems in the last 6 months?



6.a If you selected Other, please specify:

Showing 5 of 7 responses	
pretty much all of the above	110401-110395-6144713
I've had consultations with Orthopaedic surgeons but there's only so much info you can acquire in 15 minutes so Internet has added much more detail.	110401-110395-6144732
Active Release Theapist	110401-110395-6144775
Internet,surgeon, PT - about equally	110401-110395-6144793
Chiropractor	110401-110395-6144801

7 Are you a member of any other online communities for people with knee problems?

7.a If yes, please state names:

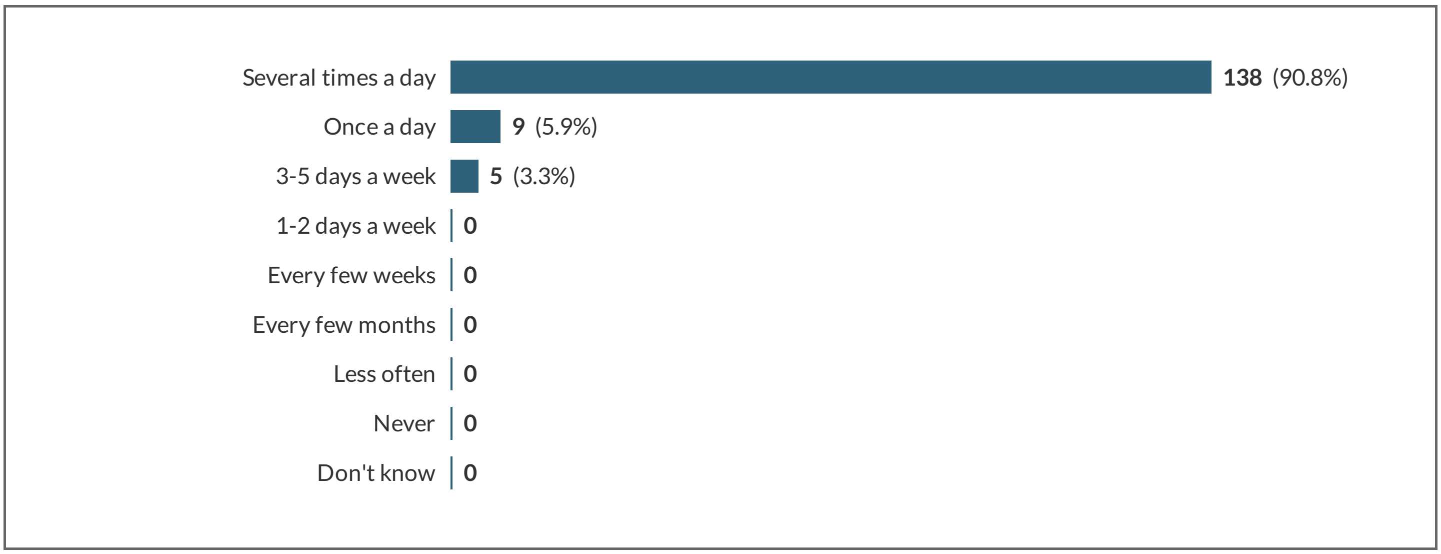
Showing all 5 responses	
some german board for general sports injuries...	110401-110395-6144762
bonesmart	110401-110395-6144782
physiobob.com	110401-110395-6144824
Mayo Clinic	110401-110395-6144828
Topix	110401-110395-6144837

8 Are you a member of any online communities for other health problems?

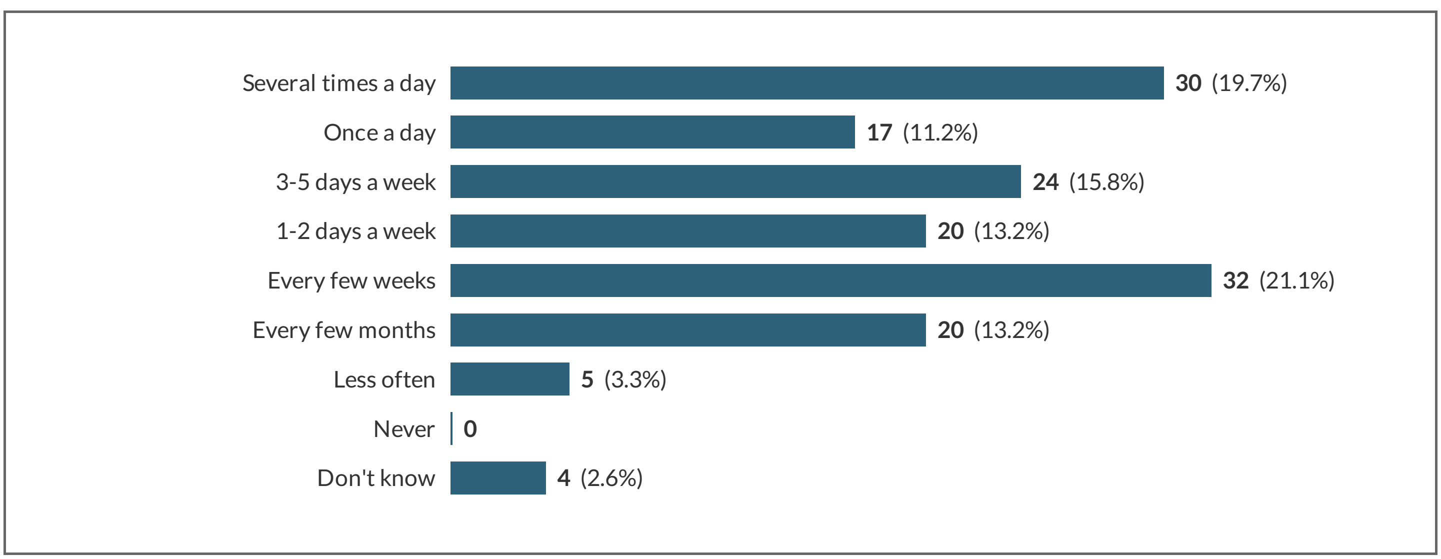
8.a If yes, please state names:

Showing 5 of 12 responses	
healthboards.com	110401-110395-6144711
Vascular Ehlers Danlos Syndrome	110401-110395-6144721
kaiser	110401-110395-6144742
sorry, cannot remember right now.	110401-110395-6144764
healthboard.com	110401-110395-6144772

9 How often do you use the internet?



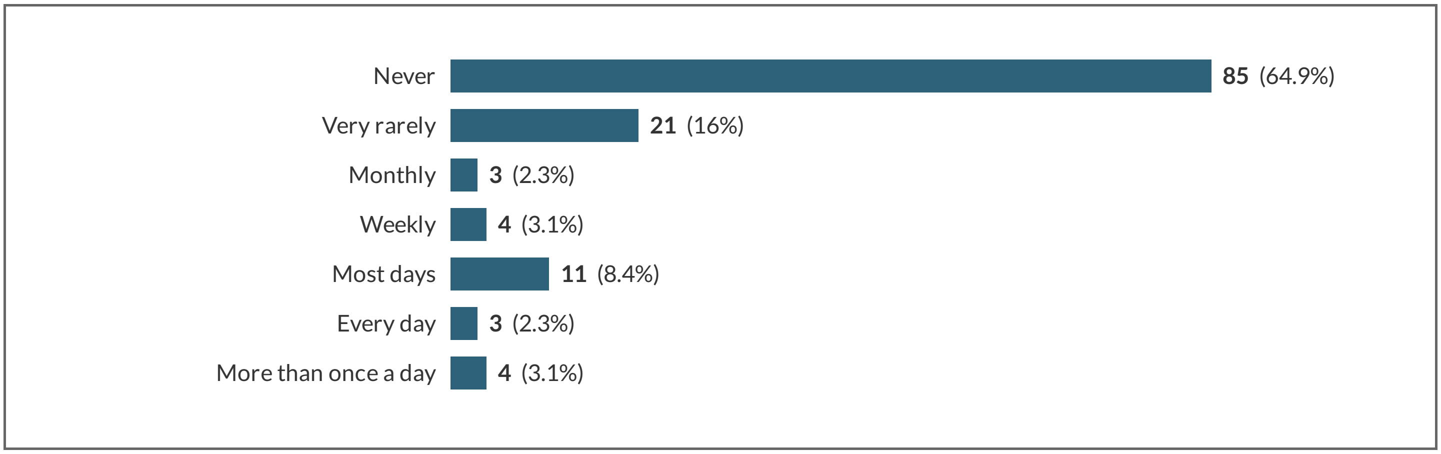
10 How often do you use the Internet to look for advice or information about health or health care?



11 What social media do you use?

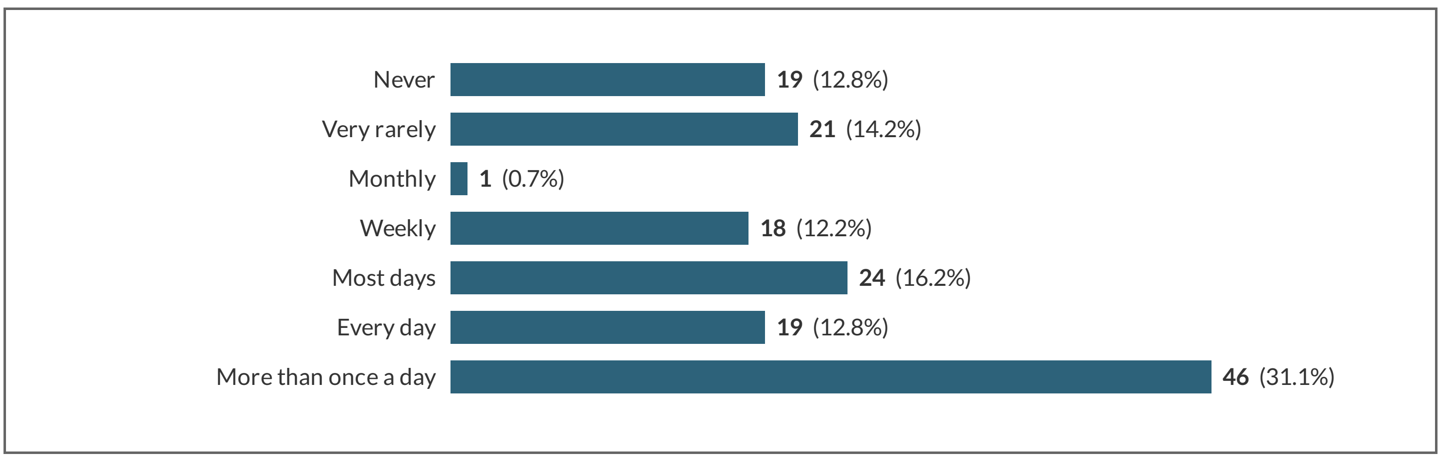
11.1 Twitter

11.1.a Twitter - How frequently?



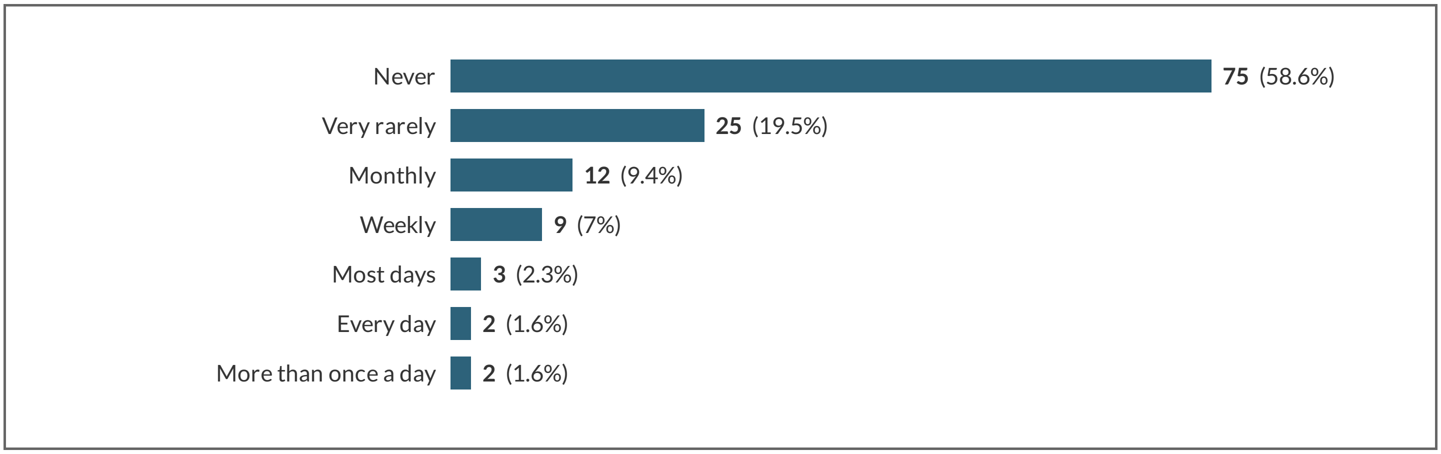
11.2 Facebook

11.2.a Facebook - How frequently?



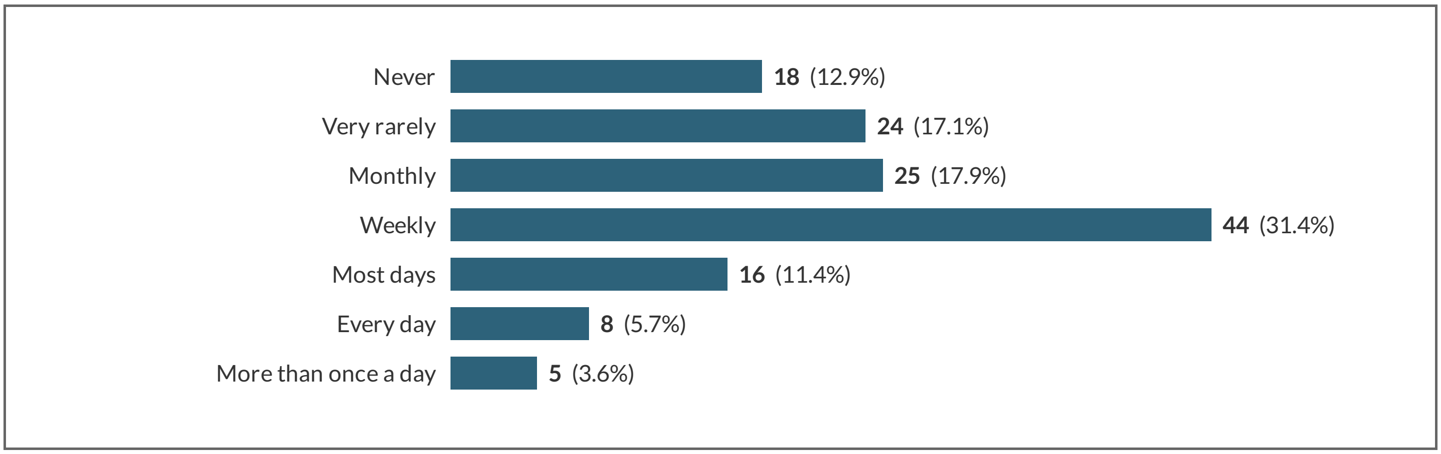
11.3 LinkedIn

11.3.a LinkedIn - How frequently?



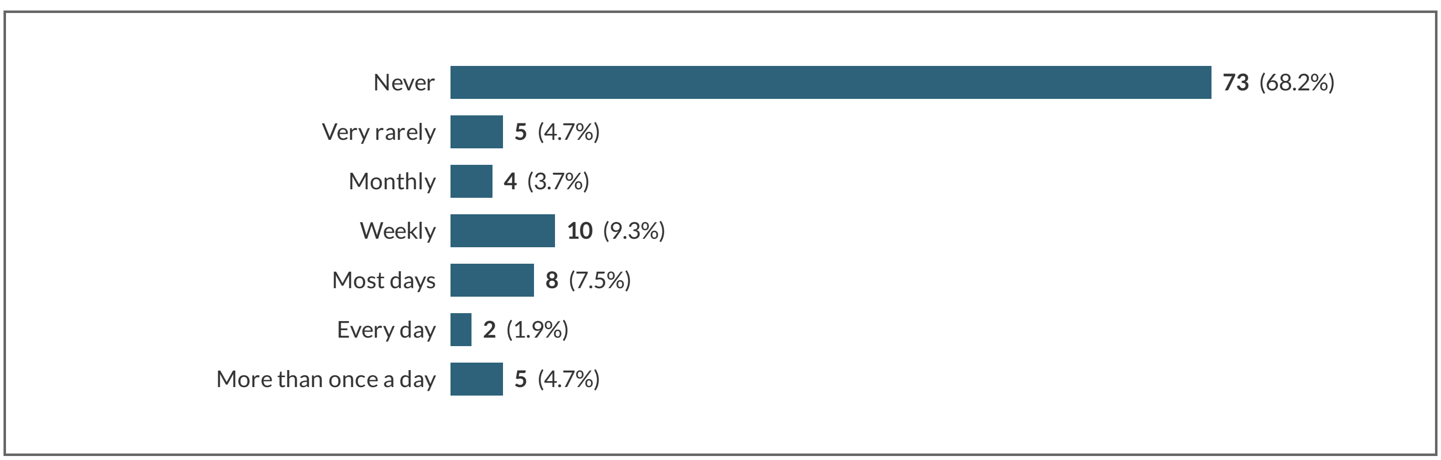
11.4 Youtube

11.4.a Youtube - How frequently?



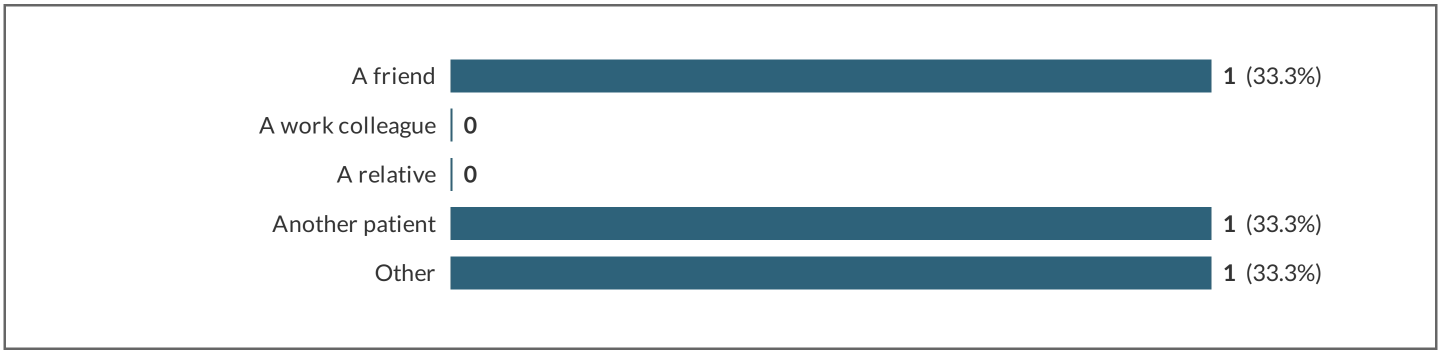
11.5 Other

11.5.a Other - How frequently?



12 Do you know someone who has already registered for KNEEguru?

12.a If yes, was the person:



12.a.i If you selected Other, please specify:

Showing 1 response	
Member of ski forum	110401-110395-6144805

12.b If yes, how did this person influence your decision to register with KNEEguru?

Showing all 4 responses	
told me about it	110401-110395-6144782
They told me about the wealth of information available via Knee Guru and that the bulletin board was largely a positive experience. Prior to joining I have avoided BB because of all the aggression I have seen and heard of.	110401-110395-6144789
Found out about KNEEguru because of detailed write up about ACL injuries on the ski forum EpicSki	110401-110395-6144805
The scheduled op is next week and I have heard that there may be an allergic reaction to the metal implant currently installed. Is this so? And what material is the new prosthesis?	110401-110395-6144825

13 Is this the first time you have visited the KNEEguru website?

13.a If no, how long have you been using the KNEEguru website?

Showing 5 of 43 responses	
4 weeks	110401-110395-6144711
one month	110401-110395-6144721
Week	110401-110395-6144723
18 months	110401-110395-6144724
8 months	110401-110395-6144731

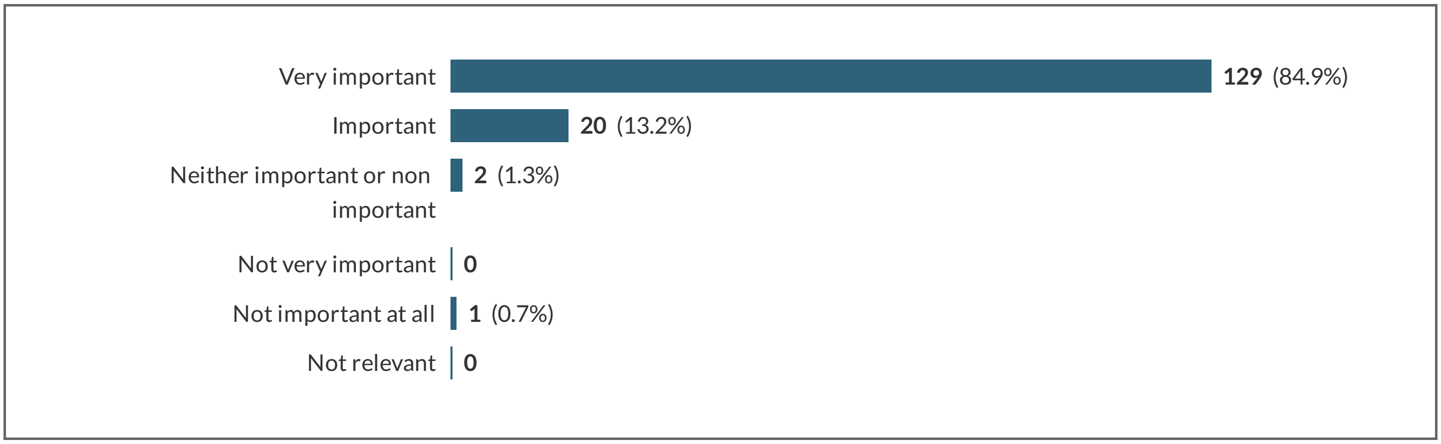
13.b If no, why have you now decided to register with KNEEguru? (Please provide as full an answer as possible in your own words).

Showing 5 of 38 responses	
I wanted to comment on a post in the forum	110401-110395-6144711
so i have the option to post if i choose to	110401-110395-6144721
to get detailed info on a forum posting	110401-110395-6144724
I went through a period of depression but eventually worked through it and found happiness without sport or any real physical activity, because engaging in it was more painful (emotionally) than not. I'm no longer happy being inactive, and I'm again seeking answers.	110401-110395-6144731
I remember seeing the website, but not the forum back in September/October 2011	110401-110395-6144737

14 What are the most important reasons for joining KNEEguru?

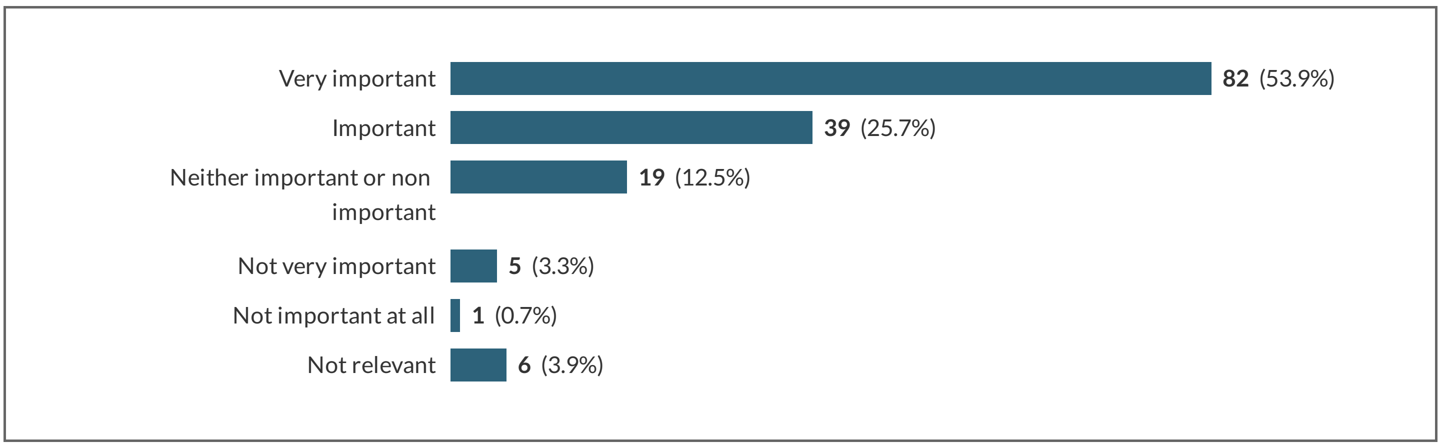
14.1 To seek information on the knee problem

14.1.a To seek information on the knee problem - How important were these needs in your decision to register with KNEEguru?



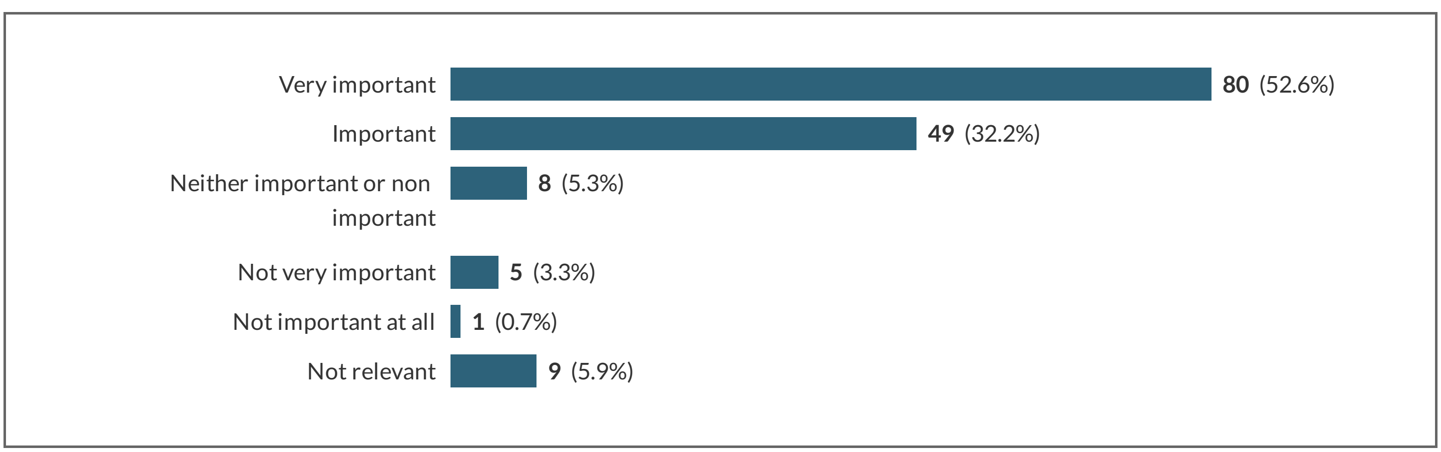
14.2 To aid my medical decision making with regards to the knee problem

14.2.a To aid my medical decision making with regards to the knee problem - How important were these needs in your decision to register with KNEEguru?



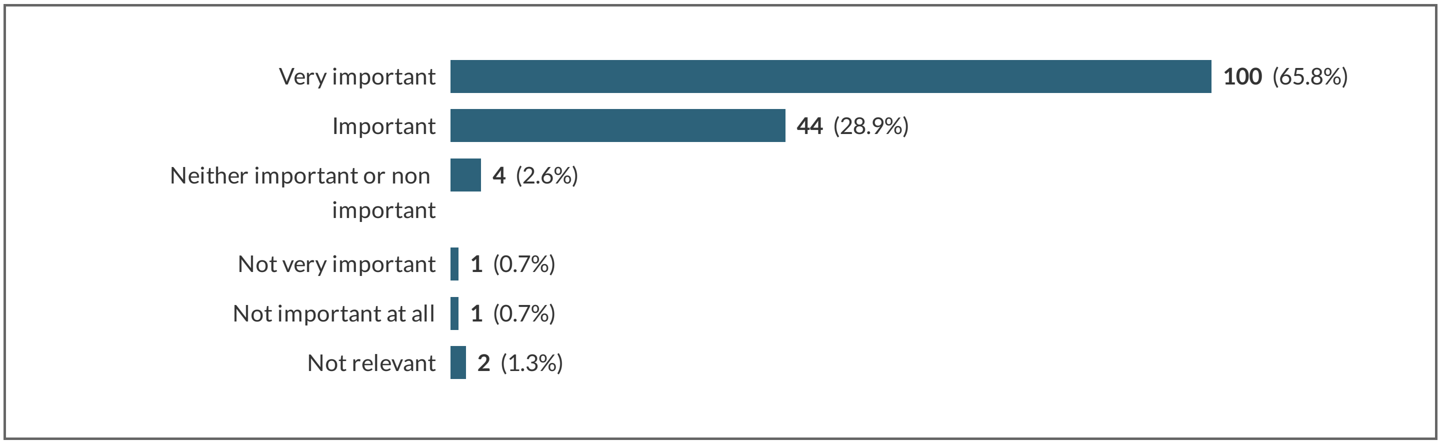
14.3 To prepare myself for treatment/interventions for the knee problem

14.3.a To prepare myself for treatment/interventions for the knee problem - How important were these needs in your decision to register with KNEEguru?



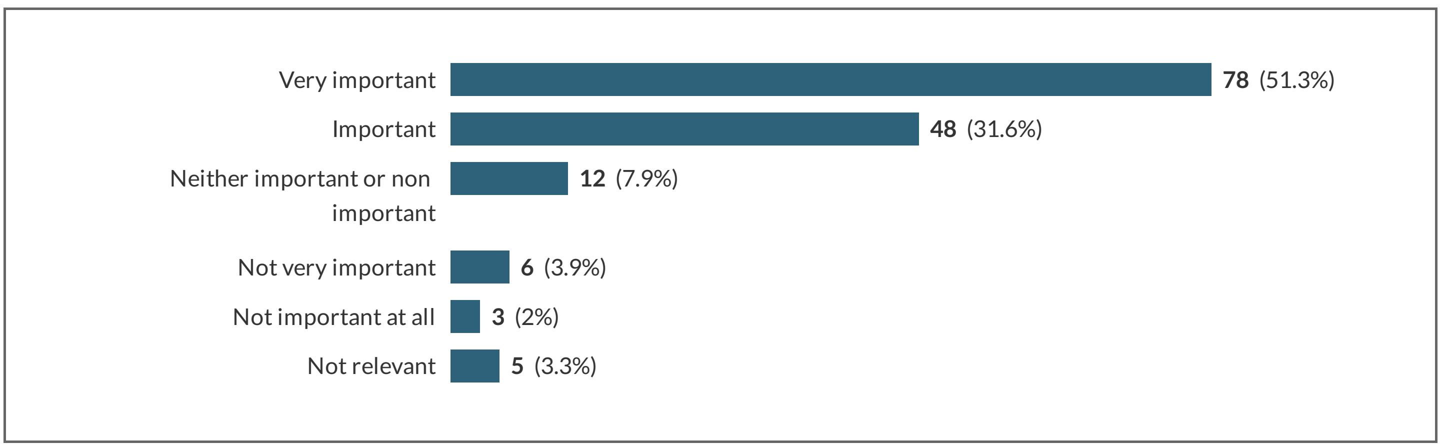
14.4 To learn what to expect with the knee problem

14.4.a To learn what to expect with the knee problem - How important were these needs in your decision to register with KNEEguru?



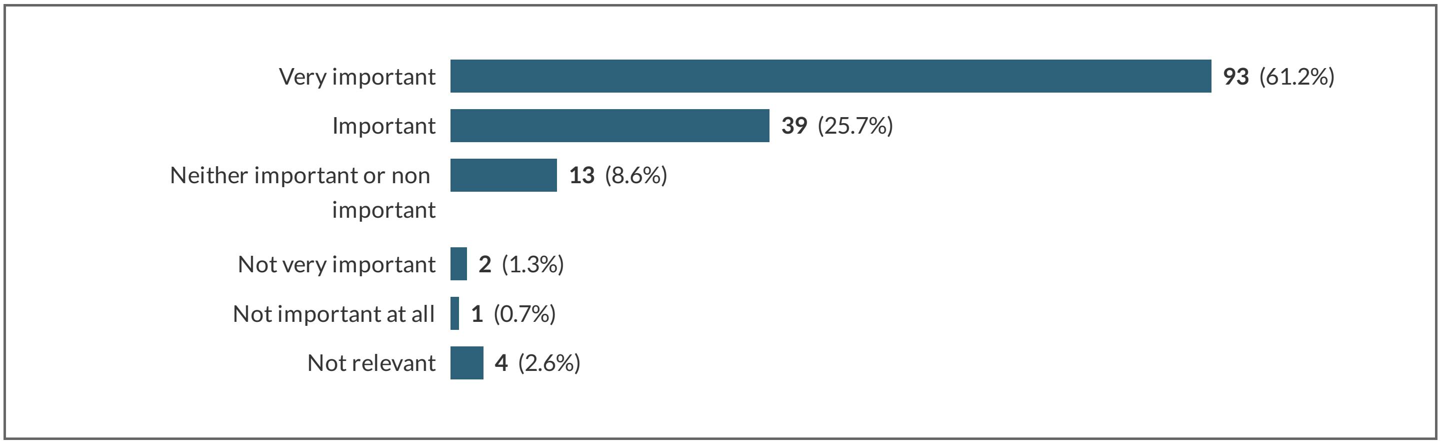
14.5 To compare my current symptom experience with the knee problem

14.5.a To compare my current symptom experience with the knee problem - How important were these needs in your decision to register with KNEEguru?



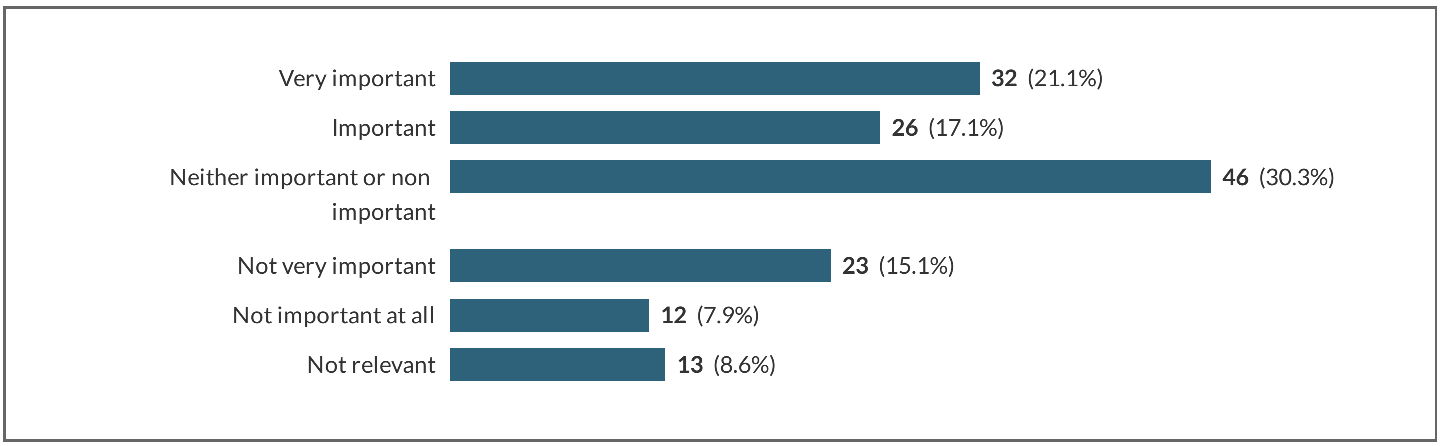
14.6 To compare recovery following injury/treatment/surgery to others

14.6.a To compare recovery following injury/treatment/surgery to others - How important were these needs in your decision to register with KNEEguru?



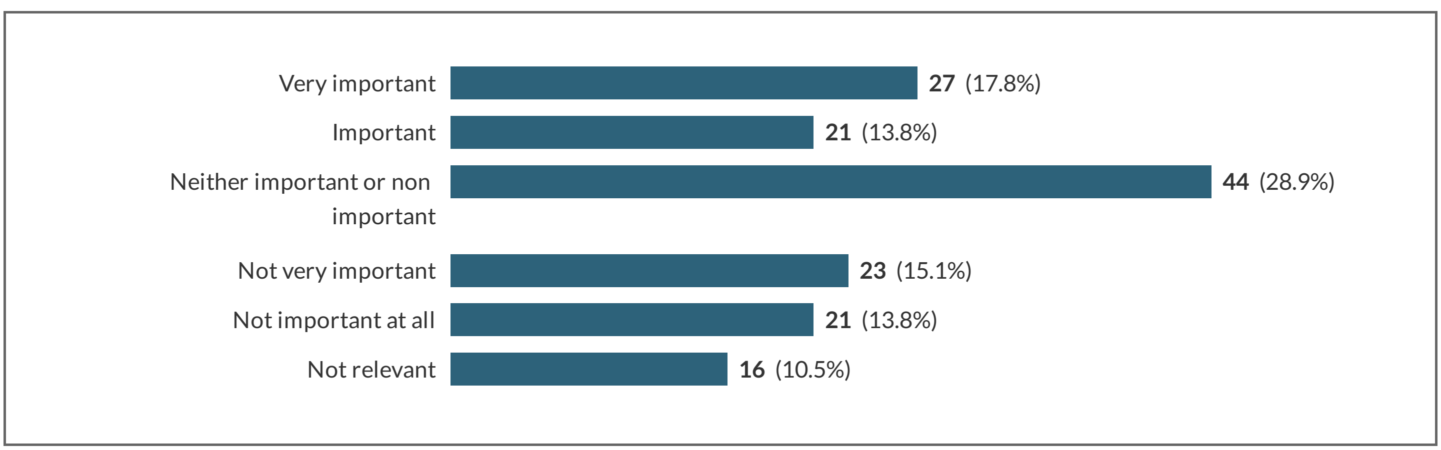
14.7 To get emotional support from others

14.7.a To get emotional support from others - How important were these needs in your decision to register with KNEEguru?



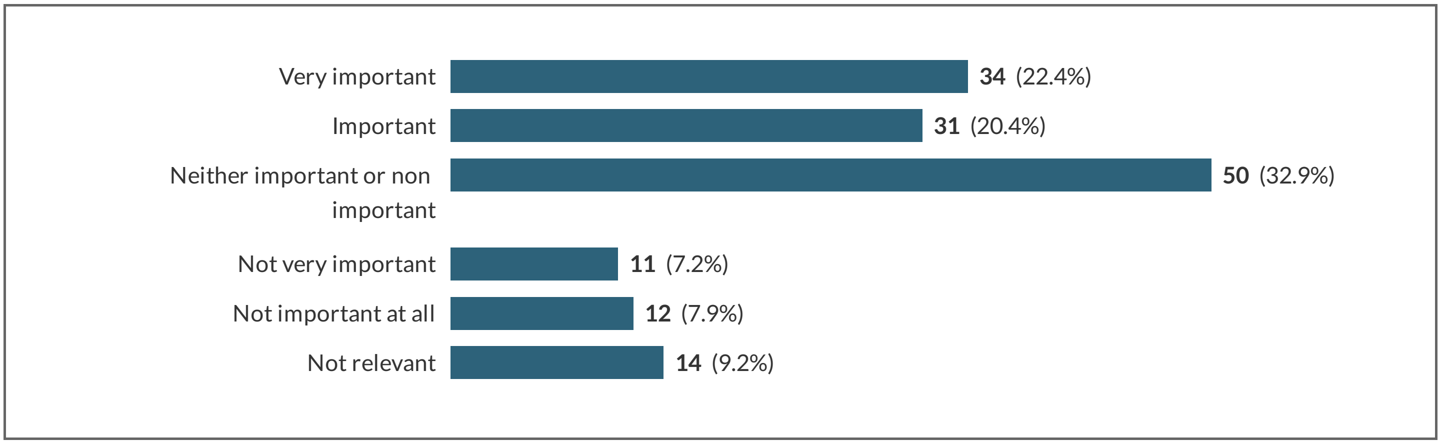
14.8 To vent out emotions related to the knee problem

14.8.a To vent out emotions related to the knee problem - How important were these needs in your decision to register with KNEEguru?



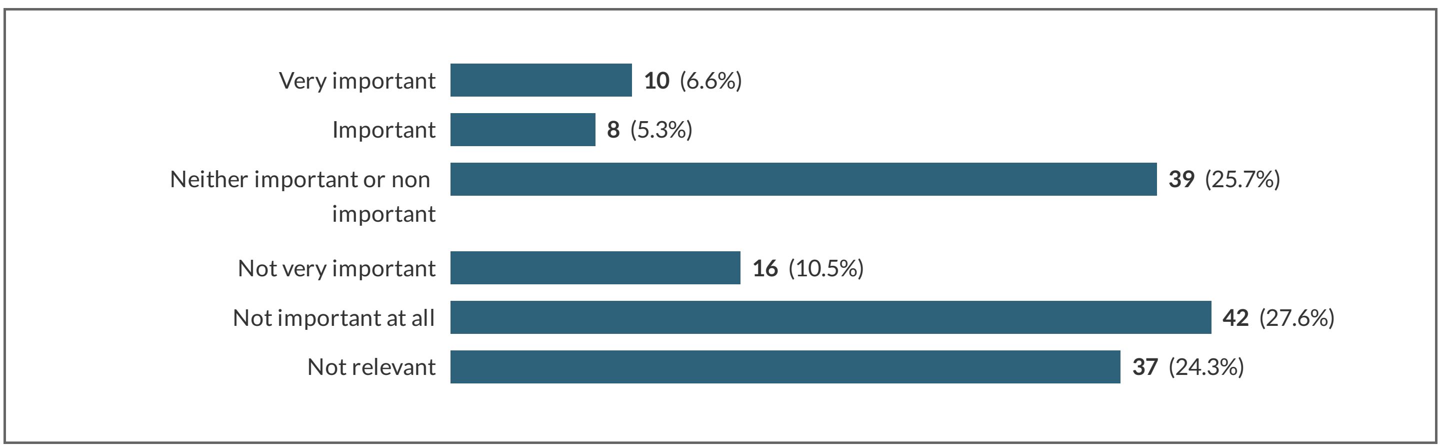
14.9 To validate my experience

14.9.a To validate my experience - How important were these needs in your decision to register with KNEEguru?



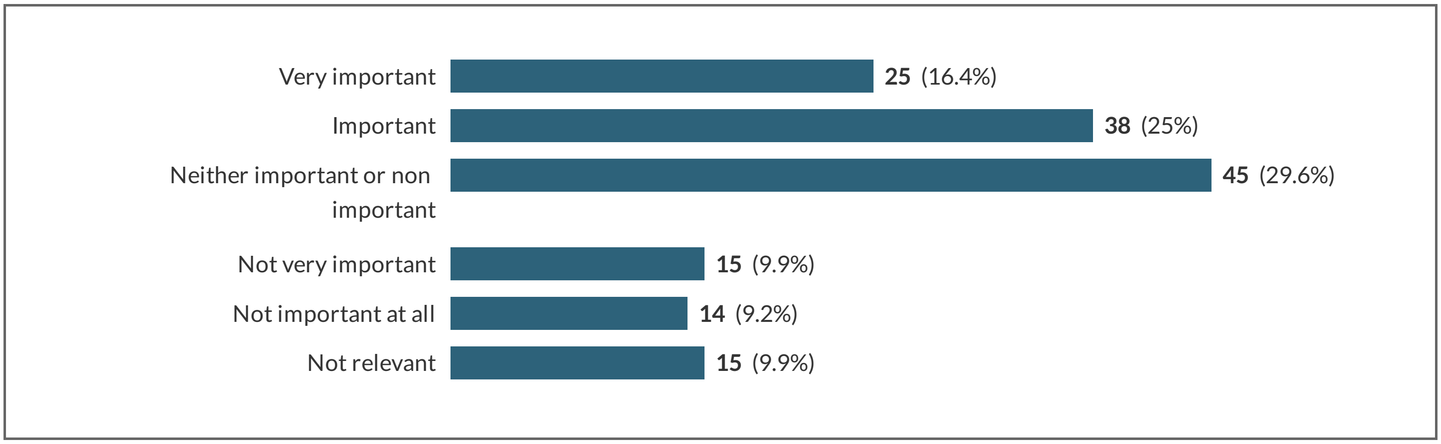
14.10 To seek recognition

14.10.a To seek recognition - How important were these needs in your decision to register with KNEEguru?



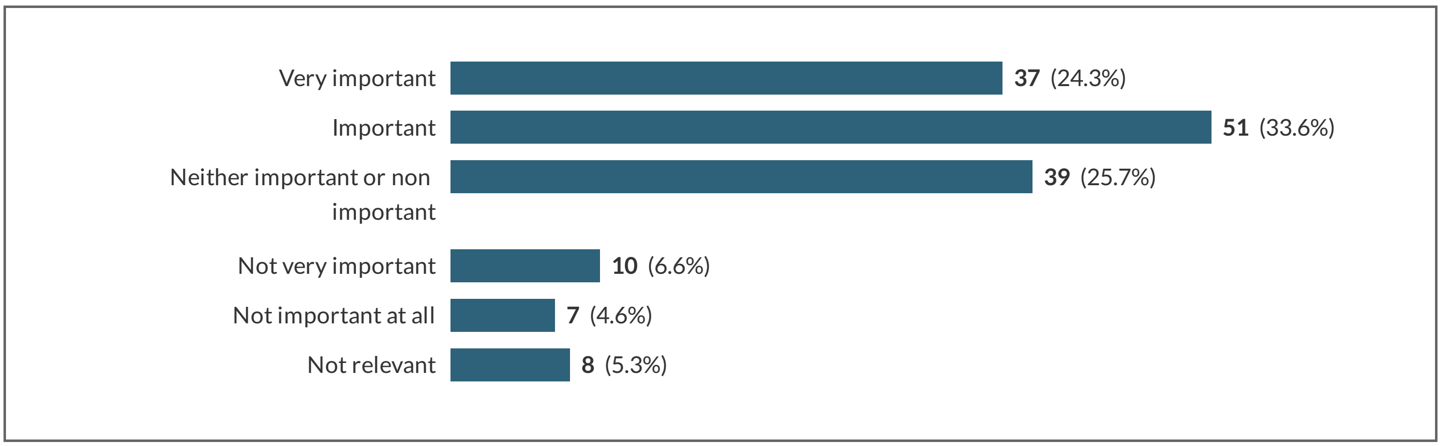
14.11 To offer emotional support to others

14.11.a To offer emotional support to others - How important were these needs in your decision to register with KNEEguru?



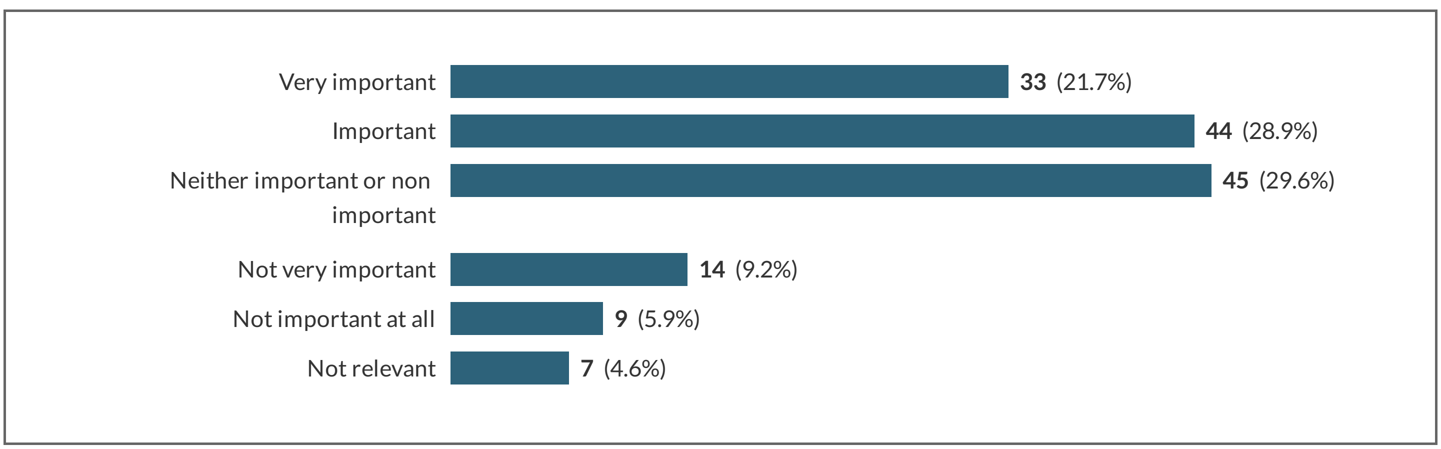
14.12 To share my experience with others

14.12.a To share my experience with others - How important were these needs in your decision to register with KNEEguru?



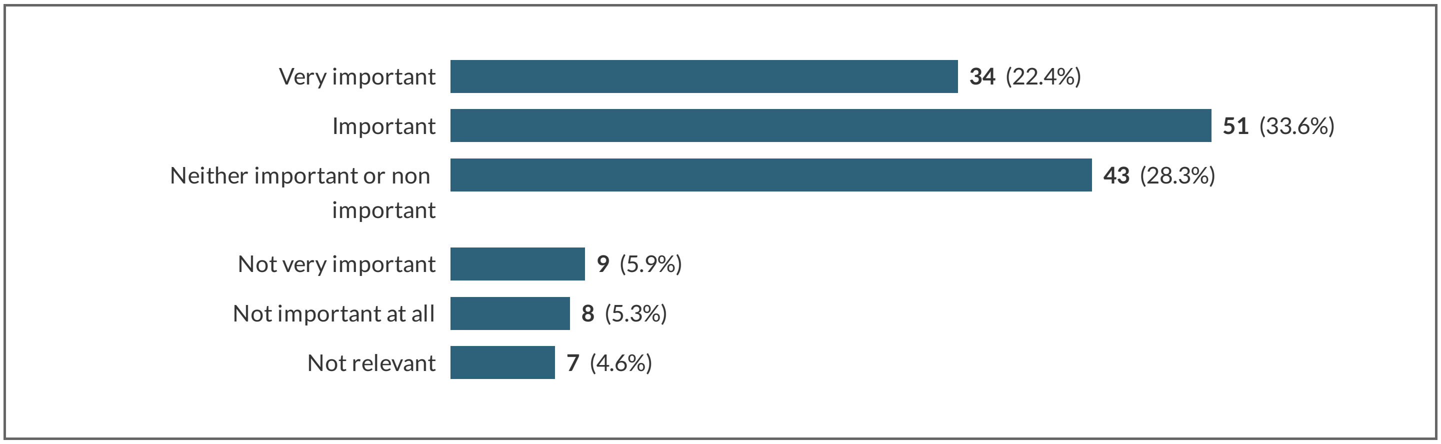
14.13 To offer advice to help others

14.13.a To offer advice to help others - How important were these needs in your decision to register with KNEEguru?



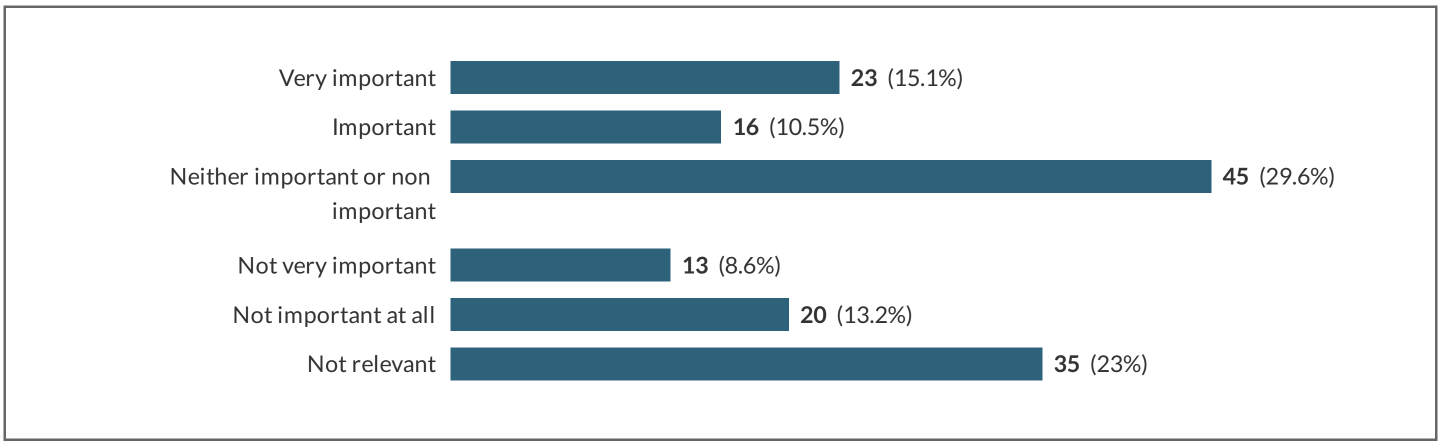
14.14 To provide information to help others

14.14.a To provide information to help others - How important were these needs in your decision to register with KNEEguru?



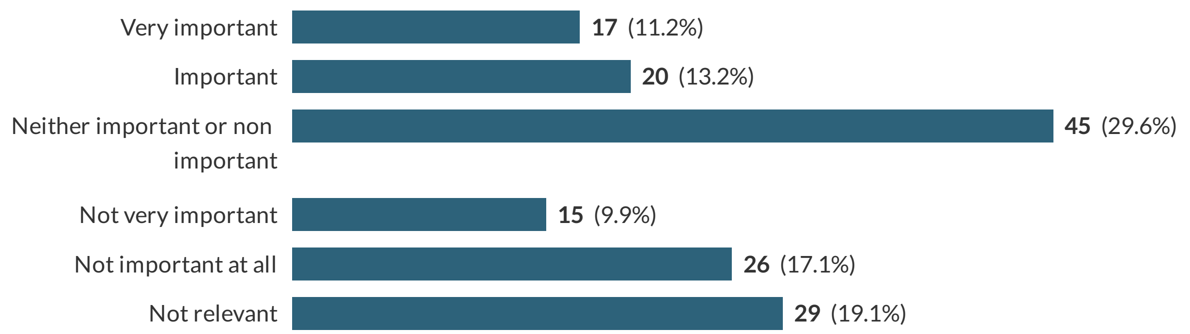
14.15 To see how my online friends are managing

14.15.a To see how my online friends are managing - How important were these needs in your decision to register with KNEEguru?



14.16 To be able to send personal messages to other registered users

14.16.a To be able to send personal messages to other registered users - How important were these needs in your decision to register with KNEEguru?



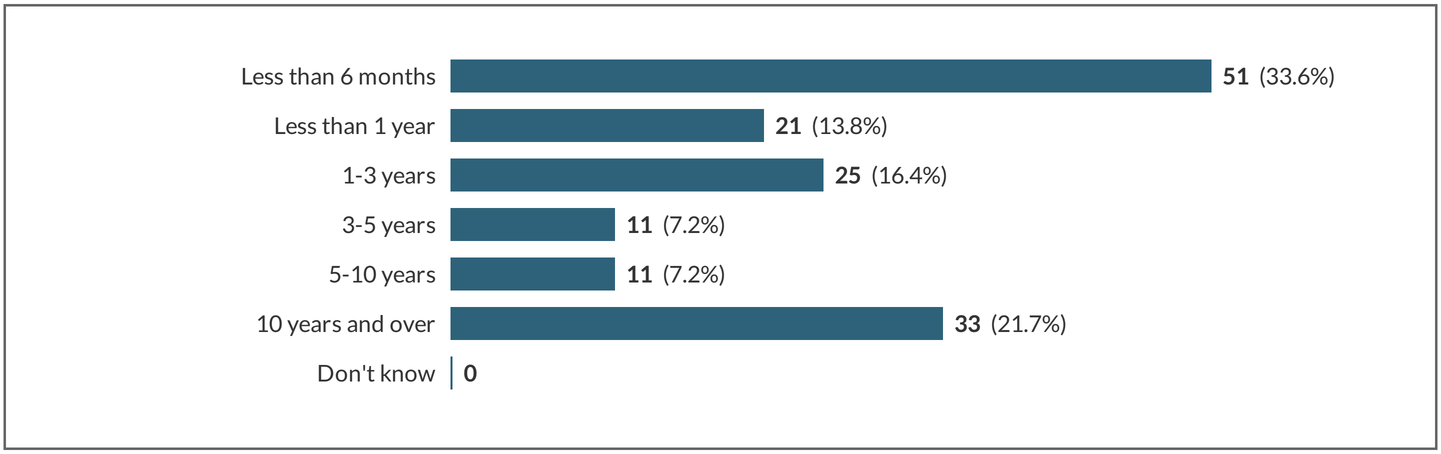
15 Are you looking for particular information on the KNEEguru website?

15.a If yes, in your own words can you tell us what information you want to find and why you want to find it.

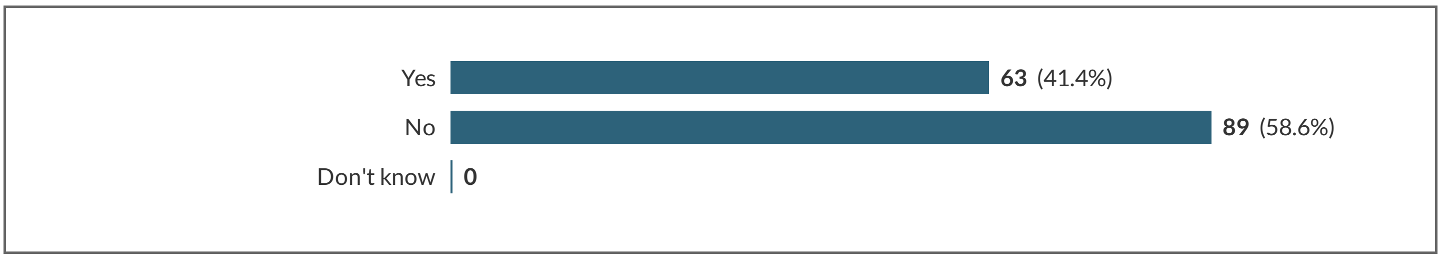
Showing 5 of 109 responses	
knee scopes and possible mensicus tear when an MRI in advance was not an option	110401-110395-6144711
MCL tears, meniscal damage	110401-110395-6144712
Everything about knees	110401-110395-6144713
Just want to see what other persons my age and activtiy level experienced after similar surgery.	110401-110395-6144714
Best practice - cutting edge info. Upcoming modalities. Staving off additional damage.	110401-110395-6144715

Tell us about the knee problem...

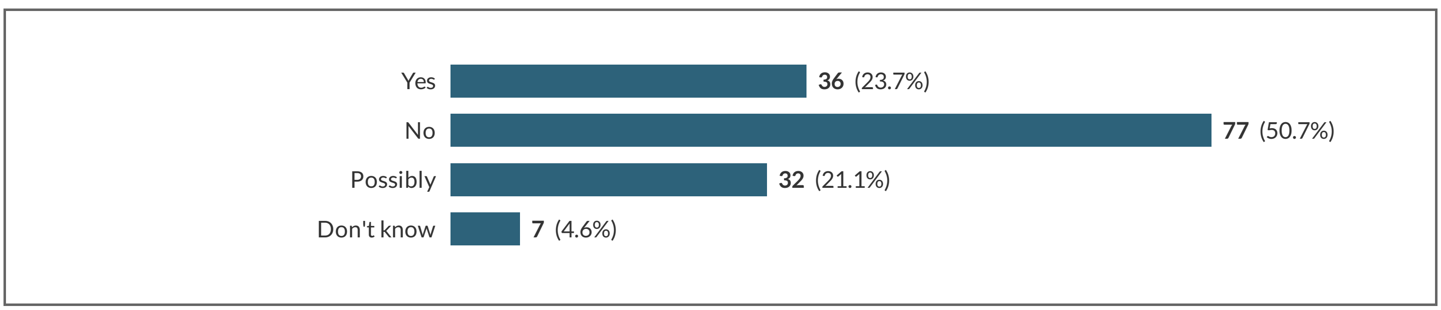
16 How long have you (or the person with the knee problem) been experiencing symptoms related to the knee problem?



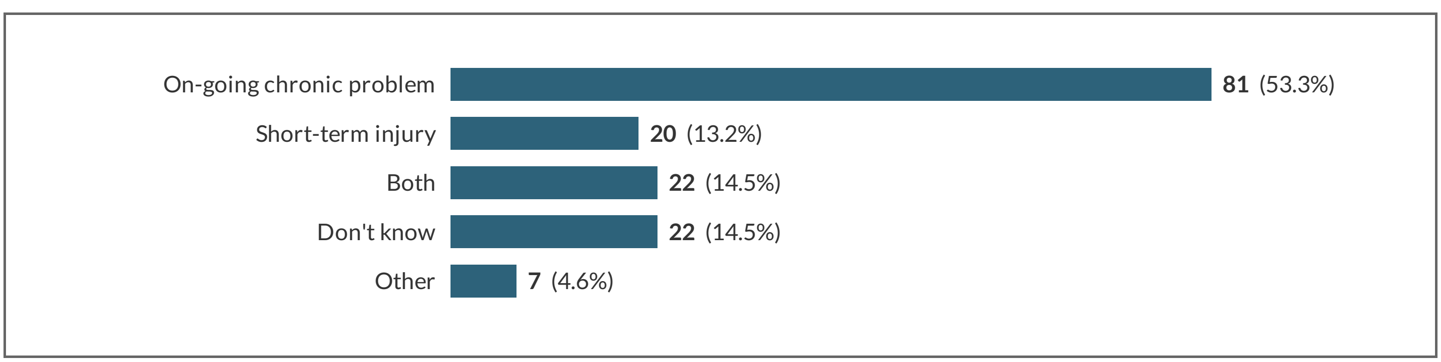
17 Have you (or the person with the knee problem) had knee surgery in the last 6 months?



18 Are you (or the person you are registering for) scheduled for knee surgery in the next 6 months?



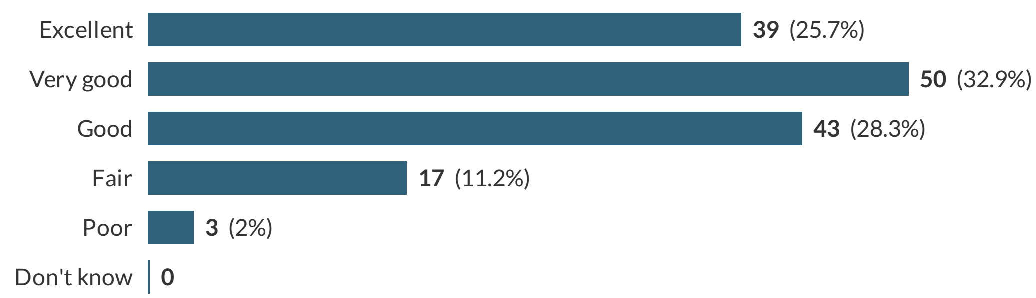
19 Would you consider the knee problem to be an on-going chronic problem or a short-term injury?



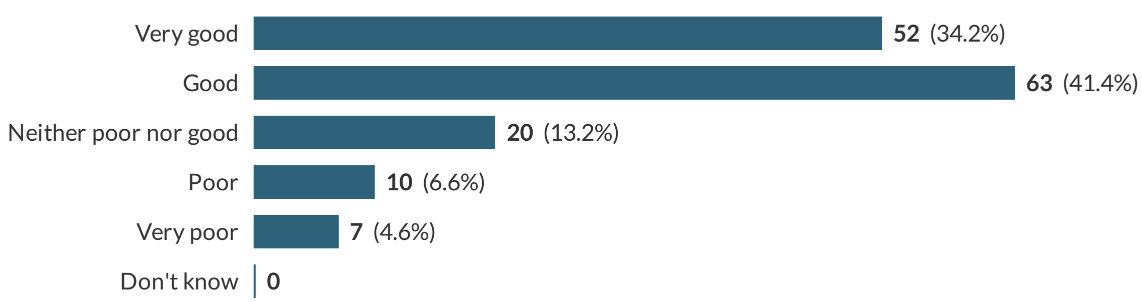
19.a If you selected Other, please specify:

Showing 5 of 7 responses	
It has been ongoing but hope it will be sorted after surgery.	110401-110395-6144734
If no ACLR then it's chronic otherwise (hopefully) it's a "medium" term injury!	110401-110395-6144732
Broken patella, but long recovery period	110401-110395-6144737
as short as possible	110401-110395-6144754
long term injury	110401-110395-6144807

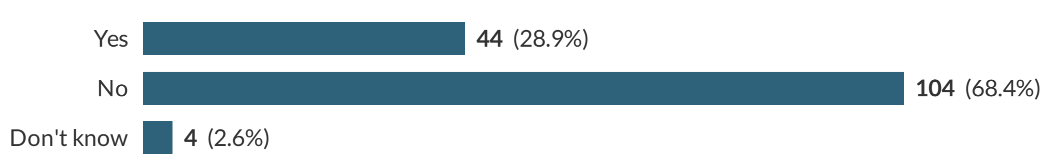
20 In general, how would you rate your own overall health?



21 How would you rate your quality of life?



22 Do you have any chronic health problems?



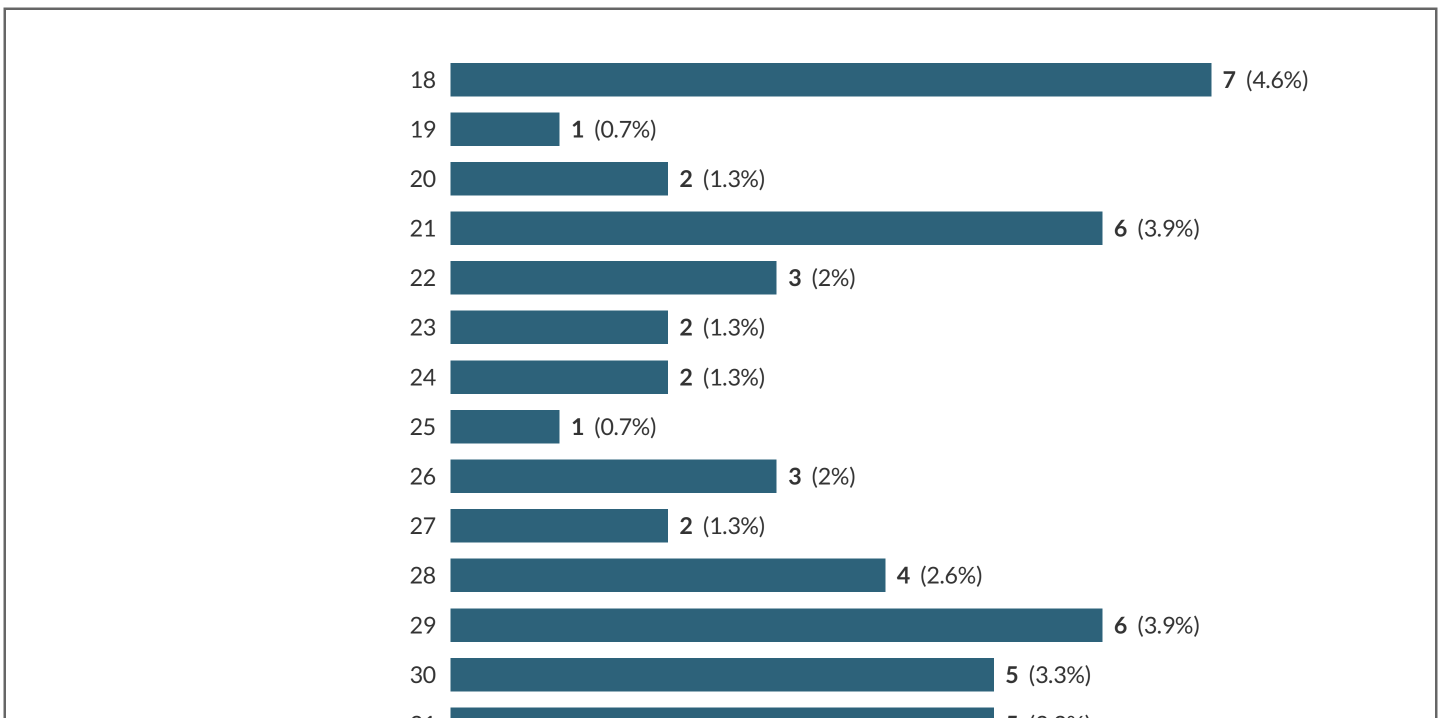
22.a If yes, please list:

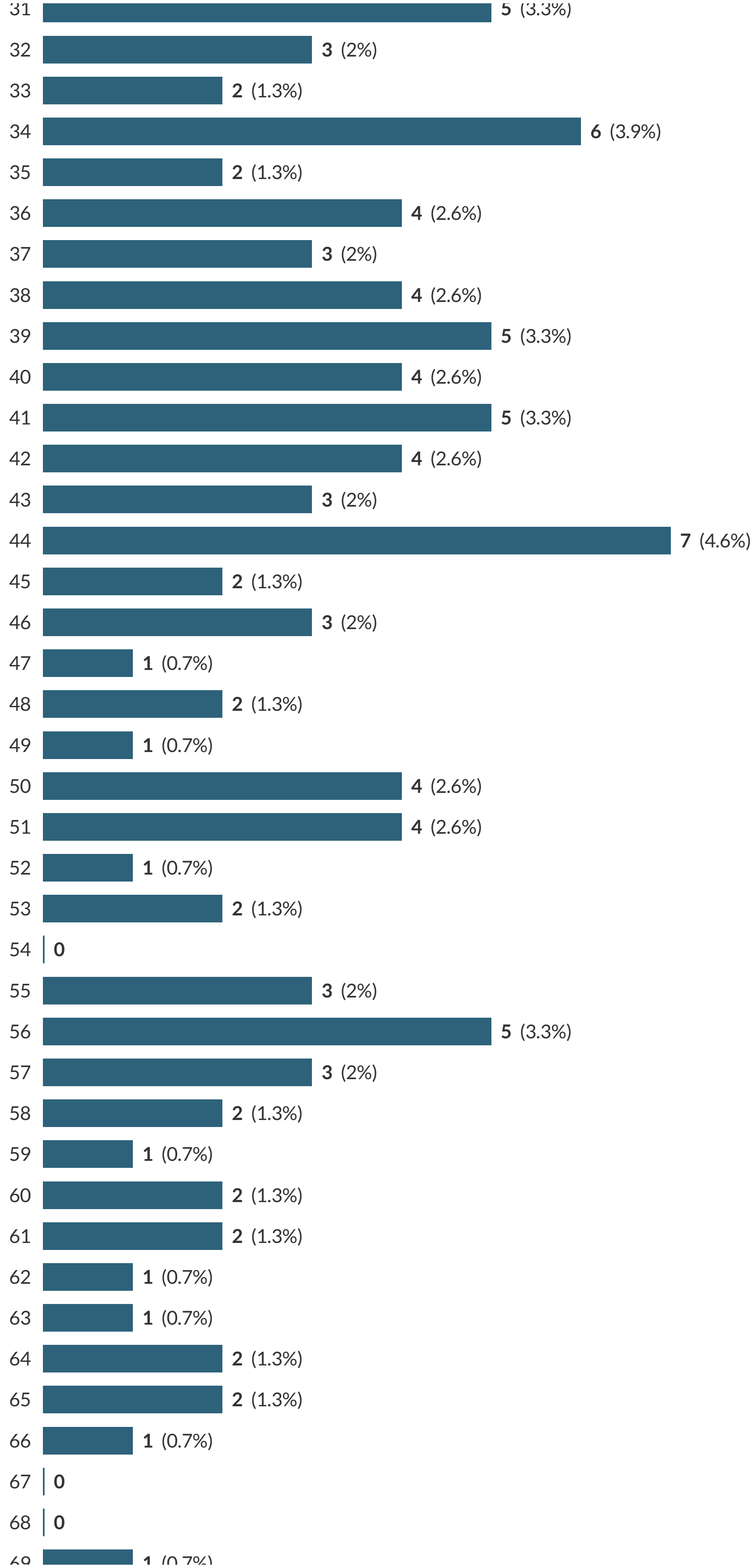
Showing 5 of 40 responses	
Seasonal allergies	110401-110395-6144714
Depression	110401-110395-6144716
Vascular Ehlers Danlos Syndrome	110401-110395-6144721
hypothyroid, gluten allergy	110401-110395-6144722
arthritis	110401-110395-6144724

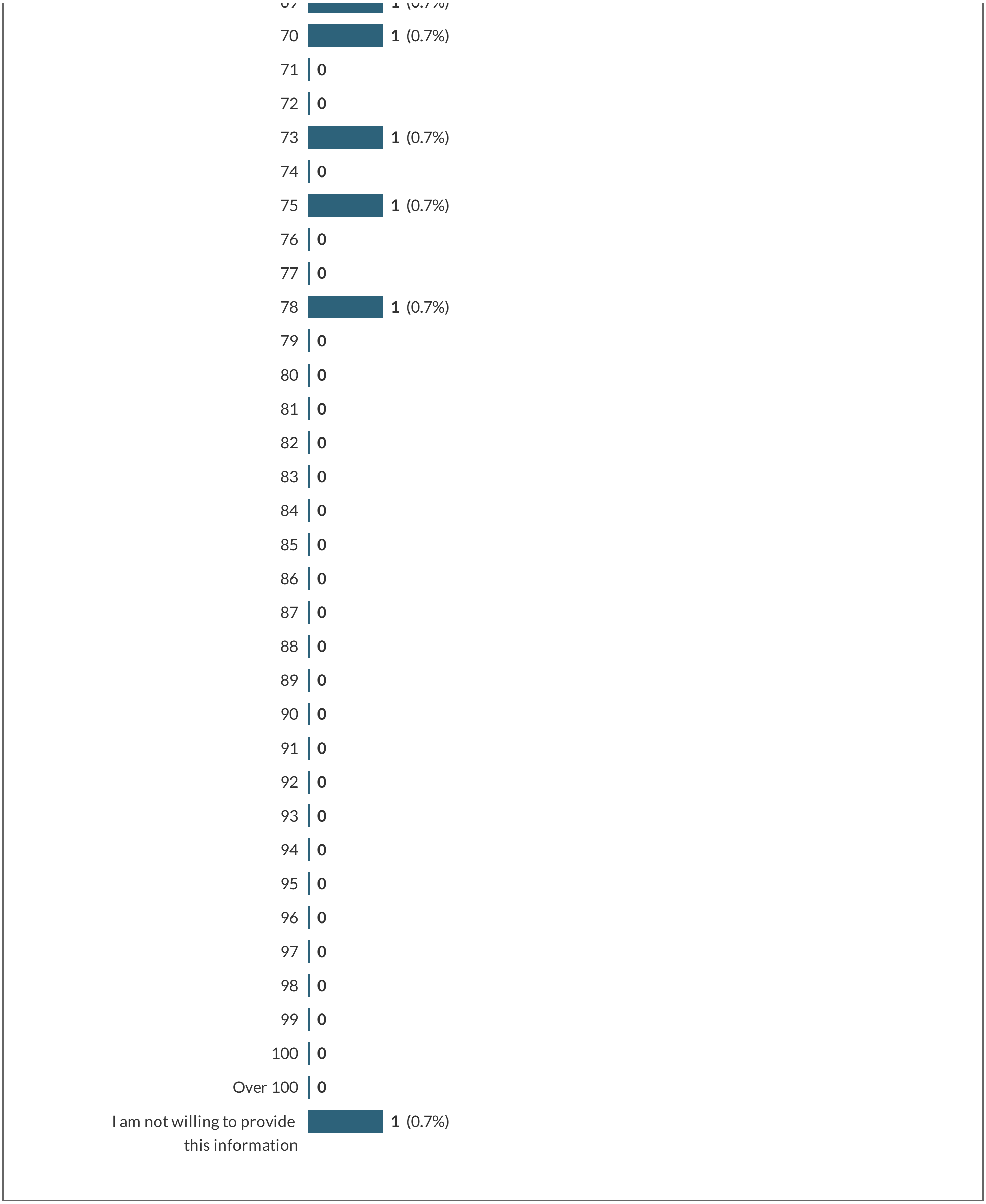
Tell us a bit about yourself...

23 Are you male or female?

24 How old are you (years)?




31 5 (3.3%)
32 3 (2%)
33 2 (1.3%)
34 6 (3.9%)
35 2 (1.3%)
36 4 (2.6%)
37 3 (2%)
38 4 (2.6%)
39 5 (3.3%)
40 4 (2.6%)
41 5 (3.3%)
42 4 (2.6%)
43 3 (2%)
44 7 (4.6%)
45 2 (1.3%)
46 3 (2%)
47 1 (0.7%)
48 2 (1.3%)
49 1 (0.7%)
50 4 (2.6%)
51 4 (2.6%)
52 1 (0.7%)
53 2 (1.3%)
54 0
55 3 (2%)
56 5 (3.3%)
57 3 (2%)
58 2 (1.3%)
59 1 (0.7%)
60 2 (1.3%)
61 2 (1.3%)
62 1 (0.7%)
63 1 (0.7%)
64 2 (1.3%)
65 2 (1.3%)
66 1 (0.7%)
67 0
68 0
69 1 (0.7%)



25 Which country do you live in?


United Kingdom 33 (21.7%)
USA 84 (55.3%)
Australia 9 (5.9%)
Afghanistan 0
Albania 0
Algeria 0
Andorra 0
Angola 0
Anguilla 0
Antigua and Barbuda 0
Argentina 0
Armenia 0
Australia 0
Austria 0
Azerbaijan 0
Bahamas 0
Bahrain 0
Bangladesh 0
Barbados 0
Belarus (Byelorussia) 0
Belgium 0
Belize (British Honduras) 0
Benin (Dahomey) 0
Bermuda 0
Bhutan 0
Bolivia 0
Bosnia and Herzegovina 0
Botswana (Bechuanaland) 0
Brazil 0
British Antarctic Territory 0
British Indian Ocean Territory 0
British Virgin Islands 0
Brunei 0
Bulgaria 0
Burkina (Burkina-Faso) 0
Burma (Myanmar) 0
Burundi (Urundi) 0

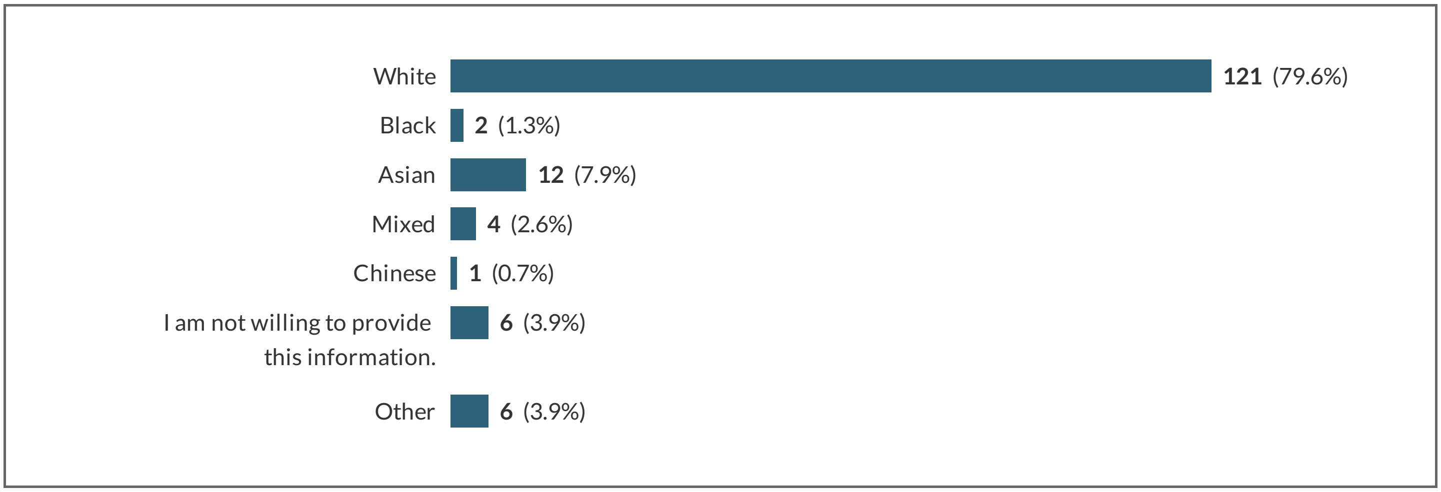
Cambodia (Kampuchea)	0
Cameroon	0
Canada	5 (3.3%)
Cape Verde Islands	0
Cayman Islands	0
Central African Republic	0
Chad (Tchad)	0
Channel Islands	0
Chile	0
China (People's Republic of) Also Tibet	1 (0.7%)
CIS (Commonwealth of Independent States)	0
Colombia	0
Comoros	0
Congo (Democratic Republic)	0
Congo (People's Republic)	0
Costa Rica	0
Croatia	0
Cuba	0
Cyprus	0
Czech Republic	0
Denmark	0
Djibouti	0
Dominica	0
Dominican Republic	0
Dutch West Indies	0
Ecuador	0
Egypt (United Arab Republic)	0
El Salvador	0
Equatorial Guinea	0
Eritrea	0
Estonia	0
Ethiopia	0
Falkland Islands	0
Fiji	0
Finland	0
France and French Overseas Depts (DCMS)	0

Gabon	0
Gambia (Senegambia)	0
Georgia	0
Germany	2 (1.3%)
Ghana	0
Gibraltar	0
Gilbert Islands/Kiribati	0
Greece	0
Greenland (also Faroe Islands)	0
Grenada	0
Guatemala	0
Guinea	0
Guinea-Bissau	0
Guyana	0
Haiti	0
Honduras	0
Hong Kong	0
Hungary	0
Iceland	0
India	3 (2%)
Indonesia	0
Iran (also Persia)	0
Iraq	0
Isle of Man	0
Israel	0
Italy (also Vatican City)	0
Ivory Coast	0
Jamaica	0
Japan	0
Jordan	0
Kazakhstan	0
Kenya	0
Kuwait	0
Kyrgyzstan (Kirgizia)	0
Laos	0
Latvia	0
Lebanon	0
Leeward Islands	0

Lesotho (Basutoland)	0
Liberia	0
Libya	0
Liechtenstein	0
Lithuania	0
Luxembourg	0
Macao	0
Macedonia	0
Madagascar (Malagasy Republic)	0
Malawi (Nyasaland)	0
Malaysia	0
Maldives	0
Mali	0
Malta	1 (0.7%)
Marshall Islands	0
Mauritania	0
Mauritius	0
Mayotte	0
Mexico	0
Micronesia	0
Moldova	0
Monaco	0
Mongolia	0
Monserrat	0
Morocco	0
Mozambique	0
Namibia	0
Nauru	0
Nepal	0
Netherlands (Holland)	0
New Zealand	0
Nicaragua	0
Niger	0
Nigeria	0
North Korea	0
Norway	0
Oman (Muscat and Oman)	0
Pakistan	1 (0.7%)

Panama	0
Papua New Guinea	0
Paraguay	0
Peru	0
Philippines	0
Poland	0
Portugal (also Madeira, Azores)	0
Puerto Rico	0
Qatar	0
Romania (Rumania)	0
Russia	0
Rwanda	0
Samoa (also Western Samoa)	0
San Marino	0
Sao Tome and Principe	0
Saudi Arabia	0
Senegal	0
Seychelles	0
Sierra Leone	0
Singapore	1 (0.7%)
Slovakia	0
Slovenia	0
Solomon Islands	0
Somalia	0
South Africa	2 (1.3%)
South Korea	0
Spain	1 (0.7%)
Sri Lanka (also Ceylon)	0
St Helena Dependencies	0
St Kitts and Nevis	0
St Lucia	0
St Vincent and the Grenadines	0
Stateless	0
Sudan	0
Surinam	0
Swaziland	0
Sweden	0
Switzerland	0

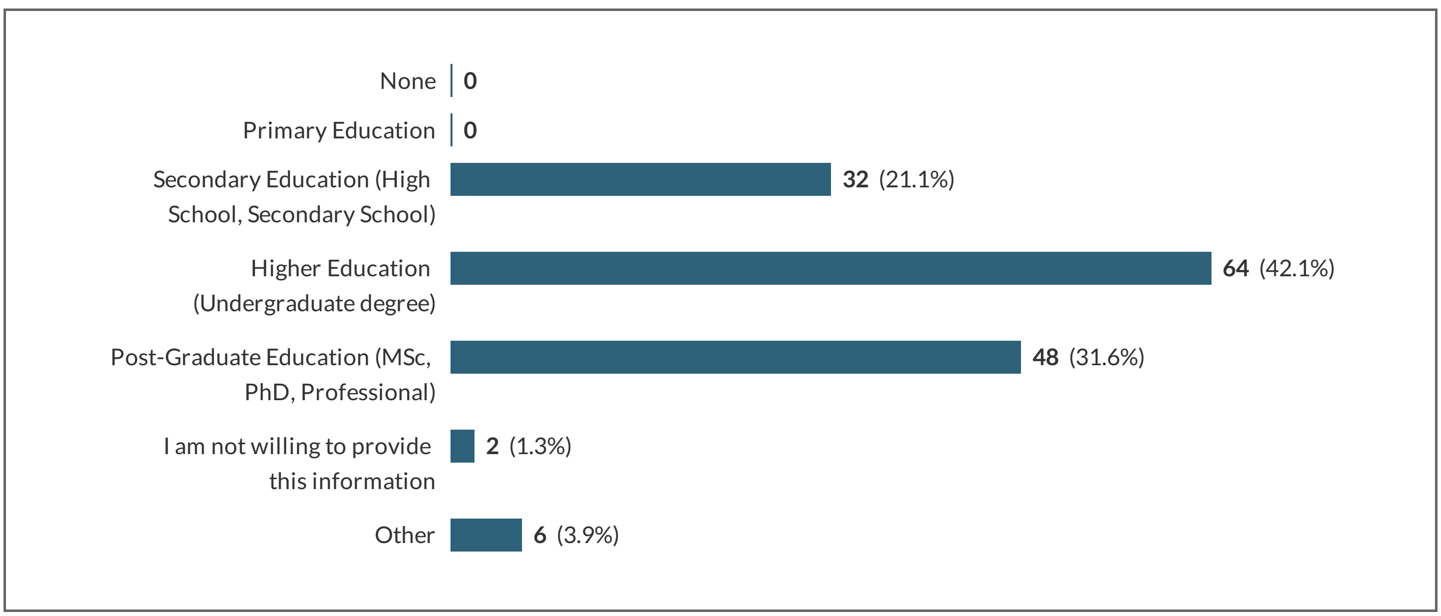
26 What is your ethnic background?



26.a If you selected Other, please specify:

Showing 5 of 6 responses	
Caucasian	110401-110395-6144728
PERSIAN	110401-110395-6144780
White/ native American	110401-110395-6144781
Hispanic	110401-110395-6144790
native	110401-110395-6144816

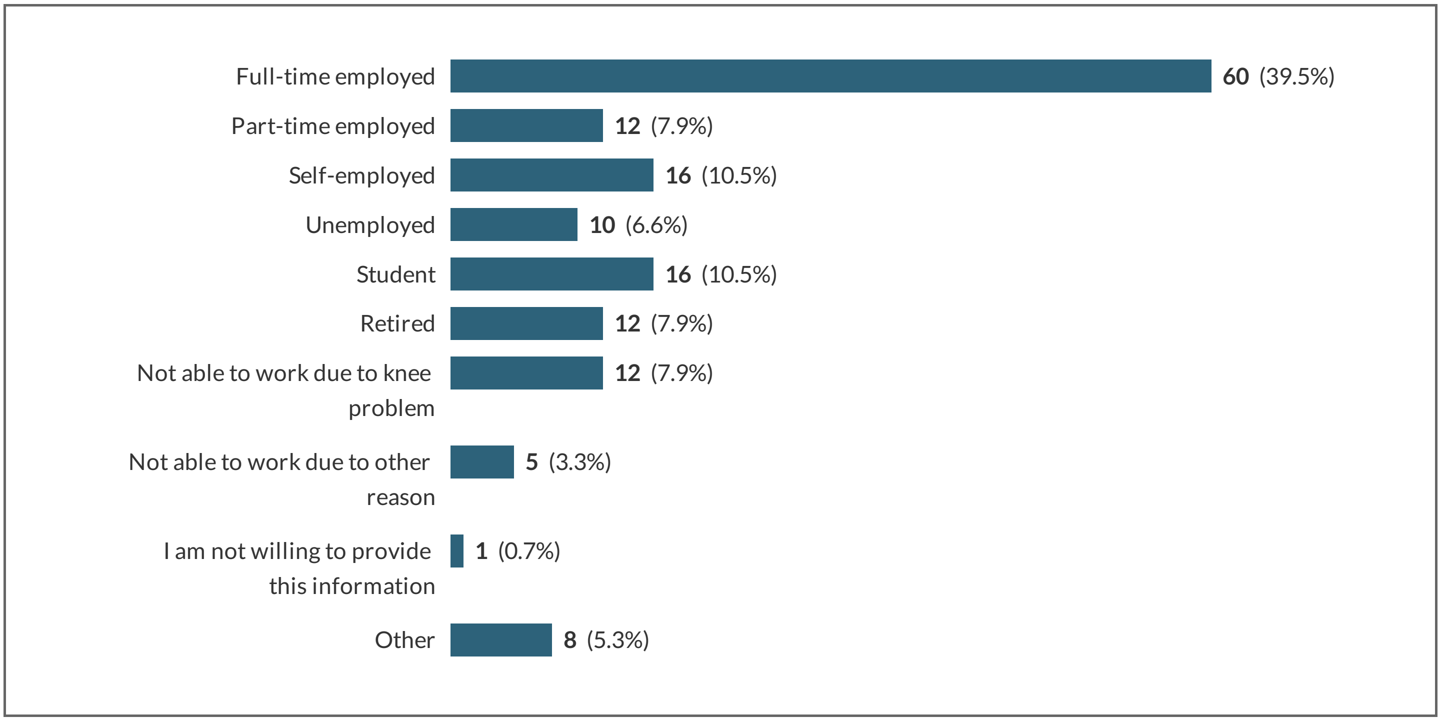
27 What is the highest level of education that you have completed?



27.a If you selected Other, please specify:

Showing 5 of 6 responses	
BSEE (undergraduate degree); plus all math credits to MSEE	110401-110395-6144750
I have 1 year of college credit.	110401-110395-6144763
some college	110401-110395-6144764
college	110401-110395-6144768
one year left of high school	110401-110395-6144794

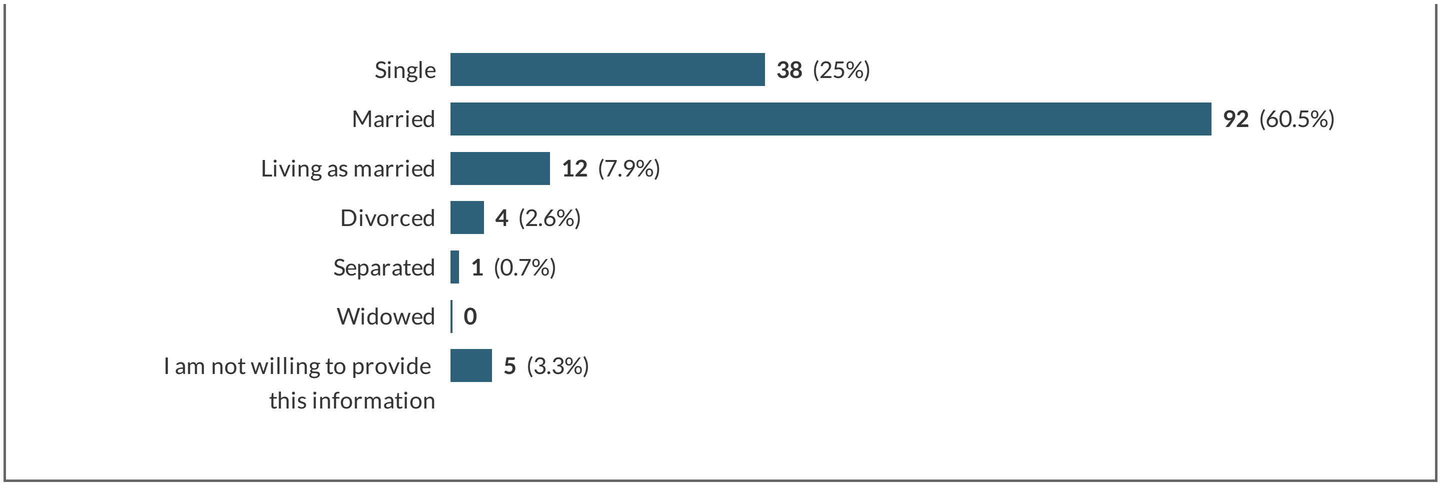
28 What is your employment status at present?



28.a If you selected Other, please specify:

Showing 5 of 8 responses	
homeschooling mom to 4	110401-110395-6144712
housewife and carer for elderly parents	110401-110395-6144724
Disability	110401-110395-6144781
I continue to work in a free lance capacity, although knee issues do hinder my abilities.	110401-110395-6144797
temporaily total disability, hoping to return to work full time	110401-110395-6144811

29 What is your marital status?



Would you be interested in participating in future online studies or an extension of this study?

30 Would you like to participate in further or similar studies?

30.a If you answered yes please provide your email address:

Appendix IV

European School of Osteopathy

INFORMATION SHEET FOR PARTICIPANTS

Research Title:

The effects on muscle recruitment during the short arc quad extension and the seated clam exercises when using bathroom scales.

We would like to invite you to participate in this research project. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others as you wish. Please ask us if there is anything that is not clear or if you would like more information. Please take your time in deciding if you wish to take part.

If you do decide to take part, you will be given this information sheet to keep and asked to sign the attached consent form to say that you agree and understand what this study is about. You are free to withdraw at any time and without giving reason. Thank you for reading this.

What is the purpose of the study?

The aim of this study is to investigate the effect on muscle recruitment when using bathroom scales during the seated clam exercise and short arc quad extension exercise.

Who have we asked to participate?

Thirty asymptomatic individuals will be recruited from students of the ESO and also students from School of Sport & Exercise Sciences, Medway.

When and where will the study take place?

The study will take place at the School of Sport & Exercise Sciences, The Medway Building, Chatham Maritime, Kent. It will take place weekdays, 9am-5pm.

How long will the study last?

The study will be set over certain dates starting in August and ending in November. There will just be one session per participant and it will last around 30 minutes.

What will happen to me if I take part?

Each participant will be asked to perform 4 sets of exercises. Two sets of 3 reps of the seated clam exercise, which targets the gluteus medius muscle - one set using a set of bathroom scales as biofeedback, and one set without. Then, 2 sets of 3 reps of the short arc quad extension exercise, which targets the quadriceps muscles - one set using a set of bathroom scales as biofeedback, and one set without. Surface EMG will be used to determine the muscle recruitment for each of the exercises. This will entail surface electrodes being placed on the participants before each of the two types of exercises. For the short arc quad extension exercise, the surface electrodes will be placed on the anterior and lateral aspect of the mid-thigh, with a grounding electrode on the tibial tuberosity. For the seated clam exercise, the electrodes will be placed at the lateral aspect of the glute medius and the posterior lateral aspect of the glute maximus, with a grounding electrode at the tibial tuberosity. For these electrodes to function effectively, participants could be required to shave the areas specified for contact.

Are there any risks involved in participating?

The risk of a major adverse event with these types of exercises is low, but you may experience minor to moderate discomfort such as soreness and tiredness up to 48 hours after participation.

Emergency care route in case of adverse event:

In the rare instance of any adverse event occurring during the course of this study you are recommended to follow your standard care pathway for follow-up treatment or consultation; this will be your GP practice or local NHS Accident & Emergency department if warranted. The researcher will need to be informed of any such occurrence after the event in order to monitor your progress through the study.

What if there is a problem or complaint?

If there is a problem at any time and you would like to contact someone regarding the study then your contact should be:

	Name	University Address	Contact Information
Principle Investigator	*Jodine Shackle*	European School of Osteopathy, Boxley House, The Street Boxley, Boxley, Maidstone, Kent, ME14 3DZ	jodieshackle@yahoo.co.uk +44(0)1622671558

If you have any complaint or you would like to discuss an element of the study with an independent party, your contact should be:

	Name	University Address	Contact Information
M.Ost Dissertation Coordinator	**Philip Bright**	European School of Osteopathy, Boxley House, The Street Boxley, Boxley, Maidstone, Kent, ME14 3DZ	philbright@eso.ac.uk +44(0)1622671558

“The effects on muscle recruitment during the short arc quad extension and the seated clam exercises when using bathroom scales”

Consent form

- I am willing to contribute information to this study.
- I have read the information sheet.
- I understand that I can withdraw from this study at any time without prejudice or reason.
- I understand that all information will be treated as confidential; it will only be seen by the researchers and will not be revealed to anyone else.
- I understand that participation in this study is implicit consent to use the data I generate in the process for analysis.

Name (please print) ……………………………………………………………………

Signed ……………………………………………………… Date …………………………

Email Address*: ……………………………………………………………………………

Home Address.
………………………………………………………………………………………………
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………………………………………………………………………………………………
……………………………………

Post Code…………………… Phone number………………………………………………

** Your email address will not be passed to any third party.*

Appendix V

European School of Osteopathy

INFORMATION SHEET FOR PARTICIPANTS

Research Title:

The effects of performing quadriceps and gluteal exercises for the knee with and without biofeedback

We would like to invite you to participate in this research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others as necessary. Please ask us if there is anything that is not clear or if you would like more information. Please take your time in deciding if you wish to take part.

If you do decide to participate, you will be given this information sheet to keep and asked to notify consent via an electronic form to say that you agree and understand what this study is about. You are free to withdraw at any time without giving reason or any fear of prejudice.

What is the purpose of the study?

The aim is to investigate the effect of performing exercises on muscle groups that control the knee and hip joint, with a set of bathroom scales providing biofeedback. This will be compared to the same standard exercises without a feedback mechanism to see if there is a difference in strength.

Who have we asked to participate?

Participants for this study will consist of volunteer students from all cohorts attending the European School of Osteopathy. The following screening criteria will be invoked.

Inclusion Criteria:

- Access to bathroom scales on a daily basis
- Ability to attend weekly assessments
- Commitment to performing exercises
- Access to online video instructions and forums
- Ability to receive reminders via text message
-

Exclusion Criteria:

- Current bilateral knee or hip pain
- Recurrent high intensity physical training
- Underlying metabolic disorder or neuromuscular condition

When and where will the study take place?

The study will take place at the European School of Osteopathy, The Street, Boxley, Maidstone during normal hours of opening. The home exercises will be completed at a place of residence during the study.

How long will the study last?

The study will be set over six weeks, starting in August/September/**October** and ending in September/October/**November.** There will be set dates and times for assessments (to be confirmed).

What will happen to me if I take part?

- Successful participants will undergo a quadriceps and gluteal strength assessment using a dynamometer and a set of bathroom scales. Both assessments will require three maximum effort contractions to push against the devices. Volume measurements of the thigh and pelvic areas will also be taken using Ultrasound and a tape measure.

- You will then be assigned to one of two groups; each group will be given exercises to perform on both legs – a short-arc quadriceps extension and a seated gluteal clam. One group will be provided with online instruction videos to provide guidance on the use of biofeedback with the exercises. The second group will undertake standard versions of the exercises, without biofeedback but prompted by text message. Each exercise will be performed twelve times on each leg but the number of sets will increase as the study progresses. The exercises will be performed by the participants every other day for six consecutive weeks.

- The text reminder will be sent to the participants on each day that they should perform their given exercises. The biofeedback group's texts will include a link to the appropriate online forum hosting video instructions for progression. This group's participants will also be asked to post their readings of their maximum effort repetition onto the forum after each exercise session.

- The group assigned to standard exercises will have an assessment at the end of each week, during which strength measurements will be taken in the same method as before the exercises. This group will receive verbal instruction on progression.

Are there any risks involved in participating?

The risk of a major adverse event with exercise is low, but you may experience minor to moderate discomfort such as soreness and tiredness up to 48 hours after exercise. These post-exercise/delayed onset muscle soreness (PEMS/DOMS) effects are short-lived and well-documented as benign.

Emergency care route in case of adverse event:

In the rare instance of any adverse event occurring during the course of this study you are recommended to follow your standard care pathway for follow-up treatment or consultation; this will be your GP practice or local NHS Accident & Emergency department if warranted. The researchers will need to be informed of any such occurrence after the event in order to monitor your progress through the study.

What if there is a problem or complaint?

If there is a problem at any time and you would like to contact someone regarding the study then your contact should be:

	Name	University Address	Contact Information
Principle Investigators	Lee Thompson, Hannah Epps	European School of Osteopathy, Boxley House, The Street Boxley, Boxley, Maidstone, Kent, ME14 3DZ	tommoleethompson@ yahoo.co,uk; han.epps@btinternet.com

If you have any complaint or you would like to discuss an element of the study with a senior researcher, your contact should be:

	Name	University Address	Contact Information
Research Dissertation Coordinator	**Philip Bright**	European School of Osteopathy, Boxley House, The Street Boxley, Boxley, Maidstone, Kent, ME14 3DZ	philbright@eso.ac.uk +44(0)1622671558

Thank you for considering taking part in this study; your time is much appreciated and is contributing to much needed research in the management of osteoarthritis in the knee and hip.

European School of Osteopathy

"The effects of performing quadriceps and gluteal exercises for the knee with and without biofeedback"

Consent form

- I am willing to contribute information to this study.
- I have read the information sheet.
- I understand that I can withdraw from this study at any time without prejudice or reason.
- I understand that all information will be treated as confidential; it will only be seen by the researchers and will not be revealed to anyone else.
- I understand that participation in this study is implicit consent to use the data I generate in the process for analysis.

Name (please print) ……………………………………………………………………

Signed ……………………………………………………… Date …………………………

Email Address*: ………………………………………………………………………

Home Address.
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Post Code…………………… Phone number………………………………………………

** Your email address will not be passed to any third party.*