Joint Position Sense in Individuals with Anterior Knee Pain

ABSTRACT

Introduction

Anterior knee pain (AKP) commonly affects physically active as well as sedentary individuals and the aetiology remains unknown. Altered joint position sense (JPS) impacts accurate motor action and knee joint stability. It is unclear whether people with AKP have altered JPS. The aim of this study was to investigate the JPS of individuals with AKP.

Methods

A descriptive cross-sectional design was used to measure JPS in twenty-five participants with unilateral or bilateral AKP. The Vicon 3D motion analysis system was used to assess JPS by means of active joint position sense testing during single leg squat and active knee extension in sitting. Target angles were self-determined based on each participant's capabilities. The absolute error (AE) was used as the main outcome measure. Impaired JPS was classified as an AE equal to or greater than five degrees.

Results

There were no significant differences in JPS when comparing the knees with AKP to the knees without AKP ($p < 0.05$). However, a sub-group of participants with altered JPS was identified. There was a tendency towards a larger AE in the knees with AKP during active knee extension in sitting.

Conclusion

The results showed that JPS is not significantly more impaired in knees with AKP compared to knees without AKP. A sub-group was identified with altered JPS in knees with and without AKP. This finding could be due to compensatory gait patterns and the precision of the Vicon 3D motion analysis system. JPS should be assessed bilaterally in individuals with AKP.

(Abstract: 248 words)

INTRODUCTION

Anterior knee pain (AKP) is a common disorder of the knee joint and affects young, physically active and sedentary individuals (Crossley et al 2016). AKP accounts for 25% to 40% of all knee problems presenting at sports medicine clinics; one in four of the active population is affected, leading to chronic knee pain among young adults(Crossley et al 2016; Coppack et al 2011; Dutton et al 2016). AKP is prevalent among runners, particularly long-distance runners. AKP has a higher prevalence among active women, with an incidence two to three times more than that of men (Dutton et al 2016; Prins & van der Wurff 2009).

AKP is characterised by anterior, peri-patellar or retro-patellar pain with an insidious onset and is exacerbated under conditions of increased patellofemoral joint stress (Dutton et al 2016; Nunes et al 2013). Aggravating activities include ascending or descending stairs, prolonged sitting, squatting, and running (Nunes et al 2013).The aetiology of AKP is unclear with a possible multi-factorial nature and develops secondary to functional or structural mal-alignment of the patellofemoral joint (Green et al 2014). Management of AKP remains challenging with 91% of patients with AKP reporting persistent symptoms after extended follow-up and medical management (Dutton et al 2016).There is a therefore a need to understand the etiological pathways that may be causing the pain.

Altered proprioception has been documented in patients with AKP (Akseki et al 2008; Baker et al 2002; Cyrillo et al 2014; Guney et al 2016). Proprioception is “the use of joint position sense and joint motion sense to respond to stresses placed upon the body by alteration of posture and movement" (Norris 2011). Clinical symptoms of altered proprioception may include disturbed balance and clumsiness due to disturbed motor function and joint reflex stabilisation. Long-term effects of altered proprioception among individuals with AKP may lead to recurrent and persistent pain with a secondary onset of joint osteoarthritis (Clark et al 2015; Röijezon et al 2015).

Altered proprioception in individuals with AKP can be as a result of mechano-receptor damage and may be associated with abnormal movement patterns and motor reactions (Clark et al 2015; Han et al 2016; Hillier et al 2015). These altered movement patterns and motor reactions include weak quadriceps muscles, altered timing of the VMO and altered tissue flexibility of the quadriceps and hamstring muscles (Kaya et al 2010; Lankhorst et al 2012). Altered motor reaction in AKP may be due to altered proprioceptive input from muscle spindles in skeletal muscles (Röijezon et al 2015). Muscle spindles in skeletal muscles are a type of mechano-receptor and a major source of proprioceptive feedback (Röijezon et al 2015). Another possible reason for altered proprioception in a population with AKP could be due to small nerve damage in the lateral retinaculum of the patella (Sanchis-Alfonso & Rosello-Sastre 2003).This nerve damage in the lateral retinaculum can be due to the maltracking of the PFJ (Sanchis-Alfonso & Rosello-Sastre, 2003). It is unclear whether altered proprioception could be a risk factor leading to AKP or could contribute to the chronicity of the condition.

The ability to accurately sense joint position (JPS) is essential for an individual to respond to stresses placed upon the body(Smith et al 2013). JPS testing can be tested under active (biasing joint mechanoreceptors) or passive (stimulating joint and muscle tendon mechanoreceptors) conditions (Roijenzon et al 2015). JPSis the ability of an individual to accurately reproduce a target angle (Selfe et al 2006; Baker et al 2002). The most common clinical metric use to assess JPS is absolute error (AE). AE refers to the difference between the target angles and the response angle (Orgard 2011; Han et al 2015; Hillier et al 2015; Röijezon et al 2015).

There is limited research investigating JPS in individuals with AKP (Yosmaoglu et al 2013).Previous studies in this field reported no significant differences in JPS between individuals with and without AKP (Bennel et al 2005; Naseri et al 2012; Yosmaoglu et al 2016).Contrary to these findings it has been reported that JPS was significantly affected in an AKP population compared to controls(Akseki et al 2008; Baker et al 2002; Cyrillo et al 2014; Guney et al 2016).

Although all of these studies measured JPS, different methods for measuring JPS were used including (1) image recorded where photography is used to assess knee joint angles (Naseri et al 2012; Baker et al 2002); (2) electro-goniometry with knee angular error (Akseki et al 2008; Cyrillo et aI 2014); (3) dynamometry (Guney et al 2016) and (4) a functional loaded squat system (Yosmaoglu et al2013). Three studies measured NWB JPS only (Akseki et al2008; Yosmaoglu et al2013, Guney et al 2016), whereas the other studies combine WB and NWB. WB positions have been shown to be more accurate, however, NWB knee JPS had the greatest potential for isolating the proprioceptive status of the knee joint only (Stillman & McMeeken 2001). There were also differences in the study samples. The studies that found no significant differences used very specific populations included pain-free subjects with induced AKP (Bennel et al 2005), athletes (Naseri 2012) and women (Yosmaoglu et al 2013).

The variation in methodology could also be due to the lack of a gold standard test to assess JPS. Furthermore, the tests used in previous studies have poor clinical applicability and are poorly evaluated and reported on by the respective authors (Guney et al 2016). Current studies use 1D and 2D systems only. It is possible that these methods are not sensitive enough to detect small changes in AE. The VICON 3D movement analysis system is considered the gold standard objective measure for 3D postural analysis (Brink et al 2013).

An additional problem with the current evidence is the lack of clear classification system of what constitutes ‘good’ or ‘poor’ JPS. The current evidence on subjects with AKP only compares differences between AKP and control groups with no clear interpretation of what the values mean. Relph and Callaghan (2016) assessed 116 healthy, pain free participants between 18-82 years old. They assessed the normative JPS AE values into flexion and extension. The mean AE values ranged between 3.1-3.9 degrees for flexion and 2.5- 3.9 for extension. The minimal detectable difference for JPS has been reported to range from 1.23-2.14 degrees in AE scores (Relph & Harrington, 2015). Clark et al (2016) reported that the AE scores ranged between 3.18 and 5.97 degrees in healthy pain-free adults. It is unknown how much of a difference in AE is needed to increase the risk of injury. However, based on these precious studies we used an AE greater than five degrees as an indication of poor JPS for the purpose of this study.

More research is needed to establish if individuals with AKP present with altered knee JPS as this could potentially lead to altered movement patterns and ongoing pain. Clinicians need to know whether to address JPS in rehabilitation when treating patients with AKP. The aim of this study, therefore, is to determine if JPS is altered in individuals with AKP. This is the first study that uses the Vicon 3D motion analysis device the accurately measure JPS during weightbearing in an AKP population.

METHODS

Research Design

CAF Human motion analysis Unit, Faculty of Medicine and Health Sciences, Stellenbosch University. Ethical approval was obtained from the Health Research Ethics Committee of Stellenbosch University under reference number S16/10/197. This study was conducted as part of a master's thesis project (Rhode 2018).

Participants

The target population consisted of 25 males and females between the ages of 14 and 40 years. This was calculated using a pragmatic approach and based on previous studies (Akseki et al 2008; Baker et al 2002; Cyrillo et al 2014; Guney et al 2016). Informed consent was obtained and completed by all participants prior to the study procedure. Where participants were under the age of 18 years an assent form was obtained as well as informed consent from the parents/guardians.

Inclusion and Exclusion Criteria

Inclusion criteria

Participants who adhered to the criteria listed below were considered for inclusion. Individuals aged between 14 and 40 years, with an insidious onset of clinical signs and symptoms of AKP. Participants were included if symptoms were provoked by prolonged sitting, squatting, stair-climbing and/or running. Participants who complied with the AKP screening tool and the diagnostic checklist (Leibbrandt & Louw 2017) were considered for inclusion. Screening was done by the primary researcher (CR) who had been trained to use the screening tool by another researcher with experience in treating AKP (DL). Participants with unilateral and bilateral AKP were considered for inclusion. In cases where both knees were affected with AKP, both knees were tested for altered JPS and compared to the knees without AKP.

Exclusion criteria

Participants were excluded if AKP had resulted from a traumatic event such as a motor vehicle accident, if they had previous knee surgery or injuries, if there was clinical evidence of other knee pathologies, if they were experiencing any other lower extremity injuries. Participants needed to comply with the initial AKP screening tool and diagnostic checklist (Leibbrandt & Louw 2017) developed specifically for this study in order to be included.

Sampling and Recruitment

Sample recruitment was aimed to attract individuals with AKP from different socio-economic backgrounds, sporting codes and areas. Letters of invitation were sent to various universities, sports clinics, physiotherapy practices and sporting clubs.

Study Procedure

Measurement Tools

Vicon 3D motion analysis system

The eight-camera Vicon T-20-series motion analysis system (Vicon Motion Systems Ltd., Oxford, UK) with Nexus 1.7 software was used to assess joint position sense (JPS). The Vicon has demonstrated high accuracy and reliability and has been shown to have less than a 1.5-degree error (Ehara et al 1997; Richards 1999). Retro-reflective markers with a diameter of 9.5mm were used. Dynamic calibration was performed according to standard laboratory protocol, and the Vicon T-wand was placed on a 3D Bertec force plate (Bertec Corporation Ltd.), which is synchronized with the Vicon motion analysis system.

H-Frame

An H-frame was constructed based on a study by Clark et al (2016). The function of the H-frame was that of a range of motion (ROM) guide when establishing the target angle (TA) for participants during the test trial. The H-frame was positioned so that the rubber band (cross bar) makes contact with the distal part of the patella during single leg squat (SLS) and that the crossbar touches the skin overlying the anterior ankle joint line during active knee extension (AKE). The H-frame was removed during the test procedure.

Kujala/anterior knee pain scale (AKPS) questionnaire

The AKPS is a 13-item knee functional questionnaire. This scale is scored out of 100, with a higher score indicating less disability. The AKPS demonstrated high reliability and responsiveness in a population of patients with AKP (Watson et al 2005; Crossley et al 2004).

Visual analogue pain scale (VAS)

This VAS scale is a well-known outcome measure to evaluate levels/intensity of pain (Crossley et al 2016). The VAS is scored from 0 (no pain) to 10 (maximum pain). The VAS demonstrates good reliability and responsiveness among a population of patients with AKP (Bennel et al 2000; Crossley et al 2004; Green et al 2014).

Lower extremity functional scale (LEFS) questionnaire

The LEFS consists of 20 items that measure the ability to perform various functional activities and activities of daily life. The LEFS is scored out of a maximum score of 80. The LEFS demonstrates high reliability and responsiveness in the population of patients with AKP (Crossley et al 2004; Watson et al 2005).

Criteria for positive and negative knee joint position sense

The main outcome measurements for knee JPS testing was absolute error (AE). AE refers to the difference between the test or target angle and the reproduced angle. Absolute error represents accuracy without directional bias. For the purpose of this study, abnormal JPS was defined as an AE equal or greater than five degrees. This criterion was based on published research by

Relph and Callaghan (2015; 2016) and Clark et al (2016) using healthy pain free participants. The mean AE from five trails for each test was used for statistical analysis (Selfe et al 2006).

Testing Procedures

Initial screening

To verify that participants met the inclusion criteria they completed a screening questionnaire via email. Prior to JPS testing, participants completed the AKP scale questionnaire (AKPS) and the LEFS questionnaire. A data collection form was used to collect participant personal details and variables including age, gender, body length, episodes and duration of AKP, area of symptoms, type of treatment received for AKP and sport participation. A flowchart of the study procedure can be seen in Figure 1.

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Physical examination and diagnosis

The diagnostic checklist was completed, and the physical examination was performed to confirm a diagnosis of AKP and to exclude other knee pathologies prior to testing. The physical examination (P/E) was conducted by the primary researcher (CR), who is an experienced physiotherapist. Additionally, anthropometrics (weight, BMI, leg length) were measured for each participant. Data were captured as part of participant demographics to describe this population group/participants.

Preparation for Vicon testing

Participants were dressed in short pants, were barefoot, with clean shaven legs with no lotion on legs to ensure effective marker placement. Thirty retro-reflective markers were placed on bony landmarks according to lower limb Plug-in Gait model (Clark et al 2016). Additional pelvic markers, a sacral wand, two extra shin markers and extra anterior and posterior thigh markers where added, to ensure joint position sense accuracy. The primary researcher (CR) performed the marker placement assisted by a research assistant. Reflective markers were placed in the standing position in preparation for SLS and re-applied with the participant in the seated position to ensure accurate positioning of markers placements for active knee extension. A static and dynamic calibration were performed in both test positions.

Pain measurement

During the test trials the participants were asked to verbally indicate the severity of their anterior knee pain using the VAS pain scale. Pain severity was measured at the start and end of proprioceptive testing.

<u>Proprioceptive Testing</u>

All participants were familiarized with the proprioceptive test procedure by means of explanation, demonstration and a practice opportunity. The participants were asked to resume the test position i.e. (i) standing or (ii) sitting. The target angle was determined by each participant according to his/her capabilities and comfort level, i.e. the target angle was unique to each participant.

Single leg squat (SLS)

Starting position

For the SLS the participant supported one hands on a chair for balance. The participant was standing on the tested leg, while the other leg was slightly flexed at the hip and knee in a position that was comfortable for the participant (Figure 2).

Instructions to participant

The participant was asked to do a SLS and stop in the mid-range. The participant was asked to briefly hold this mid-range angle to position the H-frame indicating this angle as the target angle (TA).

Test trial

The participant was cued to squat down till they felt the cross bar of the H-frame. The participant was instructed to hold the SLS for five seconds to establish and familiarize themselves with the target angle (TA). The test trial was repeated five times.

Test procedure

The participant was blindfolded, and the H-frame was removed. The participant was instructed to perform a SLS, and to indicate when they had reached the TA by shouting STOP. This position indicated the relative error (RE) and was maintained for five seconds to record the data. Testing was repeated five times. This number of repetitions has been recommended for JPS testing in previous research (Selfe et al 2006). SLS was repeated on the knees without AKP for comparison.

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Sitting: active knee extension (AKE)

Starting position

The participant was seated on an 800mm high bar stool, with both feet supported. Each participant was positioned with the popliteal fossa approximately 5cm from the edge of the chair. The participant's arms were crossed over their chests comfortably to avoid obstruction of the pelvic markers (See figure 3).

Instructions to participants

The participant actively extended the knee through the range of 90° knee flexion to 0° knee extension; thereafter they had to stop in the mid-range position. The participant was asked to briefly hold this mid-range angle to position the H-frame indicating this position as the TA. The participant was verbally cued to resume the starting position.

Test trial

The participant actively extended the knee from the starting position of 90°knee flexion to the TA. The participants were verbally cued to hold this position for five seconds to establish the TA. Thereafter the participant was asked to return to the starting position of the knee in 90°flexion. The test trail was repeated five times.

Testing

The H-frame was removed at the commencement of AKE testing. The participant was asked to repeat AKE, indicating when the TA had been reached, by shouting STOP. This position indicated the relative error (RE) and the participants maintained this position for five seconds. Testing was repeated five times. The AKE was repeated on the knees without AKP for comparison.

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Statistical Analyses

All descriptive data (demographic information, functional and pain scales) were analyzed using descriptive statistics to indicate central tendencies in data (means and standard deviations). A non-pragmatic test approach was adopted by illustrating the ranges. Data was captured through the Vicon Nexus 3D motion analyses system. Chi-square calculations was performed to determine a significant difference in JPS between the knees with AKP and the knees without AKP during single leg stance and active knee extension.

RESULTS

Participant demographics

A total of 25 participants complied with the inclusion criteria (Table 1); with the majority being female (n=22). The participants had a mean age of 27.8 years and a mean BMI of 28.2 kg/m^2 (range of 20.9- 45.7kg/m). Twelve (52%) of the participants reported having AKP symptoms in both knees and ten (40%) participants reported their right knee as most affected. Nineteen (76%) of the 25 participants reported being physically active and six (24%) were sedentary. The participants' mean usual pain level according to the VAS was 4.5/10.

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Symptom presentation

Participants' duration of symptoms ranged from two months to 11 years with a mean duration of 28.4 months (Table 2). Participant's area of symptoms was predominantly in the front of the patella (n=10;40%) or in front and just below the patella (n=10;40%) and five participants (20%) reported their area of symptoms to be behind the patella. The most frequently reported aggravating activities were squatting (n=19;76%), prolonged sitting (n=10;40%) and going up stairs (n=11;44%).

Participant activity level

The participants who stayed active through physical exercise reported a mean training frequency of 2.8 times per week and training ranged from zero to six times per week. The participants' sporting activities were predominantly gym (n=12;48%) and running (n=11; 40%), with two (8%) participants reporting being dancers. Fourteen (56%) of the participants reported not seeking any medical treatment for their AKP symptoms, whereas nine (36%) reported using NSAIDs as needed. Fifteen (60%) of the participants were able to do all activities of daily living (ADL); where as 36% of participants stopped all physical activity due to the severity and intensity of the AKP.

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Outcome measures

The participants AKPS ranged from 52 to 92 with an average of 72 out of 100 points. A score of 70-100 represents moderate disability (Singer B & Singer K 2009). The LEFS ranged from 31 to 77 with an average of 58 out of 80 points indicating moderate functional impairment. Participants reported that pain levels during proprioceptive testing procedure ranged from zero to 9/10 on the VAS scale with a mean pain level of 4.5 out of 10.

Physical examination

The aggravating functional activities that reproduced the participants known AKP symptoms were predominantly squats (n=25; 100%), going both up and down stairs (n=5; 20%) and going down stairs respectively (n=4; 16%).During the physical examination of the PFJ, the passive accessory movements easily reproduced the patients' symptoms. A positive patellar compression test was reported by 22 (88%) of participants. Other PFJ accessory movements were also positive in 11 (44%) of the participants and palpation of the patella border reproduced six (24%) of the participants' pain.

JPS results

JPS testing was performed for both knees of every participant (n=25); therefore 50 knees were assessed. Thirty-seven of the fifty knees were classified as affected with AKP (knees with AKP) and thirteen were classified as unaffected with no reported symptoms of AKP (knees without AKP). The proprioceptive results for the knees with AKP and the knees without AKP are presented in Table 3.

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SLS, comparing knees with AKP and knees without AKP

The mean target angle (TA) of the knees with AKP (n=37) was 39.5 degrees compared to 44.4 degrees in the knees without AKP (n=13). The knees with AKP had a bigger variation in the TA range compared to the knees without AKP. When comparing the absolute errors (AE) the knees with AKP had a smaller AE compared to the knees without AKP, with a greater variation in the range of the AE of the two groups. The relative error (RE) was smaller in the knees with AKP (1.4 degrees) with a greater range (-12.1 to 4.5) compared to the knees without AKP (-10.8 to 3.8). There was no difference between the AE or the RE of the knees with AKP compared to the knees without AKP during JPS testing in single leg squat.

Sitting: AKE, comparing knees with AKP to knees without AKP

The mean TA of the knees with AKP (n=36) was 31.7 degrees compared to 33.5 degrees in the knees without AKP. The AE was the same (AE=4.2 degrees) for both the knees with AKP and the knees without AKP. However, there was a difference when comparing the standard deviation and the range of the AE between the two groups. The group with AKP displayed greater variability compared to the group without AKP. The RE for knees with AKP was -1.8 degrees compared to 1.2 degrees in the knees without AKP. When comparing the RE, the knees with AKP demonstrated a greater variation in range (-16–8.7) compared to the knees without AKP (-7.2 – 6.1).

Altered JPS in both the knees with AKP and the knees without AKP (n=50)

A total of thirty-seven knees (37/50) presented with AKP (Table 4). During SLS 10/37 (27%) of the knees with AKP presented with altered JPS with an AE equal or greater than five degrees. The mean AE of the ten knees with AKP and altered JPS was 7.4 degrees with a range of five to twelve degrees. Twenty-seven (73%) of the knees with AKP had an AE of less than five degrees, with a mean AE of 2.6 degrees (range: 0.6° to 4.5°).

During AKE 10/36 (28%) of the knees with AKP presented with altered JPS with an AE equal or greater than five degrees. The mean AE of the ten knees with AKP and altered JPS was 8.3 degrees and ranged between five and 16 degrees, compared to a mean AE of 2.6 degrees and a range of 0.9° to 4.6 degrees for the 26 knees with AKP and good JPS.

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Thirteen of the fifty knees (26%) had no symptoms of AKP (knees without AKP). During SLS six of the thirteen (46%) knees without AKP had altered JPS with an AE equal or greater than five degrees. The mean AE during SLS for the knees without AKP was 8.3 degrees, with a range of 5.4 to 10.8 degrees. The mean AE of the knees without AKP during AKE, was 2.6 degrees with a range of 1.8 to 3.9 degrees. During AKE, four of the thirteen (30%) knees without AKP presented with altered JPS with an AE equal or greater than five degrees. The mean AE was 5.9 degrees with a range of 5.2 to 7.2 degrees. The remaining nine participants in this group had a mean AE of 3.5 degrees and a range of 1.6 to 4.9 degrees indicating unaffected JPS.

The Chi-square statistic was 1.61 between the knees with AKP and the knees without AKP during SLS, with a p-value was 0.20 indicating no significant difference ($p > 0.05$), whereas the Chi-square statistic was 0.04 between the knees with AKP and the knees without AKP during AKE with a p-value was 0.08, indicating no significant difference ($p > 0.05$).

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DISCUSSION

The main finding of this study is that there were no significant differences in knee JPS when comparing the knees with AKP to those without AKP. For both these groups the mean AE showed no comparative difference in either the SLS and AKE positions. However, a subgroup of subjects with impaired JPS bilaterally was identified. Approximately a third of the study participants were in this sub-group. Research into AKP and JPS has yielded inconsistent findings. Some studies have concurred with our findings of none significant JPS differences between knees with and without AKP (Bennel et al 2005; Naseri et al 2012; Yosmaoglu et al 2013). These studies also used JPS to evaluate knee proprioception and calculated the AE to express JPS. Contrary, a number of published papers have stated that JPS is affected more in people with AKP compared to individuals without AKP (Akseki et al 2008; Baker et al 2002; Cyrillo et al 2014; Guney et al 2016). These contradictory findings could be as a result of differences in study methodology and participant characteristics.

Later, an interesting observation was that a number of knees without AKP also had altered JPS according to the classification criteria (Callaghan et al., 2002). Similar results have been reported when comparing JPS in individuals with AKP compared to healthy controls (Baker et al 2002; Cyrillo et al 2014). These authors found JPS to be altered in the knees with AKP as well as the knees without AKP. The interpretation of altered JPS in the knees without AKP is unclear but could be due to compensatory mechanisms during gait in people with AKP (Barton et al 2009). Patients with AKP may develop a quadriceps avoidance gait pattern to decrease PFJ reaction forces and to avoid pain (Sanchis-Alfonso et al 2016).

It must be considered that classification of abnormal JPS has not been used in a population affected with AKP. The group of knees without AKP were much less than the knees with AKP making if very difficult to compare the proprioceptive findings. Inter-subject comparisons for each participant's proprioceptive outcomes were not compared and should be considered in future studies. A small percentage of the knees with AKP and the knees without AKP had an AE greater than five degrees. These findings cannot be generalised to the rest of the population due to the small sample group.

In this study participants with unilateral and bilateral AKP were included, which differs from previous studies that used control groups without AKP for comparison. AKP symptoms in this study population were not restricted to just one knee, as more than half the individuals reported both knees being symptomatic. The literature also makes note of this as previous studies in this field have indicated that AKP can be present in both knees (Kurt et al 2016). If the pathological and normal knees are affected this could indicate that JPS should be considered in the aetiology in this subgroup (Akseki et al 2008).

Previous studies with similar findings included an athletic population (Naseri et al 2012),females diagnosed with PFP (Yosmaoglu et al 2013) and healthy participants with induced AKP (Bennel et al 2005). In athletes (Naseri et al 2012), it seems that AKP does not affect the knee JPS, compared to pain-free controls. The lack of deficiency in patients could possibly be attributed to their severity of knee pathology, pain intensity and their physical activity level. In the present study, the patients were athletes with moderate pain in their knee joints. Whether their functional state enhanced their proprioceptive (JPS) ability and whether their severity of knee pathology and pain intensity was such that their proprioceptive abilities were not significantly affected are unclear. Athletes with a higher functional level and moderate pain may not present with proprioceptive deficits. In females (Yosmaoglu et al 2013), active reproduction of joint position did not differ between AKP and control groups. The authors also suggested that subject groups may have differed in terms of pain or strength levels.

In the current study participants were included irrespective of their sport participation or activity levels, whereas previous studies included athletes or restricted the population to only females diagnosed with AKP. The literature highlights that AKP is common among active individuals (more so runners) and has a higher incidence in females (Neal et al 2016; Prins & van der Wurff 2009).The current study population is reflective of these findings, with females constituting the majority of the study population, two-thirds were active individuals and 44% where runners. This study however highlights that AKP does not only affect the athletic population but can affect sedentary individuals as well (Crossley et al 2016).Seventy-six percent of the participants were physically active and activity levels ranged up to six times per week with an average activity level of 2.8 times per week. The athletic abilities and higher levels of motor function could account for proprioceptive feedback from adjacent joints and muscles (Naseri et al 2012; Smith et al 2013).The severity of the AKP pathology, participants' pain levels and activity levels are thought to have influenced proprioceptive function in these studies. The pain levels of the population group in the current study ranged between zero to nine out of ten with a mean pain level of (4.5/10). It can be debated that pain severity levels needed to be higher than moderate to influence proprioceptive abilities (Naseri et al 2012).

One study (Bennel et al 2005) investigated the effect of induced AKP on a healthy population to determine if the pain itself influenced JPS. The findings were that Knee JPS is reduced by an attention-demanding task but not by experimentally induced pain. Therefore, JPS dysfunction may occur before pain or be a risk factor in a subgroup rather than as a result of pain. If this is the case, then resolution of pain is unlikely to lead to improvements in JPS, and it would need to be addressed in treatment.

The current study defined abnormal knee JPS as an AE equal or greater than 5 degrees. This criterion was based on a study by Callaghan (2002), who tested the criterion on healthy participants. The definition of the normative criterion for abnormal JPS in this study was necessitated due to the lack of a defined normative criterion in participants with AKP(Callaghan 2011).

In the current study JPS was tested in both a weight bearing (SLS) and non-weightbearing position (AKE). Previous studies predominantly tested JPS in only a non-weight bearing position (Akseki et al 2008; Bennel et al 2005; Cyrillo et al 2014). The Biodex 360 was used to measure knee JPS in more recent studies. The Biodex 360 is considered a reliable measurement tool to evaluate knee JPS, however it can only account for a non-weight bearing test position. Weightbearing test positions are more likely to be relevant in an AKP population as this is when patients typically experience pain. However, JPS in weight bearing positions need to be measured accurately and reliably. In the current study Vicon 3D motion analyses allowed for testing knee JPS in both standing and sitting. The Vicon 3D motion analyses system is regarded as the gold standard in motion analyses (Ehara et al 1997; Richards 1999).The current study is the first study to make use of the Vicon 3D motion analyses to assess knee JPS in an AKP population, which allows for a weightbearing assessment of JPS. Stillman and McMeeken (2001), compared JPS testing during a weightbearing and non-weight bearing test position. They found WB testing to be more reliable and accurate for JPS compared to NWB test procedures. However, NWB testing had a greater potential to isolate the proprioceptive status of the knee joint only. Therefore, it is recommended to use a combination of both methods.

Limitations

There is still limited research on investigating JPS changes in individuals with AKP, and conflicting results remain a cause of concern. The use of larger sample groups and being able to match cases to healthy controls with unaffected knees should be addressed in future studies. In this study only JPS testing was done, which is only one aspect of proprioceptive testing.

The best test procedure still needs to be described to assess JPS as it remains challenging to conclude findings due to variation in testing methods and measurement tools. There may be a sub-group of patients who have both AKP and poor JPS (Callaghan et al 2011); which is cause and which is effect, remains uncertain, until prospective studies are undertaken.

In the current study we did not exclude participants with a high BMI. Excess soft tissue influences the reliability of the motion analysis as it can cause movement of the markers and wands during motion capture procedures. Another possible factor is that the extra weight itself could have been a contributing factor in the development and chronicity of the knee symptoms due to the increased loading of the knee joint. Future studies should consider excluding obese participants with a BMI of more than 30 to control for this.

The age range of the included participants was between 14 and 40. However, the current study did not compare the JPS of the younger adolescent participants to adult participants. Future studies should investigate the differences between these age groups with regards to JPS.

It has also been suggested that an increased Q-angle heightens the risk of developing AKP (Emami et al 2007). Nakagawa et al (2015) proposed that an increased dynamic Q angle during sls may indicate an inability of the individual to stabilize the lower limb in the frontal plane. An increase dynamic Q angle could result in increased forces on the lateral patella facets and abnormal stresses on trochlear groove during loading and subsequently knee pain. Frontal plane mechanics were not measured in this study and therefore It is therefore unclear how abnormal biomechanics correlate with JPS findings. This should eb addressed in future research.

CONCLUSION

This study investigated JPS in individuals with AKP. The findings showed that in an AKP population, JPS is not significantly more impaired in knees with AKP compared to knees without AKP during active reproduction proprioceptive testing. The use of the Vicon 3D motion analysis system added to the measurement precision. The findings in this study suggest that a subgroup of individuals with altered JPS may exist in an AKP population, however it is unclear whether altered JPS is a cause or effect of pain. Longitudinal research needed to establish how altered JPS relates to the pain experienced.

CLINICAL RELEVANCE

- A subgroup of individuals with altered JPS exists in a population with AKP
- When assessing individuals with AKP knee JPS should be assessed bilaterally and in both weightbearing and non-weightbearing positions
- Proprioceptive rehabilitation should be considered in the individualised management of population groups with AKP when deficits occur

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