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Title: The Effects of Knee Direction, Physical Activity and Age on Knee Joint Position Sense.

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Keywords: Proprioception; Knee Flexion; Knee Extension; Age; Physical Activity.

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Tuesday 5th January 2016

Dear Professor Al-Dadah & Professor Hing

Please find attached our original research paper entitled “The Effects of Knee Direction, Physical Activity and Age on Knee Joint Position Sense”. I can confirm no part of this work has been duplicated in any other publication. There are no commercial relationships which may lead to conflicts of interest. I can also confirm the typescript has been read and agreed by the other author; Lee Herrington, School of Health Sciences, University of Salford, Salford, M6 6PU, L.C.Herrington@Salford.ac.uk. I can confirm that all authors were fully involved in the study and preparation of the manuscript and that the material within has not been and will not be submitted for publication elsewhere.

Yours Faithfully,

Dr Nicola Relph

***Conflict of Interest Statement**

Declaration of Interest

The authors report no declarations of interest.

Dr Nicola Relph

***Abstract**

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Key Words: Proprioception; Knee Flexion; Knee Extension; Age; Physical Activity.

Highlights

- Normative absolute error scores ranged from 2.5° - 3.9°.
- Knee extension and flexion error scores are significantly different when age group data were pooled.
- Active participants had better knee proprioception than inactive participants.
- There may be an age related decline in knee proprioception.

The Effects of Knee Direction, Physical Activity and Age on Knee Joint Position Sense.

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1. Introduction

The subject of proprioception is steeped in history. For at least 400 years researchers have investigated how people are able to perceive and accurately control limb movements without visual input [38]. Sherrington [50] first published the word proprioception describing it as "*a deep field of receptors in which stimuli are traceable to actions of the organism*" [50, p.472]. Important spatial and temporal afferent information is provided by specialised 'proprioceptors' or mechanoreceptors located in and around joints [19]. These receptors include muscle spindles, Golgi tendon organs, ruffini nerve endings, pacinian corpuscles, Meissen's corpuscles and Merkel's discs [41]. Receptor afferent information is transmitted by transforming the mechanical energy caused by physical deformation of the joint and muscles to electrical energy of nerve action potential [51]. This information is transmitted to the central nervous system (CNS) and in turn organised and managed in various higher order areas [6]. Motor control commands are sent to relevant muscles around the joint to ensure co-ordinated, effective movement [47]. Therefore proprioception has an important role in normal co-ordinated movement and effective motor control.

Various types of mechanoreceptors have been located in and around the knee joint that contribute to knee joint homeostasis [24]. Therefore the majority of tissues in this joint and its surrounding muscles provide important afferent information on position and movement [24]. Practitioners can measure static knee joint proprioception ability using joint position sense (JPS) measures [44]. These protocols involve measurement of an error angle, taken from the difference between a target knee angle set by the researcher and a reproduced knee angle completed by the participant [5,44]. However, measurement techniques have been varied and potentially lacking in validity and reliability [45]. With up to 12 decisions to make for each JPS measurement (warm-up, instrumentation, leg, position of participant, knee angle starting position, angular velocity, direction of movement, target angle, hold time, reproduction technique, number of trials, outcome measure) it may not be surprising there is variation in measurement techniques. Therefore the reliability and validity of a methodology should be established before collection of joint position sense data [51].

An increase in age may be correlated to a decrease in certain musculoskeletal and neurological systems [16]. Therefore it is perhaps no surprise research has identified a proprioceptive decline with an increase in age. The results of cross-sectional research evidence shows reductions in static (JPS) proprioceptive ability with older populations [4, 27, 28, 35, 36]. This has been explained using theory on both peripheral and central adaptations. Furthermore, Herter, Scott and Dukelow [18] considered upper limb joint position sense in 209 healthy males and females aged between 18 and 90 and reported an age-related decline. However there is no normative knee data available that considers a large range of adult ages across a healthy population. This is needed to inform clinicians and their treatment of proprioceptive deficits.

Regular physical activity has many health benefits and the majority of research would suggest an enhanced proprioceptive ability is one of those benefits. Many studies consider the effects of regular physical activity and proprioception using elderly populations [29, 30, 36, 43, 56, 58]. The type of exercise implemented in this research ranges from Tai Chi, golf, swimming, running and strength training. Results are of the same consensus; regular physical activity appears to heighten knee proprioception. In particular with the elderly groups, regular exercise may indeed attenuate the age related decline in proprioception. This is explained by exercise induced adaptations at both peripheral and central areas. It is thought the latency of the stretch reflex is reduced and the amplitude of the stretch reflex is increased as a result of regular exercise [21]. The repetitive nature of exercise may also improve the effectiveness of the gamma motor neuron route [43]. This also improves central processing of afferent information [57]. Therefore regular exercise is thought to improve knee proprioception.

Despite these theories on an age decline and physical activity attenuation of knee joint position sense, it is unknown as to what constitutes “normal” static proprioceptive ability. Callaghan, Selfe, Bagley and Oldham [9] suggests “good” levels of knee proprioception to be below an absolute mean error score of 5°, however this figure appears arbitrary. There is also no large scale normative knee data taken from a range of ages and physically active populations to substantiate previous theories. Therefore the aim of the current study were to collect normative knee joint position sense from a representative sample of the population using a previously validated and reliable protocol. Furthermore, the study aimed to consider the effects of age and physical activity levels on knee joint position sense.

2. Method

A sample size calculation (G*Power, version 3.1.6, Germany) was utilised to provide an appropriate sample size producing 90% power and alpha set at 0.05. Using the independent t-test method, the effect size was calculated using the mean JPS scores and accompanying standard deviations from meta-analysis data [45] as previous JPS data were not available on a large-scale uninjured sample. This meta-analysis data considered differences in knee joint position sense between patients with anterior cruciate ligament injuries and uninjured controls. Therefore this sample size is representative of a large uninjured group that may be used in comparison to an injured group in future research.

The calculated appropriate sample size was 104, however the actual sample acquired was 116. The sample size was then divided into appropriate age groups, based on UK population statistics [34]. This resulted in a target of 29 participants aged 15-29, 25 participants aged 30-44, 25 participants aged 45-59, 26 participants aged 60-74 and 11 participants aged 75 and over. The participants were recruited using convenience but purposive sampling techniques. Table 1 details the sample. The exclusion criteria for participants included neurological disease, hearing deficiencies, current lower extremity injury, a history of lower extremity injury (within the last six month) and/ or surgery, participation in activity such as dance or gymnastics that may induce heightened proprioception and the inability to hold the knee in full knee extension whilst seated. Participants also completed four self-assessment surveys to indicate general activity levels that may not be specific to sport or exercise (General Practitioner Physical Activity Questionnaire, Appendix 1), activity levels based on sport and exercise (Tegner Activity Survey, Appendix 2), and current knee condition to identify any undiagnosed knee problems that may exclude the participant from the study (Knee injury and Osteoarthritis Outcome (KOOS), Appendix 3 and Lysholm Score, Appendix 4). Please see appendices for copies of these surveys with accompanying scoring methods. Participants read an information sheet and provided written informed consent. This study was approved by the University ethics board (Ref09/25).

Participants wore shorts and removed the sock and shoe from their dominant leg. The participants were prepared for data collection by placing markers on the following anatomical points; a point on a line following the greater trochanter to the lateral epicondyle, close to the lateral epicondyle (placement of a marker directly on the greater trochanter is difficult due to clothing), the lateral epicondyle and the lateral malleolus of both legs [1].

Table 1. Participant details.

Age Group (years)	Gender Split	Age (years)	Mass (kg)	Height (m)	BMI	KOOS	Lysholm Score	Tegner Score	GPPAQ Score (range)
15-29	Males = 13	22±4.3	74.2±7.33	1.79±0.061	23.1±2.01	97.9±4.08	95±8.03	7.2±1.01	Active
	Females = 16	22±3.4	65.1±11.86	1.65±0.058	23.9±3.60	99.6±1.78	99.7±1.25	5.4±1.59	Inactive - Active
30-44	Males = 13	37±4.8	84.3±14.39	1.79±0.081	26.2±3.28	92.2±18.54	94.92±10.45	5.2±2.12	Moderately Inactive - Active
	Females =12	39±3.5	70.8±16.24	1.65±0.084	25.7±4.22	94.9±10.15	93.7±11.81	4.5±1.93	Inactive-Active
45-59	Males = 12	53±3.1	76.4±11.46	1.78±0.06	24.1±3.20	96.6±6.05	96.9±7.28	4.0±1.54	Inactive - Active
	Females = 13	52±4.8	65.4±14.70	1.64±0.049	24.3±6.15	90.7±14.49	90.6±13.50	4.2±1.68	Inactive - Active
60-74	Males = 11	68±4.6	90.4±12.7	1.77±0.044	29.0±3.98	90.8±21.80	90.6±17.04	2.4±0.67	Inactive – Active
	Females = 15	64±3.2	75.1±26.00	1.60±0.090	29.4±10.49	92.5±13.53	91.3±12.23	2.6±0.63	Inactive – Active
>74	Males = 5	76±1.2	84.8±15.51	1.73±0.132	28.9±8.54	80.4±20.50	77.4±20.77	2.2±1.30	Inactive – Active
	Females = 6	77±3.1	70.8±16.47	1.59±0.067	28.1±5.68	92.5±9.87	89.3±17.05	2.2±0.98	Inactive – Moderately Inactive

Values are mean±SD unless otherwise indicated.

The JPS procedure followed in this study has been previously validated against an isokinetic dynamometer knee JPS protocol [39]. Furthermore, the intra-class correlation coefficients (ICC) value corresponding to inter-examiner reliability of this technique was 0.98 and 95% confidence intervals ranged from 0.96-0.99 and Cronbach's Alpha value was 0.99 [40]. The ICC value for intra-examiner reliability was 0.96 and 95% confidence intervals ranged from 0.91-0.98 and Cronbach's Alpha value was 0.98 [40]. Test-retest reliability has also been reported as excellent for both knee flexion (ICC = 0.92) and knee extension (ICC = 0.86) procedures [40]. These reliability and validity statistics were taken from a similar uninjured normative population.

The participant was seated on the end of a physiotherapy plinth and blindfolded. The dominant leg was passively moved by the experimenter through 30°-60° of extension from a starting knee angle of 90° (bent leg) or through 60°-90° of flexion from a starting angle of 0° (straight leg) at an approximate angular velocity of 10°/s. This angular velocity was approximated by the researcher as the limb was passively moved using a visual goniometer (see figure 1). The choice of these target positions and hence range of motions were based on the reliability and validity studies reported previously [39, 40]. The order of the target angles was randomly allocated using randomly generated numbers. The participant then actively held the leg in this position for 5s. A photograph of the leg in the target position was taken using a standard camera (Casio Exilim, EX-FC100, Casio Electronics Co.,Ltd. London, UK) placed 3m from the sagittal plane of movement on a fixed level tripod (Camlink TP-2800,Camlink UK, Leicester, UK) (see figure 1). The leg was then passively returned to the starting angle and the participant was instructed to actively move the same leg to the target angle and hold the leg in this position. Another photograph was taken and the participant instructed to move their leg back to the starting position. The process was repeated 5 times for each target angle on the dominant leg.

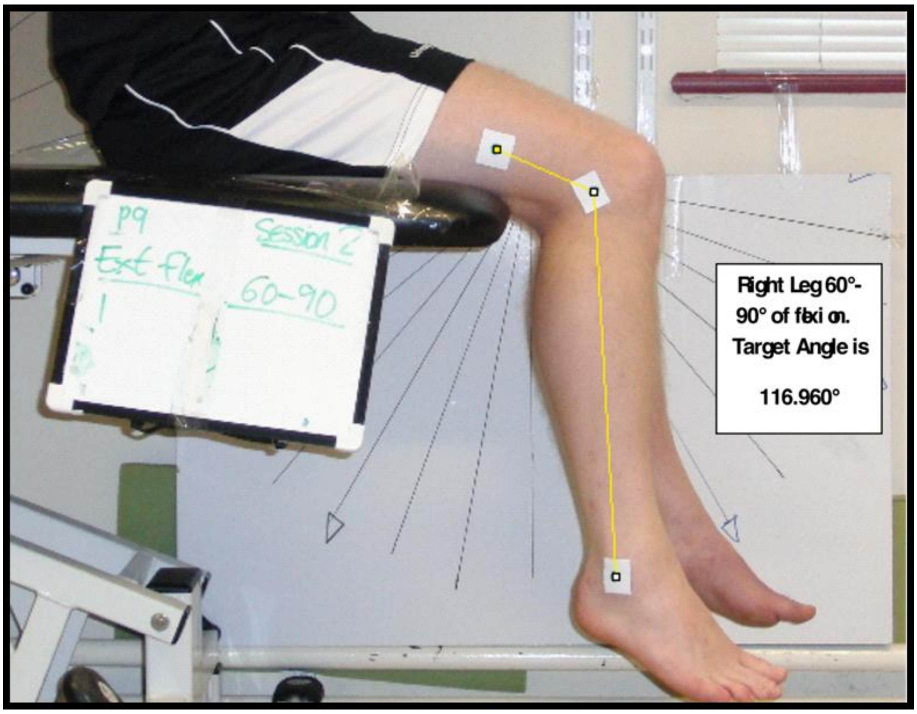

Figure 1. Typical set up and measurement of knee joint angle for knee joint position sense measurement.

Knee angles were measured using two-dimensional manual digitizing software (ImageJ, U. S. National Institutes of Health,, Maryland, USA, http://imagej.nih.gov/ij/, 1997-2012). Knee joint position sense was calculated from the average delta scores between target and reproduction angles across five flexion and five extension trials producing absolute error scores in which only magnitude was measured [5]. Means, standard deviations and 95% confidence intervals were presented. Confidence intervals at the 95% level were calculated using the following equations –

Lower boundary of confidence interval = $\bar{X} - (1.96\ X\ SE)$

Upper boundary of confidence interval = $\bar{X} + (1.96\ X\ SE)$

[15, p. 748]

All statistical analysis was completed in SPSS (Version 19, IBM Corporation, New York, USA). The Kolmogorov-Smirnov test was used to examine normality of data, which was confirmed. Significant differences between JPS flexion and extension absolute error scores were tested using a dependent t-test with an alpha level set at $p<0.05$. The effect of age group (15-29 years, 30-44 years, 45-59 years, 60-74 years, >74years) and GPPAQ score (active, moderately active, moderately inactive and inactive) on JPS flexion and extension absolute error scores was tested using a multivariate general linear model (MANOVA) [13] with an alpha level set at $p<0.05$. GPPAQ information was used for JPS differences testing as the results of this survey provide nominal level data which can define activity levels. Significant correlations between JPS flexion and extension absolute error scores and age and Tegner scores were analysed using Pearson Product Correlation Coefficients for interval level data (age) and Spearman's Rank Correlation Coefficients for ordinal level data (Tegner scores) [13] and alpha levels set at $p<0.05$. Significant relationships were defined using Cohen's definitions; r=.10 (small relationship), r=.30 (medium relationship), r=.50 (large relationship) [11].

3. Results

Normative JPS error scores are detailed in table 2. There was a significant difference between JPS flexion (3.6±1.61°) and JPS extension (2.9±1.47°) absolute error scores (p=0.0001, r=0.10) (see figure 2). However, there were no significant effects of age group (p= 0.603 and p= 0.536) on JPS flexion and extension absolute error scores respectively. There was also no significant effect of GPPAQ score on JPS flexion error scores (p=0.691). However results indicated there was an effect of GPPAQ score on JPS extension error scores (p=0.04). Post-hoc analysis revealed a significantly greater absolute error score (p=0.017) hence poorer knee joint position sense for inactive participants compared to active participants (mean difference = 1.3°, see figure 3).

There were no significant correlations between JPS flexion absolute error scores and age (p=0.540) or Tegner scores (p=0.860). However, JPS extension absolute error score were significantly correlated to age (p=0.003, r= 0.277) and Tegner scores (p=0.0001, r=-0.321). However, these correlations had a small to medium effect size [32].

Table 2. Normative knee joint position sense values of an adult UK population.

Age Group (years)	Gender Split	JPS Flexion (°)	95% CIs lower	95% CIs upper	JPS Extension (°)	95% CIs lower	95% CIs upper
15-29	Males (n=13)	3.6±1.65	2.7	4.5	2.6±1.32	1.9	3.3
	Females (n=16)	3.6±1.63	2.8	4.4	2.7±1.61	2.0	3.5
30-44	Males (n=13)	3.5±1.60	2.6	4.4	2.3±1.02	1.7	2.9
	Females (n=12)	4.3±1.90	3.2	5.4	2.7±0.82	2.2	3.2
45-59	Males (n=12)	3.5±1.19	2.8	4.2	2.7±1.31	2.0	3.4
	Females (n=13)	3.4±1.61	2.5	4.3	3.0±1.31	2.3	3.7
60-74	Males (n=11)	3.3±1.10	2.6	4.0	3.3±1.91	2.2	4.4
	Females (n=15)	4.1±2.15	3.0	5.2	3.4±1.35	2.7	4.1
75+	Males (n=5)	3.0±1.27	1.9	4.1	3.4±2.41	1.3	5.5
	Females (n=6)	3.1±1.30	2.1	4.1	4.3±1.62	3.0	5.6
Mean		**3.6±1.61**	**3.3**	**3.9**	**2.9±1.47**	**2.6**	**3.2**

Values are mean±SD unless otherwise indicated

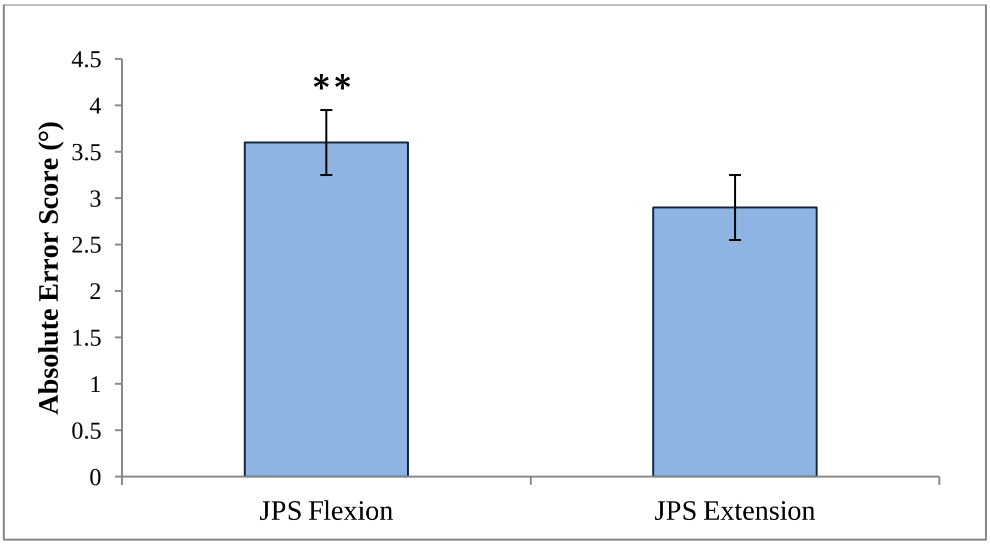

Figure 2. Mean and standard error JPS flexion and extension scores for a normative population. **Flexion scores were significantly higher (p=0.0001) than extension scores.

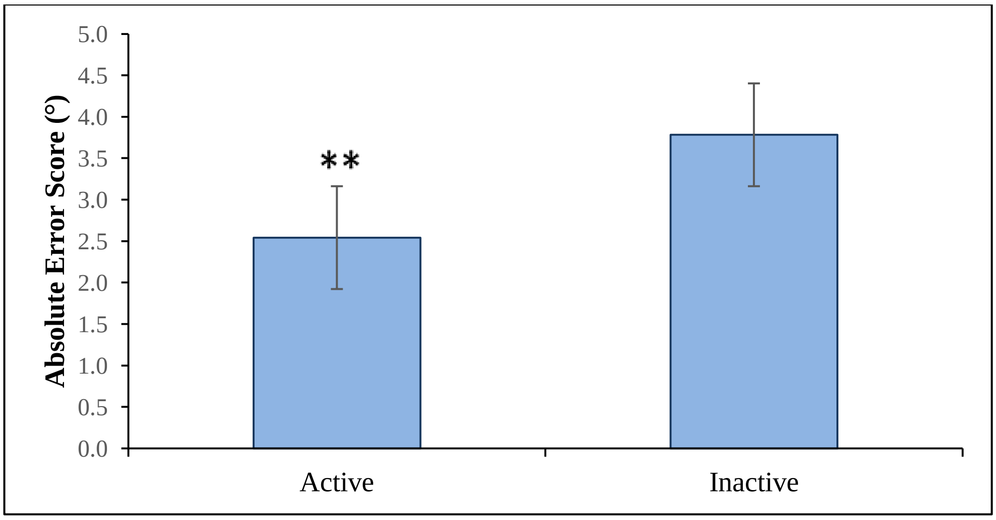

Figure 3. Mean and standard error JPS extension scores for active and inactive groups. **Active scores were significantly lower (p=0.017) than inactive scores.

4. Discussion

One aim of the current study was to provide normative knee joint position ability from an uninjured population. The values of knee JPS into flexion were 3.6°, 3.9°, 3.5°, 3,7° and 3.1° for ages 15-29, 30-44, 45-59, 60-74 and 75+ years old respectively. The normative values for knee JPS into extension were 2.7°, 2.5°, 2.9°, 3.4° and 3.9° for ages 15-29, 30-44, 45-59, 60-74 and 75+ years old respectively. Normative data may be used by practitioners to evaluate rehabilitation programmes by comparing injured patients' performance to uninjured normative data. The normative data may also be used to screen athletes for proprioception imbalances and/ or deficits.

4.1 The effect of knee direction and range of motion on joint position sense

The normative population data revealed greater JPS error scores into knee flexion than extension. The improved knee position sense into extension may be attributed to the type of agonist muscle contraction involved in the movements. The knee extension trial may have provide greater levels of afferent feedback due to greater muscle spindle and Golgi tendon organ activation in the larger concentric quadriceps muscle contraction. Participants are also working against gravity in knee extension trials, which requires production of greater torque to a longer lever arm position than knee flexion and hence greater neuromuscular control and spindle activation which may result in greater proprioception feedback. The target position in the knee flexion trials had a shorter lever arm and perhaps required less neuromuscular control to a more neutral knee position (see figure 1). Furthermore, hip extensor muscle groups are more dominant in knee extension movements, potentially providing additional joint afferent information and hence a heightened joint position sense in this movement position and direction.

The findings of this study may also be attributed to the range of motion involved in the testing procedures. The knee flexion protocol may be more dependent on muscular strength as the testing began at 0° and the participant had to move from a high torque position to a low torque target angle through 60 - 90° of motion. Hence the participants may have become more concerned with maintaining the 0° starting angle and range of motion in this procedure compared to the knee extension trials. This may have provided a more challenging environment than the lower range of motion task in the knee extension trials.

In support of these findings Boisgontier and Swinnen [8], Goble, Lewis and Brown [17] and Lonn et al. [31] reported increased joint position errors when the task range of motion was increased. This was explained by these authors due to an increased difficulty in task caused by increased cognitive load making proprioceptive processes more complex and hence resulting in greater joint position error scores.

In summary the knee flexion task may have produced greater position error scores due to; a smaller agonist muscle group contributing afferent information in this knee direction, working with gravity into flexion to a smaller lever arm target position both reducing torque production and hence potential afferent information, a more challenging starting position and greater range of motion which may have created a more difficult joint position sense task.

However, Friden et al. [14] reported opposing findings of lower error scores for knee flexion movements compared to knee extension. However different starting positions, target positions and angular velocities were used in comparison to the current study and therefore comparisons should be completed with caution. Drouin et al. [12] also considered direction and joint position sense and found no significant differences between flexion and extension again using a different joint position sense protocol. There is limited previous evidence at the knee joint to support the findings found in the current study. However, it is important to note the sample size in the current study came from a power calculation to provide 90% power and alpha set at 0.05. Results from this study suggest both knee flexion and extension should be used in clinical joint position sense testing.

4.2 The effects of physical activity on knee joint position sense

Active participants had better knee joint position sense than inactive participants. There was also a negative relationship between absolute error scores in to extension and levels of physical activity, that being as physical activity levels increased error scores decreased.

Participation in regular physical activity may improve knee joint proprioception ability [36, 42-43, 57-58]. Ribeiro and Oliveira [43] and Petrella, Lattanzio and Nelson [36] stated that populations who exercised three times a week for at least 45-60 minutes had improved knee joint position sense compared to non-exercisers. Elderly exercisers can achieve similar proprioception levels to healthy (but not necessarily active) young controls [56-57]. Further, evidence suggests exercise of any type may improve proprioceptive ability [36, 42-43, 58].

Exercise may improve proprioception at both the peripheral and central levels [21]. Exercise may reduce the loss of muscle spindle afferent ability which may occur during periods of sedentary behaviour [2]. Hutton and Atwater [21] suggest regular exercise induces morphological adaptations at muscle spindle level, specifically reduction in the latency and increase in the amplitude of stretch reflexes. The repetition of a motor skill, as occurs in regular physical activity, can also increase the sensitivity of muscle spindle sensation and increase reliance of afferent information [25-26, 55] which again would improve proprioceptive acuity.

At the central level exercise may increase gamma motor neurone signals which in turn could increase muscle spindle sensitivity [2]. Ribeiro and Oliveira [43] further suggest exercise affords the opportunity to make plastic changes in the central nervous system, which can improve the strength of synaptic connections among neurones. It is believed continuation of exercise into retirement ages creates a compensation for the loss of peripheral changes, such as reduced number of muscle spindles, by enhancement of sensitivity of the central encoding of sensory input [20]. However, further research is required to substantiate these theories.

It is evident regular exercise may improve knee joint position sense, data from the current study provided support for this during knee extension results. However, there were no significant effects of exercise on knee flexion position sense. One possible explanation for this is the target angle used in the knee flexion trial; this was unloaded with 90° of knee flexion. This position, without loading is less common in physical activity than the target angle in the knee extension task, which was a mid-range position commonly used in locomotion. Therefore physical activity may only enhance joint position sense in positions that are most commonly used in the movement.

4.3 The effects of age on knee joint position sense

In addition the current study considered the effect of age on knee joint positon sense. There was a significant but small to moderate correlation between joint position sense into extension and age, as age increased joint position sense ability decreased. A decrease in knee joint position sense ability in elderly groups is also reported by a number of authors [22, 27, 35-36]. Most recently Ribeiro and Oliveira [43] compared knee joint position sense of young (average age 20.6 years) and older (average age 72.2 years) male participants and concluded the elderly group had double the error scores in joint position measurements than the younger group.

This apparent age-related decline can be attributed to changes in both peripheral and central levels [20, 22, 43]. At peripheral levels, there is evidence to suggest the dynamic response and the total amount of muscle spindles reduce with age [32]. Specifically, there may be a reduction in intrafusal fibres and an accompanying increase in the spindle capsule thickness due to muscle denervation [18, 32-33, 42-43, 49, 52]. The changes in muscle spindle architecture may also be due to an increase in collagen and fibrous tissue content arranged in the inner capsule [32, 52]. There is evidence to suggest the fibrous tissue encapsulating extrafusal muscle fibres thickens with age [52]. In addition, nerve conduction velocity decreases and hence muscle spindle sensitivity decreases [53] and the net number of mechanoreceptors serving a joint is reduced [3, 18, 23] with ageing.

The central component of proprioception may also be altered with ageing, there is a reduction in the dendrite system in the motor cortex and hence a reduction of motor neurones in the central nervous system [20, 33, 43]. The motor neurones that remain are larger and have a reduced conduction velocity [10]. There has also been anecdotal evidence of a reduction in grey matter and hence a less effective central nervous system [18, 48].

However, the relationship between age and knee extension joint position sense only had a small to moderate effect. Furthermore, there were no significant differences between the five age groups in either knee flexion or extension absolute error scores. This suggests that age may not be the main cause of a deficit in static proprioception in all patients. This is in agreement with Pickard, Sullivan, Allison and Singer [37] who also did not find significant differences between young and old populations in joint proprioception. Pickard, Sullivan, Allison and Singer [37] did not conclude age does not influence static proprioception; rather elderly groups participating in regular physical activity may negate a proprioceptive decline. Indeed, evidence has indicated regular exercise attenuates the decline of proprioception with age. The majority of participants in the older groups in this study took part in some form of exercise; 45-59, 60-74 and 75+ age groups reported average Tegner scores of 4.1, 2.5 and 2.2 respectively and some participants in each age group reported a GPPAQ score of Active.

An alternative explanation for the small-moderate effect of age on knee joint position sense is linked to the use of cognitive resources in older age groups. Boisgontier et al. [7] reported no differences in ankle joint position sense ability between young and older adults when the task was relatively simple, with singular demands, similar to the current study design. It may be older adults are able to replicate younger adults proprioceptive ability by increasing their attention to afferent signals [7]. Therefore, future studies may need to consider dual-task paradigms that challenge the central processing of proprioception signals to identify clearly age-related declines in joint position sense ability.

4.4 Limitations

A limitation of the research findings in the current study is the large standard deviation and confidence intervals stated in the data. For example the difference between knee flexion and extension error scores was just 0.7°; this is less that the standard deviations of each corresponding mean. Furthermore the difference between active and inactive participants was 1.3°, again within one standard deviation of the means. The clinical significance of these values may be questioned. It is not yet known how much of a joint position sense difference is needed to increase the risk of an injury. Therefore future research should consider the correlation between knee JPS ability and functional performance. An additional limitation is the use of self-assessment surveys to record activity levels. It may be more appropriate to take a direct measure of physical activity such as a fitness test. However, research has indicated these both GPPAQ and Tegner activity scales are reliable and valid measures of physical activity [51, 56].

Conclusion

This study provides normative knee joint position sense data across five age groups. Normative data may be used by practitioners to evaluate rehabilitation programmes and also screen patients for proprioception imbalances and/ or deficits. There were some differences in joint position sense ability between knee flexion and extension and active and inactive participants. Results also indicated a small – moderate relationship between knee joint position sense into extension and age. Specifically, as age increased, JPS into extension worsened.

Future work needs to consider how physical activity may improve knee joint position sense. It may be that clinical practitioners should consider physical activity level as a more important proprioceptive variable than age [46]. This has important implications for clinical practitioners practice; it may not be necessary to introduce what has traditionally been known as specific “proprioceptive exercises” in training programmes but simply exercise of any type. However there is still further work to be done on exercise and position sense ability to ensure the most effective programmes are implemented. Future work should also consider the relationship between joint positon sense and functional ability.

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Appendix 1: The General Practice Physical Activity Questionnaire (GPPAQ) and Scoring Guidance Form

General Practice Physical Activity Questionnaire

Date……………………..

Name……………………..

1. Please tell us the type and amount of physical activity involved in your work.

		Please mark one box only
a	I am not in employment (e.g. retired, retired for health reasons, unemployed, full-time carer etc.)	
b	I spend most of my time at work sitting (such as in an office)	
c	I spend most of my time at work standing or walking. However, my work does not require much intense physical effort (e.g. shop assistant, hairdresser, security guard, childminder, etc.)	
d	My work involves definite physical effort including handling of heavy objects and use of tools (e.g. plumber, electrician, carpenter, cleaner, hospital nurse, gardener, postal delivery workers etc.)	
e	My work involves vigorous physical activity including handling of very heavy objects (e.g. scaffolder, construction worker, refuse collector, etc.)	

2. During the *last week*, how many hours did you spend on each of the following activities? *Please answer whether you are in employment or not*

Please mark one box only on each row

		None	Some but less than 1 hour	1 hour but less than 3 hours	3 hours or more
a	Physical exercise such as swimming, jogging, aerobics, football, tennis, gym workout etc.				
b	Cycling, including cycling to work and during leisure time				
c	Walking, including walking to work, shopping, for pleasure etc.				
d	Housework/Childcare				
e	Gardening/DIY				

3. How would you describe your usual walking pace? Please mark one box only.

Slow pace (i.e. less than 3 mph)		Steady average pace	
Brisk pace		Fast pace (i.e. over 4mph)	

A. CALCULATING THE 4-LEVEL PHYSICAL ACTIVITY INDEX (PAI)

Patients can be classified into four categories based on the original EPIC index from which the GPPAQ was developed.

Inactive	Sedentary job and no physical exercise or cycling
Moderately inactive	Sedentary job and some but < 1 hour physical exercise and / or cycling per week OR Standing job and no physical exercise or cycling
Moderately active	Sedentary job and 1-2.9 hours physical exercise and / or cycling per week OR Standing job and some but < 1 hour physical exercise and / or cycling per week OR Physical job and no physical exercise or cycling
Active	Sedentary job and ≥ 3 hours physical exercise and / or cycling per week OR Standing job and 1-2.9 hours physical exercise and / or cycling per week OR Physical job and some but < 1 hour physical exercise and / or cycling per week OR Heavy manual job

Note: Questions concerning Walking, Housework/Childcare and Gardening/DIY have been included to allow patients to record their physical activity in these categories, however these questions have not been shown to yield data of a sufficient reliability to contribute to an understanding of overall physical activity levels. As noted above further questioning is required.

B. SUMMARY OF THE PAI

	Occupation			
Physical exercise and / or cycling (hr/wk)	Sedentary	Standing	Physical	Heavy Manual
0	Inactive	Moderately Inactive	Moderately Active	Active
Some but < 1	Moderately Inactive	Moderately Active	Active	Active
1-2.9	Moderately Active	Active	Active	Active
≥ 3	Active	Active	Active	Active

Appendix 2: The Tegner Activity Scale

Level 10	**Competitive sports- soccer, football, rugby (national elite)**
Level 9	**Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball**
Level 8	**Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing**
Level 7	**Competitive sports- tennis, running, motorcars speedway, handball** **Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running**
Level 6	**Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week**
Level 5	**Work- heavy labor (construction, etc.)** **Competitive sports- cycling, cross-country skiing,** **Recreational sports- jogging on uneven ground at least twice weekly**
Level 4	**Work- moderately heavy labor (e.g. truck driving, etc.)**
Level 3	**Work- light labor (nursing, etc.)**
Level 2	**Work- light labor** **Walking on uneven ground possible, but impossible to back pack or hike**
Level 1	**Work- sedentary (secretarial, etc.)**
Level 0	**Sick leave or disability pension because of knee problems**

Appendix 3: Knee Injury and Osteoarthritis Outcome Score (KOOS) and Scoring Guidance Form

KOOS KNEE SURVEY

Today's date: _____/______/______ Date of birth: _____/______/______

Name: ____

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms

These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S3. Does your knee catch or hang up when moving?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S4. Can you straighten your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

S5. Can you bend your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

Stiffness

The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Pain

P1. How often do you experience knee pain?

Never	Monthly	Weekly	Daily	Always
☐	☐	☐	☐	☐

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P3. Straightening knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P4. Bending knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P5. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P6. Going up or down stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P7. At night while in bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P8. Sitting or lying

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P9. Standing upright

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A1. Descending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A2. Ascending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

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For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A5. Bending to floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining knee position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Jumping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Twisting/pivoting on your injured knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP5. Kneeling

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your knee problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid potentially damaging activities to your knee?

Not at all	Mildly	Moderately	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your knee?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your knee?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Thank you very much for completing all the questions in this questionnaire.

KOOS Scoring instructions

Assign the following scores to the boxes:

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐
0	1	2	3	4

Each subscale score is calculated independently. Calculate the mean score of the individual items of each subscale and divide by 4 (the highest possible score for a single answer option). Traditionally in orthopedics, 100 indicates no problems and 0 indicates extreme problems. The normalized score is transformed to meet this standard.

Appendix 4: Lysholm Scoring

Please grade each symptom that you experience currently during your highest level of activity

Swelling:	○ None ○ Mild (on severe exertion) ○ Moderate (on ordinary exertion) ○ Severe (constant)
Pain:	○ None ○ Inconstant and slight during severe exertion ○ Marked during severe exertion ○ Marked on or after walking more than 2 km ○ Marked on or after walking less than 2 km ○ Constant
Crutch Use:	○ None ○ 1 Crutch (stick or crutch) ○ 2 Crutch (stick or crutch) ○ Weight bearing impossible
Walk with Limp:	○ No (none) ○ Somewhat (slight or periodical) ○ Yes (severe or constant)
Locking:	○ No locking and no catching sensations ○ Catching sensations but no locking ○ Locking frequently ○ Locking occasionally ○ Locked joint
Instability:	○ Never giving way ○ Rarely during athletics or other severe exertion ○ Frequently during athletics or other severe exertion ○ Occasionally in daily activities ○ Often in daily activities ○ Every step
Stair-Climbing	○ No problems ○ Slightly impaired ○ One step at a time ○ Impossible
Squatting:	○ No problems ○ Slightly impaired ○ Not beyond 90 degrees ○ Impossible