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The effects of knee direction, physical activity and age on knee joint position sense

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ABSTRACT

Background: Previous research has suggested a decline in knee proprioception with age. Furthermore, regular participation in physical activity may improve proprioceptive ability. However, there is no large scale data on uninjured populations to confirm these theories. The aim of this study was to provide normative knee joint position data (JPS) from healthy participants aged 18–82 years to evaluate the effects of age, physical activity and knee direction.

Methods: A sample of 116 participants across five age groups was used. The main outcome measures were knee JPS absolute error scores into flexion and extension, Tegner activity levels and General Practitioner Physical Activity Questionnaire results.

Results: Absolute error scores in to knee flexion were 3.6°, 3.9°, 3.5°, 3.7° and 3.1° and knee 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. Knee extension and flexion absolute error scores were significantly different when age group data were pooled. There was a significant effect of age and activity level on joint position sense into knee extension. Age and lower Tegner scores were also negatively correlated to joint position sense into knee extension.

Conclusions: The results provide some evidence for a decline in knee joint position sense with age. Further, active populations may have heightened static proprioception compared to inactive groups. Normative knee joint position sense data is provided and may be used by practitioners to identify patients with reduced proprioceptive ability.

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 that there is a 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

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surprise that research has identified a proprioceptive decline with an increase in age. The results of cross-sectional research evidence show 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 that 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 that 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 was 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 months) 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 supplementary data 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].

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 was 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

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.