Knee extensor functional demand following total knee arthroplasty

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INTRODUCTION: Fatigability is a relatively new metric conceptualized to capture information about deterioration of physical performance and the increased perception of effort during activity for use in aging and clinical populations [1]. Fatigability may limit physical capacity, contribute to mobility dysfunction and lower physical activity levels. Muscle weakness leading to a greater relative effort of the muscles in daily activity (i.e., functional demand) is thought to contribute to fatigability. Knee extensor muscle (KE) weakness is well-documented in individuals with knee osteoarthritis (KOA) and is associated with increased risk of symptomatic and mobility decline [2]. This weakness contributes to a high KE functional demand during gait for KOA [3,4] that may contribute to fatiguability, neuromuscular fatigue and physical activity avoidance. Functional demand is the ratio of joint moment to maximum torque or power of the muscle, and is dependent on both muscle capacity and movement mechanics. We have shown an association between KE functional demand and the coordination of gait, suggesting that individuals may alter their gait strategy to avoid a functional demand over 50% of the muscle's capacity [4]. KE weakness often persists following total knee arthroplasty (TKA) and is thought to be an important target for improving gait mechanics and patient-reported function post operatively. However, the impact of this persistent KE weakness post-operatively on KE functional demand is not known. A high KE functional demand post-operatively would suggest a high risk of fatigability, and may provide insight about the reported low physical activity level following TKA. Therefore, the aim of this study was to quantify KE functional demand in individuals post TKA, and compare their functional demand with that of age-matched healthy older adults (OH) and those with moderate symptomatic KOA. We hypothesized that 1) KE functional demand would be greatest in KOA but remain higher in TKA compared with OH, 2) as a result of lower maximum KE torque in the clinical groups.

METHODS: Five adults with a unilateral TKA 1 – 3 years post-op (4F; 67.4± 8.2yr; BMI 30.07± 3.2 kg/m^2), 15 adults with symptomatic KOA (11F; 65.2 ± 5.2 yr, BMI: 25.6 ± 3.7 kg/m^2, KOOS pain 68.9 ± 16) and 15 healthy older adults (OH; 12F, 73 ± 3 yr, BMI: 26.0 ± 4.2 kg/m^2) participated in this study after completing the informed consent process approved by the University of Massachusetts Chan Medical School or University of Massachusetts Amherst IRBs. Participants completed three maximal isometric KE contractions on an isokinetic dynamometer (Biodex System 4 Pro, Shirley, NY) set at 70° of knee flexion. Participants also completed 3-5 overground walking trials at a preferred pace while motion capture (Oqus 7, Qualysis, Sweden) and ground reaction force (AMTI, MA, USA) data were captured. External knee joint moments were calculated using an inverse dynamic approach with Visual 3D (C-Motion, MD, USA). Functional demand was determined at the time of peak external knee flexion moment, calculated as the ratio of peak knee joint moment: maximum KE isometric muscle torque, and expressed as a percentage. One-way ANOVAs (group) were used to test for the impact of group on KE functional demand, maximum KE isometric torque, and peak knee flexion moment (p<0.05), with post-hoc testing where significant main effects were found.

RESULTS: KE functional demand varied by group (p=0.003) such that TKA was not different from KOA but both were greater than OH (Figure 1; TKA 46.3 ± 11.4; KOA 36.3 ± 3.9; p=0.3 and OH 19.8 ± 3.0; p=0.005 for TKA and p=0.002 for TKA). There was no effect of group for peak knee flexion moment (p=0.07) or maximum KE isometric torque (p=0.7, Table1). There was not a significant difference in walking speed between TKA and OH (p = 0.11) or KOA (p=0.55) but walking speed for KOA was greater than for OH (p=0.002).

DISCUSSION: In partial agreement with our first hypothesis, KE functional demand was larger for both KOA and TKA than for OH. However, functional demand was not greatest in KOA; rather, it tended to be largest in TKA. Functional demand can be increased due to low muscle strength (numerator), a greater peak joint moment (denominator), or both. Although there were no significant effects of group for either peak muscle torque or peak knee flexion moment (hypothesis 2), the TKA group tended to have smaller muscle torques but larger knee joint moments, suggesting that despite lower strength, these individuals walked with a knee-extensor dominant gait pattern. While the functional demand was not different between KOA and TKA, walking speed was slightly faster for the KOA group. We have shown that functional demand is greater when walking faster [4]. Thus, if speeds were matched for TKA and KOA, functional demand for TKA might be even greater than for KOA; this new hypothesis remains to be determined. Overall, a high functional demand following TKA leading to a greater relative effort to complete activities of daily living could contribute to fatigability and impact physical activity patterns. The consequences of this high functional demand for neuromuscular fatigue and its impact on patient reported functional outcomes should be evaluated.

SIGNIFICANCE/CLINICAL RELEVANCE: Patient-reported functional improvements are limited for up to 30% of patients following TKA [5], and there is a need to understand the factors that limit functional improvements following TKA. This preliminary study suggests that fatiguability as a result of a high KE functional demand may contribute to the cycle of poor physical performance and lower physical activity levels in this growing segment of the population.

REFERENCES: 1. Eldadah (2010) PM&R. 2. Culvenor et al., (2017) Arthritis Care Res. 3. Tung et al., (2022) Gait and Posture. 4. Holmes and Boyer (2022) Gait and Posture. 5. Franklin et al., 2008. Clin Orthop Relat Res.

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Table 1: Mean and standard error for key functional variables, including preferred walking speed, KE maximum isometric torque (MVIC) and peak external knee flexion moment normalized to bodyweight times height.

Group (n)	*Walking speed (m/s)*	*KE MVIC (Nm)*	*Knee flexion moment (% BW x Ht)*
TKA (5)	1.18 (0.07)	99.8 (19.0)	3.09 (0.79)
KOA (15)	1.22 (0.03)	109.1 (12.8)	2.88 (0.24)
OH (15)	1.07 (0.03)	117.0 (8.3)	1.93 (0.34)

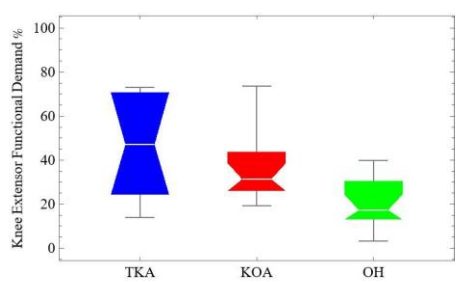

Figure 1: KE functional demand for the 3 study groups. The boxes represent the 25 – 75% quartiles, and white lines represent the median for the group.