De Vecchis, Marina, Bowd, Jake, Wilson, Chris, Whatling, Gemma, Holt, Cathy and Williams, David (2021) *Hip, knee and ankle kinematics improve after total knee replacement but do not return to normal.* Osteoarthritis and Cartilage, 29 (S1). S184-S185. ISSN 1063-4584.

Purpose: Total knee replacement (TKR) surgery is performed to reduce pain and improve the function of the lower limb. Most of the current literature focuses on knee kinematics pre and post-TKR, compared to healthy controls. However, there is limited research exploring hip and ankle kinematics before and after TKR and comparing them to non-pathological subjects (NP). This study aims to explore the differences in hip, knee and ankle kinematics in the sagittal and frontal planes pre to post-TKR and to investigate whether the lower limb joints' kinematics post-TKR normalise and compare to NP. This knowledge would help to understand to which extent TKR helps to improve the whole lower limb function.
Methods: In this longitudinal study, biomechanical data was collected using a CAST marker set on 21 patients before and approximately 12 months post-TKR (22 knees, primary TKR) and 20 NP. All participants gave written consent prior to data collection. Participants walked barefoot at self-selected speed in a motion capture lab (Qualisys camera system, Sweden) over a 10-meter walkway instrumented with 6 force plates (Bertec Inc., Ohio). Additionally, patients' active-assisted knee range of movement (ROM) was recorded from a seated position for both visits. The Oxford Knee Score (OKS) was recorded pre and post-TKR and for NP. Visual 3D (C-Motion, Inc., MD) was used to calculate hip, knee and ankle kinematics in the sagittal and frontal planes. The median differences between pre and post-TKR data were calculated using the Wilcoxon signed-rank test (p-value ≤ 0.05). The median differences between post-TKR and NP data were determined with the Mann-Whitney U test (p-value ≤ 0.05).
Results: Compared to NP (45% women), patients (25% women) pre-TKR were significantly older (median difference 19 years, p<0.001), heavier (median difference 22.2 Kg, p<0.001) and had a higher body mass index (median difference 7.32 Kg/m^2, p<0.001). The OKS improved significantly pre to post-TKR (median difference 15.5, p=0.001) but post-TKR, the OKS was not comparable to the NP (median difference 12, p<0.001). The active-assisted knee ROM, gait variables, joint angles in the sagittal and frontal planes are displayed in Table 1 for all groups. The significant differences between patients pre to post-TKR and between NP and patients post-TKR are reported in Table 1 and highlighted in dark grey. When compared to pre-TKR, patients post-TKR showed a small but significant increase in sagittal hip ROM (median difference 1.7°, p=0.008) and their value was comparable to NP. However, when looking at post-TKR and NP hip peak angles, patients had a significantly larger hip flexion (median difference 4.3°, p=0.004) and, more prominently, a reduced hip extension (median difference 8.2°, p<0.001) compared to NP. Pre to post-TKR, patients displayed a significantly improved knee extension both in the active-assisted assessment (median difference 3.1°, p=0.004) and especially while walking (median difference 5.9°, p=0.001). This change resulted in a significantly increased sagittal knee ROM during gait (median difference

8.5°, p<0.001). Despite this, after the surgery, patients' peak knee extension and ROM were still significantly reduced when compared to NP (median differences 6.9°, p<0.001 and 8.1°, p=0.001, respectively). Considering the ankle, patients had a significantly larger sagittal ROM pre to post-TKR (median difference 8.5°, p<0.001), mainly due to a significant increase in peak ankle plantarflexion (median difference 3.1°, p=0.005). When comparing post-TKR patients to NP, the sagittal ankle ROM values were similar but the patient's peak dorsiflexion was significantly greater (median difference 4.7°, p=0.001) and their peak plantar flexion was significantly smaller (median difference 4.8°, p=0.019) than NP. In the frontal plane, the hip peak angles and ROM did not change significantly pre to post-TKR. When compared to NP, patients showed a reduced peak hip abduction (median difference 3.7°, p=0.002) and frontal hip ROM (median difference 3.6°, p<0.001) post-TKR. Pre to post-TKR there was a significant increase in peak knee abduction (median difference 2.4°, p=0.019), ankle inversion (median difference 1.4°, p=0.031) and a significant decrease in ankle eversion (median difference 2.4°, p=0.051); the post-TKR values for these variables were comparable to those of NP. The frontal ankle ROM did not change significantly pre to post-TKR but it was significantly reduced post-TKR compared to NP (median difference 4.6°, p=0.017). The walking speed increased by 14% post-TKR (median difference 0.13 m/s, p<0.001) but patients' gait speed was 25% slower than NP one year after the surgery (median difference 0.31 m/s, p<0.001). The walking cycle duration was 6.9% longer in patients post-TKR compared to NP (median difference 0.08 s, p<0.001), despite the 5.7% decrease after the surgery (median difference 0.07 s, p,0.001). The stance time did not change pre to post-TKR and it was significantly longer in the patients' group post-surgery when compared to NP (median difference 2.4%, p<0.001).

Conclusions: Patients who underwent TKR showed an increased active-assisted knee extension and sagittal ROM one year after the surgery; this reflected positively in the knee extension and sagittal ROM during gait post-TKR. Pre to post-TKR, patients exhibited increased sagittal hip, ankle and mostly knee ROMs during gait, with augmented knee extension and ankle plantarflexion. In the frontal plane, only the knee peak valgus angle and ankle inversion increased and ankle eversion decreased pre to post-TKR. Patients did not display a return to healthy joints' kinematics one year after TKR and this may be because the NP group in this study was much younger than the patients' one. The sagittal hip and ankle ROM were comparable to NP but they were shifted towards the flexion range with markedly reduced extension at the hip, and towards the dorsiflexion range with reduced plantarflexion at the ankle. Patients showed a stiffer knee during gait as their knee sagittal ROM and peak extension were markedly limited compared to NP. Additionally, patients post-TKR had limited hip and ankle mobility in the frontal plane, unlike NP. The current investigation showed that patients had an improvement in hip, knee and ankle kinematics following TKR, mainly in the sagittal plane and at the knee joint. However, the lower limb kinematics was not comparable to that of NP in patients post-TKR, whose largest limitations were observed in hip and knee extension and knee ROM in the sagittal plane, and hip and ankle ROM in the frontal plane. This study suggests that it is important to consider hip and ankle joints alongside the knee when exploring patients' kinematics to evaluate TKR outcomes and during the rehabilitation process. More research is needed to determine which are the factors that could affect hip and ankle mobility following TKR surgery.

Table 1: Hip, knee, ankle kinematics and temporospatial outputs for gait and knee kinematics from the active-assisted assessment.

		Variables	Pre-TKR Median (IQR)	Post-TKR Median (IQR)	NP Median (IQR)	Median Difference pre to post-TKR	Sig. level (*p* -value)	Median Difference post-TKR to NP	Sig. Level (*p* -value)
Active Assisted ROM (°)		Knee Peak Extension (-)	6.6 (12.3)	3.5 (9.8)	-	**3.1**	**0.004**	-	-
		Knee ROM	94.9 (26.2)	98.1 (17.2)	-	4.6	0.149	-	-
Gait Variables	Sagittal Plane (°)	Hip Peak Flexion (+)	33.2 (12.2)	33.8 (6.7)	29.5 (6.6)	0.6	0.445	**-4.3**	**0.004**
		Hip Peak Extension (-)	-1.2 (13.8)	0.5 (8.6)	-9.4 (6.3)	1.0	0.677	**-8.2**	**<0.001**
		Hip ROM	32.3 (7.5)	35.2 (7.9)	37.8 (6.3)	**1.7**	**0.008**	2.6	0.178
		Knee Peak Flexion (+)	55.7 (7.4)	56.7 (9.4)	58.2 (8.3)	1.0	0.115	1.5	0.614
		Knee Peak Extension (-)	10.1 (10.3)	4.2 (5.3)	-2.7 (3.0)	**-5.9**	**0.001**	**-6.9**	**<0.001**
		Knee ROM	43.9 (13.9)	52.4 (11.7)	60.5 (10.5)	**8.5**	**<0.001**	**8.1**	**0.001**
		Ankle Peak Dorsiflexion (+)	16.3 (6.4)	17.3 (3.8)	12.6 (3.6)	1.0	0.808	**-4.7**	**<0.001**
		Ankle Peak Plantarflexion (-)	-5.3 (7.5)	-8.4 (7.1)	-13.2 (7.5)	**3.1**	**0.005**	**4.8**	**0.019**
		Ankle ROM	21.1 (5.4)	24.6 (4.2)	25.9 (6.6)	**3.5**	**0.001**	1.3	0.753
	Frontal Plane (°)	Hip Peak Adduction Angle (+)	6.3 (6.9)	7.1 (5.3)	6.1 (3.1)	0.8	0.445	-1.0	0.870
		Hip Peak Abduction Angle (-)	-1.7 (5.2)	-1.4 (4.4)	-5.1 (3.9)	0.3	0.910	**-3.7**	**0.002**
		Hip Frontal ROM	8.8 (4.1)	8.0 (2.5)	11.6 (3.4)	-0.8	0.974	**3.6**	**<0.001**
		Knee Peak Adduction Angle (+)	4.3 (6.6)	1.3 (4.8)	2.2 (4.9)	-3.0	0.355	0.9	0.428
		Knee Peak Abduction Angle (-)	-4.7 (7.4)	-7.1 (4.2)	-5.2 (4.7)	**-2.4**	**0.019**	1.9	0.087
		Knee Frontal ROM	6.8 (4.5)	9.2 (4.8)	8.8 (3.1)	2.4	0.144	-0.4	0.231
		Ankle Peak Inversion Angle (+)	9.2 (8.5)	10.6 (6.2)	13.4 (7.0)	**1.4**	**0.031**	2.8	0.110
		Ankle Peak Eversion Angle (-)	-4.4 (5.9)	-2.0 (4.5)	-2.5 (2.7)	**2.4**	**0.051**	-0.5	0.217
		Ankle Frontal ROM	12.5 (4.7)	11.6 (5.3)	16.2 (5.3)	0.9	0.733	**4.6**	**0.017**
	Other	Walking speed (m/s)	0.80 (0.25)	0.93 (0.16)	1.24 (0.12)	**0.13**	**<0.001**	**0.31**	**<0.001**
		% Stance	65.2 (2.7)	65.6 (3.4)	63.2 (1.6)	0.4	0.876	**-2.4**	**<0.001**
		Duration walking cycle (s)	1.23 (0.22)	1.16 (0.12)	1.08 (0.12)	**0.07**	**<0.001**	**-0.08**	**<0.001**

IQR - Interquartile Range
TKR – Total Knee Replacement
NP – Non-pathological subjects
ROM – Range of Motion
Significant differences highlighted in dark grey