purposes such as construction or childcare, and there is an increased prevalence of knee osteoarthritis (OA) in frequent high flexion users (Coggon, 2000). A higher knee adduction moment during gait has been implicated in both the initiation and progression of knee OA, and may be indicative of increased medial compartment loading. **The purpose of this study was to compare adduction moments across four common high flexion postures in order to determine which posture might have the lowest risk of contributing to knee OA in cases where tasks demand high flexion but do not constrain the choice of posture.** For the purposes of this study, a lower knee adduction moment indicated a lower risk posture.

Methods: 43 participants (20 males), aged 19 to 32 years, were recruited. Kinematics were recorded using an Optotrak motion capture system (NDI, Waterloo, ON, Canada) and marker clusters on the feet, shanks, thighs, and sacrum. Ground reactions were collected using 4 force plates (AMTI, Watertown, MA, USA.) Digitized bony landmarks were used to create segment coordinate systems, with net knee joint moments resolved in the tibial coordinate system. Four common high flexion postures were studied (Figure 1): two kneeling postures (dorsiflexed and plantarflexed) and two squatting postures (flat foot and heels raised). At least five trials of each posture were divided into a descending transition, a static phase, and an ascending transition. Peak and mean external knee adduction moments were determined during the transitions and static phases respectively. For each posture, data was averaged across trials and then across participants to determine a grand mean. A two-way mixed model (posture (4) x sex (2)) ANOVA was run for each of the three phases. Post-hoc Tukey tests were used to determine which postures differed from one another.

Figure 1. (left to right) flat foot squat, heels raised squat, dorsiflexed kneel, plantarflexed kneel.

Results: There was a posture main effect on the peak knee adduction moment in all phases (Table 1). Post-hoc analyses revealed no significant differences between the two types of kneeling. For the descending transition and the static phase, post-hoc analyses showed a significant difference between the flat foot squat and both styles of kneeling and heels raised squatting (superscripts, Table 1, $p < 0.001$). There were no significant differences in moments between the dorsiflexed kneel and the heels raised squat. There were no sex main effects.

Table 1
Knee adduction moments. Superscripts indicate post-hoc Tukey groupings.

	Phase	Mean (+/-SD) (%BW*Ht)
Peak Adduction Moment	Descent	Plantarflexed kneel 5.11 (3.19) [a]
		Dorsiflexed kneel: 4.51 (2.85) [a]
		Heels raised squat: 4.02 (2.96)[a]
		Flat foot squat: 2.40 (1.88) [b]
Peak Adduction Moment	Ascent	Plantarflexed kneel 5.37 (3.13) [a]
		Dorsiflexed kneel: 4.91 (3.02) [a,b]
		Heels raised squat: 3.32 (3.66) [b,c]
		Flat foot squat: 2.10 (2.11) [c]
Mean Adduction Moment	Static	Plantarflexed kneel 0.70 (1.13) [a]
		Dorsiflexed kneel: 0.49 (1.05) [a]
		Heels raised squat: 0.63 (1.05) [a]
		Flat foot squat: -0.50 (1.40) [b]

Conclusions: In the majority of cases, the flat foot squat was the only high flexion posture that had moments consistently lower than all other postures. Also, static flat foot squatting produced a moment in the opposite direction (an abduction moment), which could be a distinct advantage in terms of medial loading when prolonged high flexion is required. **In order to reduce the knee joint adduction moments, with the aim of reducing the risk of injury or joint damage, flat foot squatting should be used as the high flexion posture of choice when possible.** Flat foot squatting can be challenging for those unfamiliar with the pose, however, based on the popularity of the pose as a resting posture and a toileting posture in some cultures, we expect that it can be learned with practice. If flat foot squatting is unobtainable, heels raised squatting or dorsiflexed kneeling should be employed. There were no significant differences between these postures and, since kneeling is a more stable posture due to the larger base of support, it might be more practical in applications where prolonged high flexion is required and the flat foot squat cannot be accomplished. Future work should include factors such as blood occlusion, muscular contributions, contact forces, and location of loading to further determine effects of frequent high flexion postures on biological outcomes.

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AN EXPLORATION OF A VARUS MALALIGNED PHENOTYPE IN KNEE OSTEOARTHRITIS

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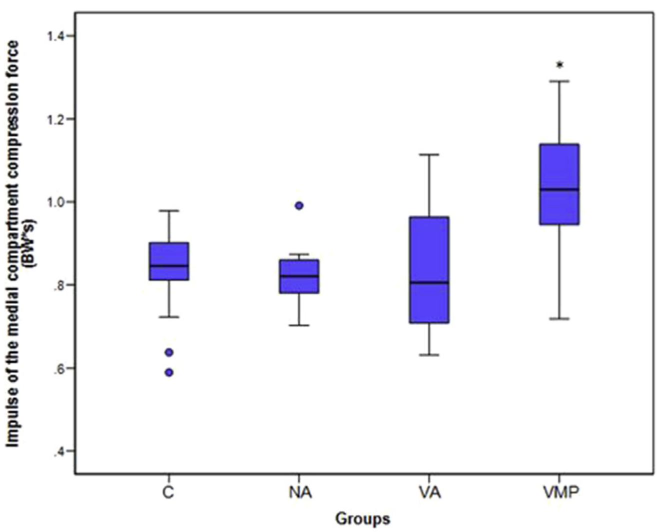
Purpose: Multiple phenotypes characterised by different disease mechanisms have been hypothesised to explain the large variability in the knee osteoarthritis (KOA) population. Repeated evidence showed that varus malalignment alone is sufficient to determine disease progression in absence of other known risk factors. Therefore, the purpose of this study is: (1) to estimate the knee compression force (CF) during the stance phase of KOA patients with a varus malaligned phenotype (VMP) characterised by exclusive degeneration of the medial compartment; (2) to compare the estimated CF and other MRI biomarkers (i.e. bone marrow lesions [BML], meniscal damage) of this VMP with a group of controls (C), a group of KOA subjects with normal alignment (NA) and a group of KOA subjects with varus malalignment and cartilage degeneration that extends to the lateral compartment (VA).

Methods: A secondary data analysis was conducted on a sample of 39 KOA subjects and 18 controls recruited for a previous study. The KOA subjects were classified using MRI cartilage biomarkers assessed with the Boston Leeds Osteoarthritis Knee Score (BLOKS) and the hip-knee-ankle (HKA) angle estimated from the gait analysis data. The patients were classified in the different groups according to the following criteria: VMP (12): varus alignment ($\geq 2^\circ$) and cartilage degeneration exclusive in the medial compartment (BLOKS ≥ 2 in the tibial or femoral medial compartment and BLOKS ≤ 1 in both femur and tibial lateral compartments). VA (17): varus alignment ($\geq 2^\circ$) and cartilage degeneration that does not meet the VMP criteria. NA (10): normal alignment ($-2^\circ < x < 2^\circ$). The medial and lateral CF corrected for body weight were estimated using an inverse dynamics model (AnyBody Modeling System, AnyBody Technology) . To examine between-group differences in the estimated knee CF, one-way analysis of covariance (ANCOVA) was used with walking speed included as a covariate. Sidak post hoc test and bootstrapping were performed to obtain robust p values. Differences in the presence of BML and meniscal damage were assessed using a chi-square exact test with post hoc correction for multiple comparisons. The relationship between alignment and medial CF was further analysed with a regression model introducing group membership as a moderator.

Results: No differences were identified in age and disease duration between the groups. The impulse of the medial CF (overall effect of the CF over the stance time) was significantly higher ($p < 0.01$) in the VMP compared to all the other groups. The peak of the medial CF was higher in the VMP compared to the VA group ($p < 0.05$), and no statistical differences were found between the VMP and the C and NA groups. No differences were found in the impulse of the lateral compartment CF. The VMP peak of the lateral CF was the lowest among the analysed groups with a $p < 0.01$ when compared to the C and NA groups. Subjects in the VMP group showed a higher prevalence of meniscal maceration in the medial compartment compared to all the other groups (VMP: 92%, VA: 28%, NA 10%, C: 6%; $p < 0.05$); and a higher prevalence of large BML

[BLOKS 2–3] in the tibia medial compartment (VMP: 83%, VA: 29%, NA 0%, C: 6%) and in the femur medial compartment (VMP: 58%, VA: 18%, NA 10%, C: 6%) compared to all the other groups ($p < 0.05$). No differences were identified for these features in the lateral compartment. The results of the regression analysis showed a significant moderation by group membership on the relationship between alignment and impulse of the medial CF ($p < 0.01$). When subjects are classified in the VMP, there is a significant relationship between alignment and impulse of the medial CF($p < 0.01$). This relationship disappears in the other groups.

Conclusions: The VMP showed higher medial joint force and lower lateral joint force compared to the other groups; in particular with the VA group despite no difference in alignment. The higher prevalence of meniscal maceration and large BML in the medial compartment of the VMP seems to confirm the hypothesis of a distinct biomechanical phenotype characterised by increased joint load. The alignment was related to the impulse of the medial CF only in the VMP. This suggests that in this phenotype, the malalignment and the increased force may be the main determinant of the knee disease while, in the VA group, other factors may be involved in the disease process and be responsible for the progression of the disease in the lateral compartment. Therefore, treatments aiming to reduce the knee force may see improved efficacy if tested in this phenotype.



C: control group.

NA: normal alignment group.

VA: varus alignment group.

VMP: varus malaligned phenotype.

*: statistical difference $p < 0.01$ compared to the C, NA and VA groups.

The blue dots in the graphs represent outliers.

Fig 1. Impulse of the medial compartment compression force by groups.

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COMPENSATORY MECHANICS DURING STAIR NEGOTIATION IN PATIENTS WITH MEDIAL KNEE OSTEOARTHRITIS.

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Purpose: In stair ascent/descent, each joint in lower extremity interact to increase/decrease potential energy of the body. Hence, patients with knee osteoarthritis (OA) would alter energetics especially at the knee joint due to their pathology, which might be strongly related to the functional ability for stair negotiation. However, there is no study investigating the relationship between mechanical work at the knee joint during stair negotiation and the stair performance. Moreover, how patients compensate altered energetics at knee joint was also unclear. The purposes of this study were to investigate relationship between energetics at the knee joint during stair negotiation and its functional ability in patients with knee OA, and to clarify the compensatory mechanics using mechanical energy analysis.

Methods: Forty patients with medial knee OA participated. Three-dimensional motion analysis system and force platforms were used to acquire biomechanical data. The participants were instructed to ascend/descend a 2-step staircase at the controlled pace of 90 bpm and repeat it 3 times. The mechanical power exhibited during whole stance phase at the 1st step was computed. Mechanical Energy Expenditure (MEE) at each joint was calculated by integral of net joint power at each joint. Mechanical Energy Compensation (MEC) was defined as the proportion of muscle energy compensated by inter-segmental energy transfer. Based on energy transfer modes, MEE and MEC were determined separately as three phases; concentric, eccentric transfer, and no-transfer phase. Timed stair test was used to measure functional ability for stair ascent/descent. Pearson's correlation coefficients were calculated to examine the relationships between the ability for stair negotiation and MEE and MEC at knee joint in each phase. If any MEE or MEC variables at the knee joint was found to be significantly correlated with the stair ascent/descent ability, stepwise regression analysis was applied to reveal which MEE and/or MEC variables at hip and ankle joints would explain the variability of knee joint work that was associated with the stair ascent/descent ability.

Results: In stair ascent, no-transfer MEE at knee joint in first half of stance were negatively correlated to the ability for stair ascent ($r = -0.33$). Namely, patients who could not generate enough energy at the knee joint when their body were elevated had lower ability for stair ascent. This MEE at the knee joint was associated with no-transfer MEE at hip joint (standardized regression coefficient = -0.39) and ankle (standardized regression coefficient = -0.34) joint (adjusted $R^2 = 0.25$). In other words, lower mechanical energy generated by knee extensor muscles' contraction was compensated by muscle power at the hip and ankle joint. The amount of mechanical energy absorbed at the knee joint in later stance of stair descent were also correlated to the ability ($r = 0.35$), which means patients who could not absorb enough mechanical energy at the knee joint when their body were lowered had lower ability. The multiple regression analysis showed that MEE at the knee joint in later stance of descent were significantly correlated with no-transfer MEE at the hip (standardized regression coefficient = -0.38) and ankle (standardized regression coefficient = -0.53) joint (adjusted $R^2 = 0.54$). This meant negative joint work at the hip and the ankle joint were required to compensate decreased energy absorption at the knee joint. Since MEE and MEC in concentric and eccentric transfer phases at the hip and the ankle joint were not correlated with the knee joint work, inter-segmental mechanical energy transfer was supposed not to compensate the deficit of the knee joint work in both stair ascent and descent.

Conclusions: Decrease in knee joint work were associated with the performance degradation in both stair ascent and descent in patients with knee OA. Moreover, mechanical energy generation/absorption by muscle contraction at the hip and the ankle joint were supposed to be capable of compensating the deficit of knee joint work. Those findings provide insights into compensatory strategies for patients with stair negotiation difficulties.

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MUSCLE ACTIVATION PATTERNS DURING STAIR ASCENT AFTER TOTAL KNEE ARTHROPLASTY

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Purpose: The total knee arthroplasty (TKA) reliably reduces pain and improves function in older adults with knee osteoarthritis. Although TKA reduces pain, functional performance deficits may persist over several months after surgery. Bade et al. described that TKA patients had less performance in stair climbing test (SCT) than healthy older adults at one month after surgery. The slower of SCT times in TKA patients may be due to functional deficit, which associated with changes in muscle activity. The previous study was reported that patellofemoral pain syndrome patients showed earlier onset of the adductor longus (AL) and later onset of the gluteus medius (GMe),