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Effect of exercise on knee joint contact forces in people following medial partial meniscectomy: A secondary analysis of a randomised controlled trial

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Title: Effect of exercise on knee joint contact forces in people following medial partial meniscectomy: A secondary analysis of a randomised controlled trial

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Highlights

- No effect of exercise on medial knee loading following meniscal surgery
- At the individual level, high variability was observed for change in knee joint loads
- Individual-specific muscle activation patterns during walking may be present
- Electromyogram-driven modelling is a novel means to analyse knee loads following exercise.

ABSTRACT

Background: Arthroscopic partial meniscectomy may cause knee osteoarthritis, which may be related to altered joint loading. Previous research has failed to demonstrate that exercise can reduce medial compartment knee loads following meniscectomy but has not considered muscular loading in their estimates.

Research question: What is the effect of exercise compared to no intervention on peak medial tibiofemoral joint contact force during walking using an electromyogram-driven neuromusculoskeletal model, following medial arthroscopic partial meniscectomy?

Methods: This is a secondary analysis of a randomized controlled trial (RCT). 41 participants aged between 30-50 years with medial arthroscopic partial meniscectomy within the past 3-12 months, were randomly allocated to either a 12-week, home-based, physiotherapist-guided exercise program or to no exercise (control group). Three-dimensional lower-body motion, ground reaction forces, and surface electromyograms from eight lower-limb muscles were acquired during self-selected normal- and fast-paced walking at baseline and follow-up. An electromyogram-driven neuromusculoskeletal model estimated medial compartment contact forces (body weight). Linear regression models evaluated between-group differences (mean difference (95% CI)).

Results: There were no significant between-group differences in the change (follow-up minus baseline) in first peak medial contact force during self-selected normal- or fast-paced walking (0.07 (-0.08 to 0.23), $P=0.34$ and 0.01 (-0.19 to 0.22), $P=0.89$ respectively). No significant between-group difference was found for change in second peak medial contact force during normal- or fast-paced walking (0.09 (-0.09 to 0.28), $P=0.31$ and 0.02 (-0.17 to 0.22), $P=0.81$ respectively). At the individual level, variability was observed for changes in first (range -26.2% to +31.7 %) and second (range -46.5% to +59.9%) peak tibiofemoral contact force.

Significance: This is the first study to apply electromyogram-driven neuromusculoskeletal modelling to an exercise intervention in a RCT. While our results suggest that a 12-week exercise program does not alter peak medial knee loads after meniscectomy, within-participant variability suggests individual-specific muscle activation patterns that warrant further investigation.

Keywords: knee biomechanics; exercise; gait; neuromusculoskeletal modelling; knee osteoarthritis, RCT, loading

1. Introduction

Meniscus damage is highly prevalent in middle-aged people, and the medial meniscus is most commonly affected [1]. Individuals who have undergone arthroscopic partial meniscectomy (APM) experience significant cartilage loss within three years [2] and are at risk of developing

knee osteoarthritis [3]. Exercise is recommended following meniscal surgery [4] and clinical trials indicate beneficial effects of exercise on self-reported symptoms [5], physical function [6], and cartilage quality [7]. However, the mechanisms underpinning the benefits of exercise post-APM are not understood and may in part be explained by altered knee joint loads.

Middle-aged people following APM have a higher medial-to-lateral distribution of knee joint loading as assessed by the external knee adduction moment (KAM) [8], which has been implicated in medial tibiofemoral structural disease onset/progression in this population [9]. Previously we have failed to demonstrate that exercise can reduce KAM during walking in people who underwent medial APM [10], and with knee osteoarthritis [11]. However, use of the KAM as an indirect measure of knee load distribution may limit our ability to detect effects of exercise on knee joint load.

The main limitation of using the KAM to infer internal joint loading is that external joint loads do not account for the contribution of muscle forces to internal load sharing. In fact, muscle forces estimated using muscle activation patterns through computational models account for a substantial proportion (>50%) of medial tibiofemoral joint contact force during walking [12,13]. Preliminary evidence in knee osteoarthritis suggests predominantly weightbearing exercises emphasising postural awareness [14] can reduce knee muscle co-contraction of agonist and antagonist muscles. Following APM there is higher overall knee muscle activation during walking [15,16], hence it is plausible that an exercise program may lower knee joint contact forces during walking in the absence of changes in the KAM. In particular, exercise that challenges dynamic knee alignment [17] may lower the contribution of muscle force to joint contact force by reducing knee muscle activation. Electromyogram-driven (EMG)

neuromusculoskeletal modelling has been developed [12,13] as a method to account for muscle activation in estimates of tibiofemoral contact force.

Our previous randomised controlled trial (RCT) compared a 12-week physiotherapist-supervised exercise program to no intervention and found no between group differences for the KAM following medial APM [10]. Using our RCT data [10], we aimed to evaluate the effect of the exercise program on peak medial tibiofemoral joint contact force during walking estimated with EMG-driven neuromusculoskeletal modelling. We also evaluated between-group differences in the relative muscle contributions to these peak contact forces and explored individual joint contact force change scores.

2. Methods

We performed a secondary analysis of data from a RCT that compared the effects of a 12-week, home-based, physiotherapist-supervised exercise program on the KAM to a control group with no intervention in people aged 30-50 years after isolated medial APM within the past 3-12 months [10,18]. The study was approved by the institutional ethics committee and all participants provided written informed consent. The same blinded assessor performed measures at baseline and follow-up at The University of Melbourne.

2.1 Participants

Participants were recruited from May 2012 to July 2013, with follow-up measures completed in November 2013. The main exclusion criteria were: (i) average overall pain severity ≥ 3 out of 10 in the past week on a numeric rating scale, (ii) moderate or severe radiographic osteoarthritis (Kellgren-Lawrence grade 3 or 4) [19], (iii) prior lower-limb surgery (other than one knee

arthroscopy), (iv) complete anterior or posterior cruciate ligament tears, and (v) body mass index $>36 \text{ kg}\cdot\text{m}^{-2}$.

2.2 Intervention

The trial protocol has been published previously [18]. Eligible participants performed a 12-week exercise program and attended physiotherapy in a private practice eight times over the 12-weeks. Participants in the exercise group performed six weightbearing exercises, aimed at strengthening the lower-limb muscles whilst maintaining neutral alignment of the lower-limb (Table 1) [10]. This program was adapted from previous studies that reported improved cartilage quality and physical function in people at risk of developing or progressing established knee osteoarthritis [6,7,17]. The first physiotherapy session focused on introducing the exercise program and lasted for 45 minutes. The remaining seven sessions lasted approximately 30 minutes and aimed to progress the exercises as appropriate. Additionally, participants were asked to perform home exercises on both legs at least three times per week throughout the 12 weeks, with adherence reported through weekly logbooks. Exercises were progressed based on the physiotherapists' assessment of quality of performance and on participants' reported pain and degree of difficulty experienced. Progression was achieved by either adding equipment, additional loads, increasing the hold phase of the exercise, changing direction, and/or changing the supporting surface. Participants were also encouraged to progress as they felt able to increase exercise sets and repetitions. Participants in the control group did not receive any intervention.

2.3 Descriptive measures

Radiographic disease severity was assessed from the screening x-ray using the Kellgren-Lawrence grading system [19]. A clinical measure of static knee alignment was taken using an

inclinometer. Self-reported knee pain, symptoms, function, and knee-related quality of life over the past week were measured with the Knee Injury and Osteoarthritis Outcome Score (KOOS) [20]. Participants also rated their knee pain severity out of 10 on an 11-point numerical rating scale (NRS).

2.4 Gait analysis

At baseline and follow-up, 12 walking trials were collected, of which six were performed at self-selected normal pace and six at self-selected fast pace. For participants who did not walk within 5% of baseline walking speed at follow-up, six additional walking trials were collected to match with $\pm 5\%$ of baseline walking speed. Primary analyses used the data set where follow-up walking speed was matched to baseline. Supplementary analyses were also performed on data with self-selected walking speed at follow-up. Kinematic and ground reaction force data were recorded using a 12-camera motion analysis system (Vicon MX, Oxford, UK) at 120 Hz and three ground-embedded force plates (AMTI, MA, USA) at 1200 Hz, respectively. Reflective markers were placed on the participants skin according to the University of Western Australia (UWA) marker set [21]. Surface EMG were acquired in each trial using a telemetered Noraxon Telemetry 900 system (Noraxon, AZ, USA) for eight major lower-limb muscles: gluteus medius, rectus femoris, vastus lateralis, vastus medialis, biceps femoris, semimembranosus, medial gastrocnemius, and lateral gastrocnemius. EMG were amplified 2000 times and digitised at 1080 samples utilizing the 16-bit analogue inputs of the Vicon motion analysis system. EMG recordings for each of the eight muscles were also obtained during a set of maximum voluntary exertion isometric strength trials as previously described [18] for knee flexion, knee extension, hip abduction and plantarflexion.

A flowchart of the secondary data analysis process is provided in Figure 1 and has been provided in detail previously [12]. Pre-processing of laboratory force plate, marker, and EMG data was performed within Matlab (MathWorks, 2018a) using MOtoNMS [22]. The raw EMG data were first band-pass filtered (30–400 Hz), fully rectified, then low-pass filtered using zero-lag 2nd order Butterworth filters with 6 Hz low-pass frequency. The linear envelopes obtained were then amplitude-normalized to the maximum EMG value recorded during the maximal voluntary exertion trials at both time points. A generic, full-body musculoskeletal model [23] was used within OpenSim [24], which had three rotational degrees of freedom at the hip, one at the knee, and one at the ankle. Lower-limb model segment lengths were linearly scaled to match individual's anthropometry using distances between pairs of markers that were acquired during a static pose and corresponding model markers. Once scaled, OpenSim inverse kinematics, inverse dynamics, and muscle analysis tools were used to determine the lower-limb joint kinematics, joint moments, and muscle-tendon unit kinematics, respectively.

The modelled joint moments, muscle-tendon unit kinematics, and processed EMG were then used to calibrate an EMG-driven neuromusculoskeletal model for each participant using the Calibrated EMG-Informed Neuromusculoskeletal modelling toolbox (CEINMS) [25]. The eight experimental EMG signals were mapped to thirteen muscle-tendon units in the model [25,26]. A hybrid-mode neural solution within CEINMS was used for this dataset [26], which allows for excitation patterns to be constructed using optimisation algorithms for muscles that were not, or could not, be collected experimentally through EMG (e.g., deep hip muscles).

For each participant, muscular parameters of muscles spanning the tibiofemoral joint were first optimised using morphometric scaling [27]. In a subset of walking trials, activation dynamics and muscular model parameters were then functionally calibrated in CEINMS by minimising the

squared error between (i) knee flexion-extension moments generated by CEINMS and estimated through inverse-dynamics, and (ii) by penalising excessively large or low peak tibiofemoral joint contact forces [12]. Following calibration, CEINMS was used to estimate the muscle forces from experimental EMG and muscle-tendon unit kinematics for the remaining walking trials that were not used for calibration. These muscle forces were used as inputs into a planar knee mechanism to estimate medial and lateral tibiofemoral contact forces [13]. The relative contribution of muscle forces and external loads to compartmental tibiofemoral contact force were determined by summing the muscle moments about the medial and lateral contact points (total muscle) and summing the KAM and frontal plane contact moments (total external) [12,13].

2.5 Gait variables

The first and second peak of medial tibiofemoral joint contact force normalised to bodyweight (BW) during normal- and fast-paced walking were assessed. Other outcomes included the percentage of muscle contribution to first and second peak medial tibiofemoral joint contact force and mean percentage of muscle contribution to medial tibiofemoral joint contact force during stance phase. Individual participant change scores (% from baseline) for first and second peak medial tibiofemoral contact force were extracted.

2.6 Statistical analysis

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS), version 25 (IBM, New York, USA) with significance at $P < 0.05$. Independent t-tests compared baseline characteristics and original study primary outcomes of participants who had complete data and incomplete data. Shapiro-Wilk tests and visual inspection of Q-Q plots were used to examine data distribution. Consistent with the analytical approach of the original RCT [10], linear

regression models were used to determine the effects of the exercise program on the change in peaks of medial tibiofemoral joint contact forces and relative contribution of the muscles to joint contact forces, accounting for baseline scores of the relevant variable. Residuals of each model conformed to appropriate assumptions (i.e., scatter plots of residuals satisfied the assumption of normality and constant variance).

3. Results

Forty-one of the 62 (66%) participants randomised had valid data suitable for this secondary analysis (Table 2). Two participants (3%) from the control group did not return for follow-up assessment during the original trial, and 19 participants (31%) (exercise group = 10, control group = 9) had incomplete EMG data due to technical issues with equipment. The cohort was middle-aged, predominantly male and had minimal pain (Table 2). There were no baseline differences in participant characteristics or primary trial outcomes (i.e., peak KAM and KAM impulse) between those included in the analysis and those who were not (data not shown). There were no significant between-group differences in spatiotemporal variables and joint kinematics over 12 weeks (Table 3; Supplementary Table 1). Visual inspection of ensemble averaged medial tibiofemoral joint contact force (time-normalized over stance phase), revealed similar waveforms across groups at follow-up (Figure 2).

There were no significant between-group differences in first or second peak of the medial tibiofemoral joint contact force during normal- or fast-paced walking over 12 weeks (Table 3). Muscle contribution to first peak, second peak and overall stance medial tibiofemoral joint contact did not change significantly between groups at normal- or fast-paced walking. There was notable variation in individual change scores for first (range -26.2% to +31.7%) and second (range -46.5% to +59.9%) peak medial tibiofemoral joint contact forces during normal- and fast-

paced walking (Figure 3). Results were similar with supplementary analyses using the data set with self-selected follow-up walking speeds (Supplementary Table 2).

4. Discussion

Exercise is recommended following meniscectomy [4] with demonstrated improvements in symptoms and cartilage quality [5-7]. Benefits of exercise may be partly attributable to reductions in medial tibiofemoral joint contact force. Previous studies have used the external KAM as a surrogate of knee load distribution, but this does not account for the muscle contribution to tibiofemoral joint contact force. To overcome this limitation, we implemented an EMG-driven neuromusculoskeletal model to estimate medial tibiofemoral joint contact forces, and the relative muscle contributions to these contact forces. However, preliminary evidence suggests that the exercise program did not reduce peak medial tibiofemoral joint contact force in our study population.

The first and second peak contact force of the medial tibiofemoral joint were selected as the main outcomes of interest in this secondary analysis due to the association between the KAM and cartilage loss and defects following medial APM [9]. Following APM, people demonstrate higher levels of knee muscle activation during walking [15,16]. An exercise program [17], with a focus on functional stability and neutral alignment of the lower-limb was thought to reduce medial tibiofemoral joint contact force by targeting lower-limb motor control that would facilitate muscular unloading of the medial compartment. Despite this reasoning, the results did not show reductions in medial tibiofemoral joint contact force in response to exercise. There were no between-group differences in the change in overall muscle contribution to medial tibiofemoral joint contact force during stance phase. Overall, our findings suggest that exercise,

as assessed in this study, does not result in reductions in peak medial knee joint contact force compared to no exercise in this population.

There are several factors that could explain why we failed to observe a reduction in peak medial tibiofemoral joint contact force with our exercise program. As expected, the mean relative contributions of muscle to medial tibiofemoral joint contact force across the stance phase of gait were higher at baseline than those reported in healthy adults, estimated using similar methods [12]. However, there was no significant between-group change for mean muscle contribution to contact force across stance at either walking pace. This suggests the exercise program used in this study did not cause favorable reductions in muscle activation that would unload the medial tibiofemoral joint. A key feature of the exercise program was to challenge alignment of the lower limb. However, as our participants had on average static neutral knee alignment, this program may have had a limited capacity to reduce medial contact force through dynamic knee realignment. Knee malalignment is associated with poorer disease prognosis and reduced response to traditional quadriceps strengthening in those with established knee osteoarthritis [11]. Indeed, knee alignment may be an important consideration in determining exercise program selection in the APM population as well. Our participants reported less difficulty in performing activities related to sport and recreation compared to APM populations within 3-5 years after surgery [10, 28]. It is possible that the exercise program may have lacked the intensity required to challenge the knee stabilising muscles to produce favorable adaptations in a group of high functioning participants. Our exercise program may also have lacked training specificity to target medial contact force during walking as none of the exercises in our program mimicked the heel-to-toe action of walking.

Irrespective of group, substantial individual participant variability was observed for change in medial tibiofemoral joint contact force over the 12 weeks (Figure 3). The variation evident across the groups may in part be due to participants exhibiting individual-specific muscle activation patterns during walking. Similar variability has been reported previously using real-time estimation of tibiofemoral contact forces, in which individuals used different gait strategies to influence their medial tibiofemoral contact force [29]. Indeed, gait biofeedback to alter tibiofemoral joint contact force may be an appropriate adjunct to an exercise intervention. Nonetheless, further research is required to understand how individuals exhibit these patterns and whether more patient-specific exercise programs should be developed, to conclusively understand the effect of exercise on medial knee joint loading. Interestingly, 70% of participants in the exercise group and 55% of the control group increased in first peak medial tibiofemoral joint contact force during normal-paced walking. In the absence of minimal detectable change scores for the model used in this study, it is unclear what threshold represents real change. Importantly, the minimal clinically important differences in tibiofemoral joint contact forces are unknown for optimal knee joint structure or symptoms. Thus, limited inferences can be made from the individual change scores in peak medial tibiofemoral joint contact forces.

This secondary analysis is the first to apply an EMG-driven neuromusculoskeletal model to determine the effects of exercise on tibiofemoral contact force, in any population. Strengths of this study also include its rigorous randomised controlled study design and good self-reported adherence to the exercise program (from 36 required exercise sessions, the exercise group self-logged a mean of 71% sessions (median 29, interquartile range 10)), and excellent attendance to the eight physiotherapy sessions (mean 91%, median 8, interquartile range 1). Several limitations warrant consideration. First, this study was not designed a priori to detect between-group

differences in changes in medial tibiofemoral joint contact forces and thus its findings should be considered exploratory (hypothesis-generating) rather than conclusive. Second, the maximal EMG contractions used to scale the EMG for analysis may not have been true maximums, which may have resulted in over-estimations of muscle activations during the walking tasks and subsequently increased estimates of tibiofemoral contact forces. However, this should not impact on the between-group findings as both groups had minimal pain. Third, we used a generic anatomic model [23], rather than a patient-specific model to model musculoskeletal biomechanics. Patient-specific anatomic models use imaging to inform anatomic geometry and increase accuracy of estimated tibiofemoral contact force compared to a generic anatomic model [30]. However, these models require expensive imaging, which was not an option for the original RCT. Nonetheless, a similar generic anatomic model has previously demonstrated acceptable accuracy when compared to in-vivo instrumented knee prostheses [13].

5. Conclusion

These exploratory findings suggest that our 12-week exercise program did not reduce peak medial tibiofemoral joint contact force in people 3-12 months following APM. Further research using EMG-driven neuromusculoskeletal modelling is required to confirm these findings, and conclusively determine whether exercise can alter medial tibiofemoral joint contact force.

Author contributions: MH, DJS, RH, KB, DGL conceived the idea for the paper. MH and TW contributed to data acquisition. SS, GL, DJS and MH contributed to data analysis. SS, MH and DJS wrote the first draft of the article. All authors provided scientific input and revised the paper. All authors approved the final version of the manuscript.

6. Conflict of interest statement

No authors have a conflict of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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Figure 1 (Colour). Flowchart outlining the secondary data analysis process from data capture (inputs) to study outcomes (outputs).

Figure 2 (Colour). Ensemble average ($\pm$ standard deviation) medial tibiofemoral joint contact force at follow-up during (A) normal-paced walking and (B) fast-paced walking.

Figure 3. Change from baseline in (A) first peak and (B) second peak medial tibiofemoral joint contact force (%) for each participant during normal- and fast-paced walking.

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Table 1. Outline of exercise program

Exercise	Primary muscles	Description of starting level
Abdominal curls	Abdominals	Abdominal curls performed in supine with both knees flexed on exercise ball and arms along sides (short lever arm)
Bridge	Gluteals, hamstrings, and hip adductors	Performed in supine with knees flexed on the exercise ball, participants lift pelvis up and hold the position whilst squeezing a towel between knees and then return to starting position
Lunge	Gluteals, quadriceps, and hamstrings	Standing upright, participants take a large step forwards into a lunge then return to starting position
Incomplete circle	Hip abductors	Performed in a unipedal stance while the opposite leg rotates in a semi-circular motion
Get tapping	Knee extensors and hip abductors	Performed in a unipedal stance on a stepper, as the opposite leg taps the ground behind the step
Knee bends	Quadriceps, gluteals, and hip abductors	Performed in a bipedal stance in front of a chair with feet hip width apart and feet in full contact with the floor. Knees are bent so the bottom nearly touches the chair, then returned to starting position

Table 2. Demographic and clinical characteristics of the participants included in this secondary analysis, according to exercise and control groups. Mean (SD) or n (%) unless otherwise stated.

Characteristics	Exercise group (n=20)	Control group (n = 21)
Age, yr	43.0 (5.1)	43.2 (6.1)
Males, %	16 (80%)	15 (71%)
Height, m	1.77 (0.7)	1.74 (5.9)
Body mass, kg	84.2 (10.1)	81.1 (9.9)
Body mass index, kg m ⁻²	26.8 (2.9)	26.4 (3.2)
Affected knee (right:left)	14:6	13:8
Dominant side affected	18 (90%)	20 (95%)
Time from surgery (months)	6.2 (3.0)	6.4 (2.8)
Average knee pain over the past week ^a	1.1 (0.8)	1.1 (0.9)
Knee alignment ^b (°)	1.5 (2.0)	0.4 (2.4)
KOOS ^c		
Pain	86.8 (10.6)	87.4 (9.6)
Symptoms	87.3 (15.8)	85.9 (9.9)
Physical function	95.5 (6.1)	93.7 (8.9)
Sport and recreation	83.8 (15.2)	80.5 (16.0)
Quality of life	65.9 (23.7)	67.9 (19.0)
Radiographic disease severity ^d		
Grade 0	9 (45%)	8 (38%)
Grade 1	5 (25%)	8 (38%)
Grade 2	6 (30%)	6 (29%)

^a Numerical Rating Scale (scored out of 10, higher indicates more pain); ^b Values greater than zero indicate varus; ^c KOOS: Knee Injury and Osteoarthritis Outcome Score (normalised to score of 100, lower indicates worse symptoms); ^d Kellgren-Lawrence grading system.

Table 3. Mean (SD) of groups and mean (95% CI) change within and between groups, adjusted for baseline scores.

Outcome	Groups				Within Group Change		Difference in Change Between-group	
	Baseline		Follow-up		Follow-up minus Baseline		Exercise minus Control	P Value
	Exercise	Control	Exercise	Control	Exercise	Control		
Normal pace	(n = 20)	(n = 20)	(n = 20)	(n = 20)	(n = 20)	(n = 20)		
Walking speed	1.35 (0.15)	1.37 (0.14)	1.37	1.40	0.02 (-0.01, 0.05)	0.04 (-0.01, 0.08)	-0.02 (-0.07, 0.03)	0.43
<i>Joint contact forces</i>								
First peak medial	2.12 (0.33)	2.04 (0.38)	2.20	2.09	0.08 (-0.05, 0.21)	0.04 (-0.10, 0.18)	0.07 (-0.08, 0.22)	0.34
Second peak medial	1.46 (0.22)	1.39 (0.29)	1.49	1.40	0.04 (-0.15, 0.23)	0.00 (-0.17, 0.18)	0.09 (-0.09, 0.27)	0.31
<i>Muscle</i>								
First peak medial	60.14	56.09	60.06	57.00	-0.08 (-0.45, 0.29)	0.91 (-2.44, 4.26)	1.68 (-3.60, 6.96)	0.52
Second peak medial	87.85	89.02	92.24	91.79	4.39 (-0.76, 9.54)	2.77 (-0.63, 6.17)	0.63 (-2.53, 3.79)	0.69
Overall stance medial	70.99 (6.00)	65.44	72.12	67.82	1.13 (-2.81, 5.07)	2.38 (-0.51, 5.27)	2.67 (-1.43, 6.77)	0.20
Fast pace walking	(n = 20)	(n = 21)	(n = 20)	(n = 21)	(n = 20)	(n = 21)		
Walking speed	1.84 (0.18)	1.91 (0.21)	1.81	1.86	-0.03 (-0.10, 0.04)	-0.04 (-0.10, 0.03)	0.01 (-0.07, 0.09)	0.77
<i>Joint contact</i>								
First peak medial	2.75 (0.34)	2.84 (0.38)	2.82	2.85	0.07 (-0.11, 0.25)	0.02 (-0.13, 0.17)	0.01 (-0.19, 0.21)	0.89
Second peak	1.62 (0.31)	1.44 (0.25)	1.54	1.40	-0.08 (-0.25, 0.09)	-0.04 (-0.15, 0.08)	0.02 (-0.17, 0.21)	0.81
<i>Muscle</i>								
First peak medial	62.12 (6.81)	58.37	61.48	57.98	-0.64 (-1.48, 0.20)	-0.39 (-1.15, 0.37)	1.69 (-1.45, 4.83)	0.28
Second peak	75.83	75.97	82.81	78.52	6.98 (-0.97, 14.93)	2.54 (-2.17, 7.25)	4.33 (-1.90, 10.56)	0.17
Overall stance	74.49 (5.00)	69.55	73.96	70.22	-0.53 (-1.60, 0.54)	0.68 (-1.28, 2.64)	0.62 (-2.87, 4.11)	0.72