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Does frontal knee kinematics predict treatment outcomes? Exploratory analyses from the Intensive Diet and Exercise for Arthritis (IDEA) trial

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ABSTRACT

Background: Pain is a cardinal symptom of knee osteoarthritis (OA) and although conservative treatments such as exercise and diet related interventions can reduce pain, effects are modest and can be improved. Frontal plane knee joint motion has been associated with knee pain, and is suggested as a patient-specific characteristic on which to tailor interventions.
Research question: Does the association between baseline frontal plane knee joint kinematics and pain-relief differ among overweight and obese people with knee OA who underwent an intervention from the Intensive Diet and Exercise for Arthritis (IDEA) clinical trial: diet-only, exercise-only, and combined diet and exercise intervention?
Methods: 323 participants with knee OA were included in the analysis (77% females; 66 ± 6 years; 33.5 ± 3.7 kg/m^2). At baseline, frontal plane knee joint kinematics during walking were measured using 3-dimensional gait analysis and characterised as peak varus-valgus knee angle, peak varus-valgus excursion, and peak varus angular velocity. Pain was assessed at baseline and 18-month follow-up using the Western Ontario and McMaster Universities Osteoarthritis Index pain subscale. Linear regressions were performed unadjusted and adjusted for covariates to determine if the associations between baseline frontal plane knee joint kinematics and 18-month change in pain differed according to intervention.
Results: The interaction terms between the intervention and measures of frontal plane knee joint kinematics were not statistically significant (all P ≥ 0.05).
Significance: We found no evidence to suggest that 18-months of either exercise, diet, or a combination of diet and exercise could be more effective than the other to improve pain based on frontal plane measures of knee kinematics.

1. Introduction

Core conservative treatments recommended by clinical guidelines to treat knee osteoarthritis (OA) include exercise and weight loss for those who are overweight or obese [1]. While diet and exercise are effective interventions, and the combination can reduce pain by over 50% [2]; tailoring these interventions to patient-specific characteristics may further enhance their effectiveness. Specifically, knee position in the frontal knee plane may, in part, predict clinical outcomes of treatments [3,4]. Frontal plane knee kinematics are related to knee load and disease severity [5]. In addition to frontal plane static malalignment, osteoarthritic knees can present with altered dynamic movement in the frontal plane [3,6]. Both objective and subjective techniques are used to characterise frontal plane knee kinematics [3,6–9]. Objective measures include knee excursion, [8,9] peak varus-valgus angle and peak varus knee angular velocity, [7,8] of which the latter two are related to a varus thrust assessed subjectively [7].

Individuals with knee OA who have a varus thrust are four times more likely to have pain compared to patients without varus thrust [10] .Exploratory analysis from a randomised controlled trial (RCT) suggests that varus thrust moderates pain-relief when comparing two different types of exercise (neuromuscular versus quadriceps strengthening) in patients with medial compartment knee OA [3]. To date, no study has examined the effect of varus thrust on knee pain in people undergoing

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diet interventions. It is reasonable to speculate that exercise could improve control of frontal plane knee kinematics during walking by altering knee muscle activation patterns [11] and strengthening the knee muscles [12], and thereby reduce pain. Alternatively, the effects of weight-loss are less obvious and unlikely to alter frontal plane knee kinematics during walking. Hence, it possible that participants with greater measures of frontal plane knee kinematics would have greater-pain relief undergoing exercise, compared to those undergoing weight loss. Given that frontal plane knee joint kinematics are quantifiable in a clinical-setting, finding clinically important moderators could potentially increase the efficacy of core treatments for knee OA.

The Intensive Diet and Exercise for Arthritis (IDEA) clinical trial assessed the effect of three inventions: i) diet-only, ii) exercise-only, and iii) combination of diet and exercise on self-reported pain over 18-months in overweight and obese individuals with knee OA [2]. Participants' treatment responses varied within each intervention and this variation may have partially depended on frontal plane knee joint kinematics. Therefore, in overweight and obese individuals with knee OA, the objective of this exploratory study was to determine if the effect of the IDEA interventions (diet-only, exercise-only, and combined diet and exercise) on pain were moderated by baseline frontal plane knee joint kinematics. We hypothesised that participants with greater frontal plane knee kinematics would have greater pain-relief undergoing exercise (either in the exercise only intervention or the combined diet and exercise intervention) compared to those undergoing diet-only.

2. Methods

2.1. Study design

This study utilised data from a single-blind, 18-month, randomised controlled trial (IDEA) [2]. The sample size calculation was estimated for original IDEA trial [2] to detect a 20% difference in interleukin-6 and a 15% difference in knee joint loads at the two-sided 0.008 significance level (adjusted for 3 pairwise intervention comparisons and 2 outcomes) with 80% retention. The human subjects committee of Wake Forest Health Sciences approved the study and all participants provided written informed consent. Baseline measures of frontal plane knee joint kinematics were acquired from the symptomatic knee and the most symptomatic knee in bilaterally eligible cases before the intervention.

2.2. Participants

Participants were recruited from the community between November 2006 – December 2009. The primary recruitment strategies included mass mailings (existing databases), newspaper advertisements and presentations within local community organisations (e.g. senior centres and churches). For the IDEA trial, 454 participants enrolled into trial following application of the following eligibility criteria. Eligibility criteria included: i) age ≥ 55 years; ii) Kellgren-Lawrence (KL) grade 2 or 3 tibiofemoral OA or in combination with patellofemoral OA of one or both knees, [13] iii) pain on most days of the week as a result of knee OA; iv) body mass index (BMI) from 27 kg/m^2 to 41 kg/m^2; and v) sedentary lifestyle (< 30 min/week of formal exercise within the past 6 months). Exclusion criteria included: i) significant co-morbid disease that would pose a safety threat or impair ability to participate; ii) a previous acute knee injury; iii) patellofemoral OA in the absence of tibiofemoral OA; iv) unwillingness or inability to modify dietary or exercise behaviours; v) excessive alcohol use; vi) any condition that prohibited knee magnetic resonance imaging; and vii) significant cognitive impairment or depression. Since the rationale for our study was based on preliminary evidence that varus thrust may influence pain-relief following an exercise intervention [3], we included only those participants with a greater peak varus angular velocity compared to peak valgus angular velocity. Participants with incomplete pain data were also excluded.

Table 1
Demographic, clinical and biomechanical characteristics of study participants at baseline.

Variable	Overall n = 323	Exercise only n = 113	Diet-only n = 103	Diet & Exercise n = 107
Age, mean (SD), yr	66 (6)	66 (6)	66 (6)	66 (6)
Female, n (%)	251 (77)	88 (78)	80 (78)	83 (78)
BMI, mean (SD), kg/m^2	33.5 (3.7)	33.4 (3.7)	33.4 (3.8)	33.6 (3.7)
Kellgren-Lawrence grade 2, n (%)	160 (49)	58.0 (51)	49.0 (48)	53.0 (50)
WOMAC pain (0–20)	6.5 (3.1)	6.0 (2.9)	6.3 (3.1)	6.9 (3.4)
StaticAlignment[a]				
Valgus (< 0 deg), n (%)	134 (44)	44 (40)	43 (43)	48 (47.5)
Neutral (0–2 deg), n (%)	60 (19)	24 (22)	20 (20)	16 (15.8)
Varus (2+ deg), n (%)	114 (37)	41 (38)	36 (39)	37 (36.6)
Gait related variables				
Gait speed (m/s)	1.22 (0.18)	1.24 (0.17)	1.20 (0.18)	1.21 (0.19)
Peak valgus-varus angle (deg)	−1.4 (5.6)	−1.6 (5.5)	−1.6 (5.8)	−0.9 (5.5)
Knee excursion (deg)	4.6 (1.9)	4.7 (1.6)	4.5 (2.0)	4.6 (2.1)
Peak varus angular velocity (deg/s)	54.3 (20.7)	54.0 (18.1)	55.7 (24.3)	53.2 (20.0)

BMI: body mass index; WOMAC: Western Ontario and McMaster Universities Osteoarthritis.
[a] Static alignment; overall n = 309; exercise only group n = 109; diet only group n = 99; diet and exercise group n = 101.

2.3. Interventions

A detailed protocol of the interventions and randomisation has been previously published [2,14]. Following baseline assessments, a stratified-block randomisation method (stratified by BMI and sex) was used to assign all eligible participants to one of three 18-month interventions: i) diet-only; ii) exercise-only; and iii) diet and exercise. Both the diet alone group and combined diet and exercise group underwent the same dietary intervention [14]. The exercise intervention was similar for the exercise only group and for the combined diet and exercise group [14]. This study was conducted at Wake Forest University and Wake Forest School of Medicine between July 2006 and April 2011.

2.4. Baseline only measures

Lower limb static alignment was measured from a short-length anteroposterior radiograph according to previously described methods [15]. Using established cut-points, participants were categorized as having either varus malalignment (static alignment > 2°); valgus alignment (static alignment < 0°); or neutral alignment (static alignment between 0° and 2°) [16].

Frontal plane knee kinematics were assessed using a motion analysis system (Motion Analysis Corp., Santa Rosa, CA, USA) with six cameras operating at 60 Hz and the standard Cleveland Clinic 37-marker set. Participants performed six trials at a self-selected pace within 3.5% of pre-determined preferred self-selected walking speed. Walking speed was monitored using a Lafayette Model 63501 photoelectric control system with photocells positioned 7.3 m apart. Every participant wore the same make and model of shoe (Nike Air Pegasus) during gait analysis. Raw kinematic coordinate data were filtered using a Butterworth low-pass digital filter with a cut-off frequency of 6 Hz. Segmental coordinate systems were located with origins in the proximal end of each segment and with X, Y, and Z axes corresponding to the mediolateral, anteroposterior, and vertical (axial) directions. Knee joint angle was quantified using a Cardan angle sequence of flexion-extension (X), varus-valgus (Y), and internal-external rotation (X). Frontal plane knee joint kinematics were extracted during the first 40% of gait cycle and included: i) peak varus-valgus knee angle; ii) excursion, defined as the

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