Is barefoot regional plantar loading related to self-reported foot pain in patients with midfoot osteoarthritis

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Objective: While recent evidence suggests that foot pain may be related to mechanical stress, quantitative data elucidating the role of regional plantar loading in foot pain in individuals with midfoot osteoarthritis (OA) are lacking. Therefore the authors’ objective is to examine regional plantar loading and self-reported foot pain in patients with midfoot OA compared to asymptomatic, matched control subjects.

Method: Fifty subjects, 30 patients with midfoot OA and 20 control subjects participated in this study. Self-reported function was assessed using the Foot Function Index – Revised (FFI-R). Plantar loading during barefoot walking at self-selected, monitored walking speed was quantified using an EMED pedobarograph. Between-group differences in FFI-R score and plantar loading were assessed using an independent t-test and the Mann–Whitney U-test respectively. The relationship between FFI-R score and plantar loading was assessed using Spearman rank correlation. A k-means cluster analysis was used to identify potential sub-groups of patients through regional plantar loading.

Results: The key findings of this study showed that patients with midfoot OA reported significantly higher FFI-R scores, and higher heel and medial midfoot average pressure compared to control subjects. Medial midfoot pressure-time integral was positively associated with FFI-R Pain Subscale Score ($r = 0.524$, $P < 0.01$). Based on the adequacy index, the two-cluster solution was deemed most appropriate.

Conclusion: This study demonstrated that patients with midfoot OA sustain increased magnitude and duration of regional plantar loading during walking compared to matched control subjects. Our findings support the theory that regional mechanical stress may be associated with symptoms in patients with midfoot OA. Future studies should assess whether interventions designed to reduce plantar loading are effective in relieving foot pain, and preventing progression of symptoms in patients with midfoot OA.

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SUMMARY

Introduction

The incidence and progression of osteoarthritis (OA), characterized by progressive loss of articular cartilage and attendant pain and disability, has been linked to mechanical stress sustained during weight-bearing activities of daily living. Increasing evidence indicates that mechanical stress plays an important role in cartilage homeostasis because chondrocytes function as mechanotransducers and respond to their mechanical milieu by upregulating synthetic activity or increasing the production of inflammatory cytokines and matrix-degrading enzymes. Progressive cartilage breakdown is accompanied by increasing disease severity, pain and disability. While the role of mechanical stress and patients’ self-reported pain and disability has been assessed in patients with OA of the knee joint, few studies have assessed mechanical stress in patients who have arthritis in the joints of the foot.

OA of the tarso-metatarsal joints (midfoot) has emerged as a challenging problem due to its high potential for foot pain and chronic secondary disability. Individuals with midfoot OA experience foot pain which limits their participation in walking and weight-bearing activities. Midfoot injuries affect approximately 55,000 people per year and are commonly seen in the athletic population. Despite their seemingly low incidence, they are particularly concerning because as many as 20% are missed or misdiagnosed. In recent years, these injuries have increased with alarming incidence as a consequence of plantar impact sustained in restrained motor vehicle trauma. Additionally, as our population ages, chronic increased joint loads sustained with high heeled...
footwear may be linked to the development of midfoot OA, irrespective of the mechanism of trauma, midfoot OA has been reported to be inevitable sequelae of significant tarsometatarsal joint disease.

Recent evidence from a variety of clinical populations suggests that foot pain may be related to mechanical stress, quantified as regional plantar loading. Mechanical stress, combined with local and central sensitization of neural pathways, may interact with inflammatory mediators and contribute to pain perception in patients with OA. Additionally, regional loading may influence net joint reaction forces and moments, and lead to abnormal articular (joint) stress. Burns et al. (2005) reported a significant positive relationship between total foot pressure time integral and foot pain in patients with rigid high arches secondary to pes cavus foot deformity. In patients with acquired flat foot deformity and hindfoot pain, Ellis et al. noted increased lateral midfoot pressure and concomitant degenerative changes at the subtalar joint, following surgical correction of flat foot deformity. Compared to asymptomatic control subjects, patients with OA of the first metatarsophalangeal joint (hallux rigidus/limitus), demonstrated higher plantar loads under the great toe region. Taken together, these studies suggest that increased regional plantar loads may contribute to mechanical overloading and consequently, to foot pain in patients with foot pathology.

While growing evidence confirms the presence of elevated regional plantar loading and foot pain in patients with rheumatoid arthritis compared to control subjects, within-group analyses in studies examining the relationship between regional plantar loading and foot pain have reported conflicting results. One recent report found greater lateral forefoot loading in patients with rheumatoid arthritis and higher Health Assessment Questionnaire (HAQ) score (less disability, less pain) compared to patients with lower HAQ score. These results may suggest that patients with lower HAQ score (more disability, more pain) may adopt an antalgic loading strategy characterized by lower plantar loading. In contrast, two other studies have reported that elevated plantar loading is associated with increasing foot pain in patients with foot pain may demonstrate either an antalgic strategy (increasing pain associated with lower loading) or a mechanical overloading strategy (increasing pain associated with higher loading), and underscore gaps in current knowledge elucidating the relationship between regional plantar loading and foot pain. Further, while regional plantar loading has been identified as a key determinant in mediating foot pain, previous studies have been limited to patients with neurogenic foot problems or inflammatory arthritis. Midfoot OA differs from neurogenic foot pain and inflammatory arthritis both in the etiology, as well as location of pain. Quantitative data elucidating the role of regional plantar loading in foot pain in individuals with midfoot OA are lacking.

Walking has been ranked as the highest priority for improvement by patients seeking specialized care for foot and ankle disorders. In order to design the most effective intervention and minimize secondary disability in patients with midfoot OA, investigations that critically evaluate factors contributing to foot pain during functional activities are essential. Based on these data, corrective intervention may be designed and instituted to optimize patients’ function. The purpose of our study was to examine regional plantar loading and self-reported foot pain in patients with midfoot OA compared to asymptomatic, matched control subjects using between-group comparisons. In addition, we sought to examine the relationship between plantar loading and self-reported foot pain, using linear correlations and within-group analysis of clusters.

Methods

Subjects

The sample comprised 50 subjects, 30 patients with midfoot OA and 20 asymptomatic control subjects, matched in age, sex and body mass index. All procedures were approved by the Institutional Review Boards of Ithaca College and the University of Rochester. Patients were recruited from the Outpatient Orthopedic Clinic at the University of Rochester Medical Center. All data were collected at the Movement Analysis Lab, Center for Foot and Ankle Research, at the Department of Physical Therapy, Ithaca College — Rochester Center, Rochester, NY, USA.

Inclusion and exclusion criteria

All patients presented with unilateral foot pain localized to the medial tarso-metatarsal region, and aggravated by weight bearing. The diagnosis of isolated midfoot OA was confirmed by radiographic evidence of degenerative changes at one or more tarsometatarsal joints on antero-posterior and lateral weight-bearing radiographs. All patients diagnosed with midfoot OA were invited to participate in this study with the following exclusion criteria: (1) injury or surgery of the lower extremity within the past 6 months, (2) other conditions such as stroke that may affect walking, or (3) use of assistive devices such as a cane or walker. Sixty-eight patients with medial foot pain were screened and 32 met the inclusion criteria. Twenty-five patients had a history of injury or surgery to the index lower extremity over the last 6 months, six patients had diabetes, five patients used an assistive device (cane) during walking. Of the 32 patients who met the inclusion criteria, two refused to participate for logistical reasons (lived more than 2 h away). Since the purpose of this study was to examine regional plantar loading and foot pain in patients with midfoot OA compared to matched control subjects, medial midfoot average pressure served as the primary outcome measure. Based on normative data from previous reports using similar methodology to evaluate medial midfoot average pressure, a priori power analysis indicated that group sizes of 18 and 18 are needed to achieve 81% power to detect a moderate effect size (Cohen’s d = 0.55) with a significance level (alpha) of 0.05, using a two-sided Mann—Whitney test.

Radiographic assessment

Degenerative changes were assessed using medial longitudinal arch alignment, quantified as the calcaneal-first metatarsal angle (Fig. 1) on the lateral radiograph. and Kellgren Lawrence grades

Fig. 1. Weight bearing lateral radiograph depicting calcaneal-first metatarsal angle, used to characterize medial longitudinal arch alignment.
on lateral and anterior–posterior radiographs. A single rater obtained all radiographic measurements. Personal identifiers were eliminated from radiographs and three blinded readings (i.e., the rater was not allowed to refer to the previous reading) of each measurement were made. Intra-rater reliability was examined using Intra-class Correlation Coefficient (ICC) (Model (3,3))\(^{31,32}\).

Excellent intra-rater reliability, reflected in ICC(3,3) of 0.96, 0.95 and 0.93, for calcaneal-first metatarsal angle, lateral and anterior–posterior tarsometatarsal Kellgren Lawrence grade respectively, was noted. Lower arch alignment was noted in patients with midfoot OA. Patients with midfoot OA demonstrated calcaneal-first metatarsal angle of 145° (standard deviation (SD): 8) compared to normative values of 132° (SD: 11)\(^{28,29}\). Median Kellgren Lawrence grades and percentage of patients showing degenerative changes at each articulation (Kellgren Lawrence grade 1 and higher) are reported in Table I.

### Control group

Asymptomatic subjects were recruited from the community using fliers, screened by a single trained physical therapist (SR) for lower extremity pain and/or dysfunction, and were matched for age, gender and BMI to patients with midfoot OA. Demographic characteristics of the study and control group are summarized in Table II.

### Self-reported pain and foot function

The Foot Function Index – Revised (FFI-R) was used to assess self-reported pain and foot function. The FFI-R is the revised version\(^{33}\) of an anatomically-specific outcomes instrument with previously established validity, test–retest reliability, internal consistency and responsiveness\(^{33–37}\). The FFI-R assesses self-reported foot function the following dimensions: pain, activity limitation, disability and psychosocial issues. Psychometric properties of the FFI-R have been tested using Rasch analysis, and established on a sample of 92 patients, of whom slightly over two-thirds (63/92, 69%) reported having degenerative arthritis\(^{33}\). Given its robust psychometric properties, the FFI-R was selected to assess the subjects in this study.

### Plantar loading

Plantar loading during barefoot walking at self-selected, monitored walking speed was quantified using an EMED pedobarograph (Novel Inc, St Paul, MN). The capacitative pedobarograph was embedded flush with the walkway. Plantar loading data were acquired at 50 Hz and at a spatial resolution of four sensors per square centimeter. Patients walked at self-selected speed, monitored to ±5% using an infra-red timing system (Brower Inc, UT). Control subjects’ speed was matched to patients’ walking speed, because walking speed is known to influence magnitude of plantar loading\(^{38}\). Prior to data collection, all subjects were encouraged to attempt practice trials to establish walking speed. Subjects were allowed as many practice trials as they needed prior to data collection. Starting position was standardized to avoid targeting and to ensure clean foot contact on the pedobarograph. Using a mid-gait protocol, a minimum of three and maximum of five steps were collected to ensure adequate reliability\(^{39,40}\). Data were analyzed using Novel Projects software (Novel Inc, St Paul, MN). The foot was divided into the following regions of interest or “masks”, defined as a percent of foot length and width: heel, medial and lateral midfoot, medial and lateral forefoot, and great toe. Given the location of pain in patients with midfoot OA, loading characteristics at the medial midfoot were the primary focus of analysis. In addition, the heel, medial and lateral forefoot masks were used for a secondary evaluation of comparative regional loading, or load transfer\(^{41}\).

Plantar loading data was analyzed using Novel Win software™ (St Paul, MN). The following dependent variables were evaluated: average pressure, contact time and pressure time integral. Average pressure was defined as the mean of the highest pressures sustained within each mask and expressed in kilopascals (kPa). Contact time was defined as the duration of loading for each mask and expressed in % stance. Pressure time integral was defined as the area under the peak pressure within each mask and expressed in kilopascals.seconds (kPa.s). These definitions of dependent variables used to characterize plantar loading are consistent with definitions used in previous studies\(^{17,42,43}\).

### Statistical analysis

All dependent variables were assessed for normality, using the Kolmogorov–Smirnov test, and variance homogeneity, using Levene’s test. Subsequently, independent t-tests, not assuming equal variance, were used to assess statistical significance of differences in FFI-R scores in patients with midfoot OA compared to asymptomatic control subjects. The statistical significance of between-group comparisons in regional plantar loading was assessed using the Mann–Whitney U-test. Differences between groups were considered significant if P < 0.05. Correlations were assessed using Spearman rank correlation.

A k-means cluster analysis was used to identify potential clusters (sub-groups of patients) present in the midfoot OA patient cohort. K-means analysis applies an optimization approach to minimize the sum of the squared Euclidean distances between observations and their group mean over multiple features of the dataset\(^{44}\). K-means cluster analysis is an exploratory data analysis technique and may be valuable in studies that assess plantar loading because k-means analysis allows us to simultaneously

### Table I

Summary of radiographic characteristics in patients with midfoot arthritis

<table>
<thead>
<tr>
<th>Joint</th>
<th>Median Kellgren Lawrence grade on lateral radiographs</th>
<th>Percent of patients with Kellgren Lawrence grade of 1 and higher</th>
<th>Joint</th>
<th>Median Kellgren Lawrence grade on anterior–posterior radiographs</th>
<th>Percent of patients with Kellgren Lawrence grade of 1 and higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarso-metatarsal</td>
<td>3.1</td>
<td>70</td>
<td>first tarso-metatarsal</td>
<td>1.9</td>
<td>68</td>
</tr>
<tr>
<td>Naviculo-cuneiform</td>
<td>1.8</td>
<td>40</td>
<td>second tarso-metatarsal</td>
<td>1.4</td>
<td>60</td>
</tr>
<tr>
<td>Talo-navicular</td>
<td>0.0</td>
<td>25</td>
<td>Inter-tarsal</td>
<td>1.3</td>
<td>70</td>
</tr>
<tr>
<td>Subtalar</td>
<td>0.0</td>
<td>25</td>
<td>Inter-metatarsal</td>
<td>0.7</td>
<td>40</td>
</tr>
<tr>
<td>Calcaneo-cuboid</td>
<td>0.0</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table II

Mean (SD) summary of demographic characteristics

<table>
<thead>
<tr>
<th></th>
<th>Midfoot arthritis</th>
<th>Control group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62 (7)</td>
<td>58 (7)</td>
<td>0.678</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>29.7 (5.7)</td>
<td>29.3 (4.3)</td>
<td>0.594</td>
</tr>
<tr>
<td>Sex (M:F)</td>
<td>2:28</td>
<td>1:19</td>
<td></td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>0.71 (0.20)</td>
<td>0.74 (0.17)</td>
<td>0.834</td>
</tr>
</tbody>
</table>

Results

Self-reported pain and foot function

Patients with midfoot OA reported significantly higher FFI-R Total Scores compared to matched control subjects (Table III). An examination of subscale scores revealed that patients with midfoot OA scored significantly higher on all the subscales (Pain, Activity Limitation, Disability and Psychosocial Issues) of the FFI-R compared to matched control subjects (Table III).

Plantar loading

Average pressure was higher in the heel and medial midfoot regions in patients with midfoot OA compared to asymptomatic control subjects (Table IV). Similar trends were noted at the lateral midfoot. Contact time was higher in the heel, medial and lateral midfoot, and medial forefoot regions in patients with midfoot OA compared to asymptomatic control subjects (Table IV).

Correlations

There was a significant positive correlation between medial midfoot pressure—time integral and FFI-R Pain Subscale Score \( (r = 0.524, P < 0.01) \) and between medial midfoot average pressure and FFI-R Pain Subscale Score \( (r = 0.448, P < 0.01) \). However, medial midfoot pressure—time integral and medial midfoot average pressure were highly correlated \( (r = 0.927, P = 0.01) \).

Cluster analysis

Based on the adequacy index, the two-cluster solution was deemed most appropriate for this cohort of patients with midfoot OA. Graphical depiction of the adequacy index and bivariate scatter plots of the two-cluster solution are presented in Fig. 2. Mean (SD) FFI-R Pain Subscale Score, and Average Pressure sustained at the Heel, Medial and Lateral Midfoot, Medial and Lateral Forefoot and Great Toe.
Great Toe for the two-cluster solution are presented in Table V. K-means clustering identified two subgroups, Cluster 1 (higher medial midfoot average pressure group \( n = 20 \)) and Cluster 2 (lower medial midfoot average group \( n = 10 \)). Cluster 1 \( n = 20 \) showed higher medial midfoot average pressure, higher FFI-R Pain Subscale scores, and lower heel and forefoot pressure compared to Cluster 2 \( n = 10 \).

### Discussion

Increasing evidence indicates that mechanical stress plays an important role in cartilage breakdown and clinical outcomes in individuals with knee OA. However, limited objective data are available examining the relationship between mechanical stress and self-reported function in patients with arthritis in their foot. The key findings of our study showed that patients with midfoot OA report significant pain and disability, reflected as higher scores on the FFI-R Pain Subscale and Total Scores, compared to asymptomatic control subjects. In addition, patients with midfoot OA demonstrated elevated magnitude and duration of regional plantar loading, evidenced as increased medial midfoot average pressure, contact time, and pressure time integral. To our knowledge, these results are the first to support the theory that regional plantar loading is related to symptoms in patients with midfoot OA. These findings emphasize the significant disability experienced by patients with midfoot OA and suggest potential mechanisms by which mechanical stress may contribute to patients’ clinical symptoms and self-reported pain.

Our cohort of patients with midfoot OA reported moderate to severe foot pain in weight-bearing activities of daily living compared to asymptomatic matched controls, evidenced as significantly higher FFI-R Pain Subscale Scores. Consistent with previous reports of foot function in patients with midfoot OA compared to asymptomatic matched controls, our patients also demonstrated significant activity limitation and reduction in overall foot function\(^{45,46}\). The preponderance of female patients \( 28/30 \) in our study, is consistent with previous studies examining patients with midfoot OA as well as other types of arthritis affecting the foot\(^{5,47}\). Contrary to our expectation that the majority of patients would present with post-traumatic midfoot OA\(^5\), none of our patients recalled a major traumatic event leading to their midfoot symptoms. While our study sample is similar in terms of etiology and patient demographics, to that reported in more recent reports\(^{45,46}\), the absence of major trauma combined with the gender distribution, may be indicative of the potential role of chronic increased joint loads accompanying poor footwear choices\(^{48}\) in the development of midfoot OA.

The magnitudes of pressure time integral sustained in the control group during barefoot walking are in agreement with previous reports of pressure time integral in asymptomatic subjects\(^{26,27}\). The magnitude of pressure time integral sustained at the heel and forefoot in patients with midfoot OA is consistent with previous reports of pressure time integral sustained during barefoot walking in asymptomatic subjects\(^{26,27}\) as well as in subjects with chronic rheumatoid arthritis\(^{14}\). However, the magnitude of medial midfoot pressure time integral as well as medial midfoot average pressure sustained during barefoot walking in patients with midfoot OA was higher than that reported in previous studies\(^{24,26,27}\). Increased medial midfoot loading in asymptomatic subjects\(^{49}\) and in individuals with arthritis of the talo-navicular and navicular-first cuneiform joints\(^{50}\) has been linked with low arch alignment. Increased medial midfoot loading may be related to motion, such as calcaneal pronation, that occurs at proximal joints\(^{51}\). However, recent evidence does not support this contention\(^{52}\). Using an in vivo three-dimensional kinematic model of the foot, motion of the first metatarsal and calcaneus was assessed during barefoot walking. No between-group differences were noted in calcaneal eversion in patients with midfoot arthritis compared to matched control subjects\(^{52}\). In addition to arch alignment and pronation, several reports have suggested that disease severity, quantified using radiographs, is related to midfoot plantar loading.

In patients with hindfoot pain, Ellis et al. noted increased lateral midfoot loading\(^{18}\) and subtalar arthritis\(^{18}\). In patients with rheumatoid arthritis, increased joint erosion, determined using the Larsen score, was accompanied by increased forefoot plantar loading\(^{2,3,42}\). Consistent with the literature, our findings may suggest that increased medial midfoot plantar loading may be linked with pain experienced by patients with midfoot OA.

In agreement with the mechanical overloading theory, a modest positive association between medial midfoot plantar loading and patients’ self-reported pain score was noted. Regional plantar loading explained about 28% of the variance in patients’ pain. In a study involving patients with painful pes cavus, Burns et al. found that pressure time integral accounted for 24% of the variance in foot pain\(^{47}\). In patients with rheumatoid arthritis, previous studies have noted that the magnitude of forefoot plantar loading accounts for 10–30% of the variance in patients’ self-reported pain\(^{14,24}\). Taken together, the results of our study combined with previous findings, suggest that regional plantar loading may account for approximately one third of the variance in self-reported foot pain, and support the contention that mechanical stress may be related to patients’ symptoms.

In an attempt to identify potential clusters (sub-groups of patients) present in the midfoot OA patient cohort, k-means analysis was used as an exploratory data analysis technique\(^{44}\). Previous studies evaluating plantar loading in patients with foot pain have assessed one foot region at a time\(^{17,22,24}\). The chief limitation of this approach (assessing one foot region at a time) is that it does not take into account changes in load distribution that may occur concurrently over multiple regions of the foot. As a novel solution to this problem, we used k-means cluster analysis to simultaneously assess plantar loading in multiple regions of the foot. Using k-means cluster analysis, we discerned two subgroups within our cohort of patients with midfoot OA. Cluster 1 \( n = 20 \) showed higher medial midfoot average pressure, higher FFI-R Pain Subscale Scores, and lower heel and forefoot pressure compared to Cluster 2 \( n = 10 \). These clusters are consistent with the regional mechanical overloading theory and may represent different load redistribution strategies. Mechanical stress, through its effect on cartilage homeostasis and breakdown, may contribute to the development and progression of osteoarthritic changes\(^3\).
Shape-based k-means cluster analysis has been previously used to classify subjects based on their plantar loading characteristics, with varying degrees of success in terms of providing clinically meaningful results. De Cock et al. used forefoot pressure time integral obtained during jogging to classify asymptomatic subjects into four foot types. K-means cluster analysis of the peak pressure curve was applied in symptomatic patients with rheumatoid arthritis and indicated the presence of three well-separated subgroups. However, classification of patients using k-means cluster analysis did not agree with a HAQ-based clinical classification.

Whether the inclusion of plantar loading parameters from multiple regions of the foot in k-means analysis will improve agreement remains unknown and requires further study. Our results indicate that the inclusion of multiple regions of the foot is valuable in the assessment of patients with foot pain and pathology. Additionally, alternative multi-variate techniques such as principal components analysis may reduce the dimensionality of plantar loading parameters and may help characterize loading strategies that contribute to patients’ symptoms.

The chief limitations of this study are its relatively small sample size and cross-sectional nature. Prospective studies are indicated to examine the time course of the evolution of foot pain and changes in plantar loading in patients with midfoot OA. Additional studies are indicated to assess whether anatomical subtypes exist within midfoot OA, based on anatomical location of joints affected. We assessed regional plantar loading during barefoot walking to avoid confounding effects due to footwear and shoe inserts. However, in individuals with foot pain, barefoot walking may have limited external validity. Patients with midfoot OA report symptoms during dynamic weight-bearing activities such as walking. For this reason, we assessed midfoot plantar loading during walking. However, normal force (the product of pressure and area) and dynamic loads through the forefoot, particularly during the propulsion phase of gait may also contribute to patients’ symptoms. Future investigations modeling biomechanical loads at the midfoot are indicated to assess net joint forces and moments at the tarso-metatarsal joints. Additional studies are indicated to quantify the direct relationship between regional plantar loading and articular stress sustained in the joints of the foot during weight-bearing activities.

Conclusions

This study demonstrated that patients with midfoot OA sustain increased magnitude and duration of regional plantar loading during walking compared to matched control subjects. Future studies should assess whether interventions designed to reduce plantar loading are effective in relieving foot pain and/or preventing progression of symptoms in patients with midfoot OA. Further analysis using k-means cluster analysis distinguished two sub-groups. Prospective studies are indicated to assess disease progression and response to intervention in these two subgroups.

Contributions

All authors were involved in study design, data analysis and manuscript preparation. The Corresponding Author (Smita Rao) was primarily responsible for seeking consent and collecting data, and is responsible for the integrity of the work as a whole, from inception to finished article.

Role of the funding source

The study sponsors played no role in the study design; collection; analysis or interpretation of data.

Conflict of interest

We, the authors of this manuscript, affirm that we have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript except as cited in the manuscript.

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Supplementary data

Supplementary data related to this article can be found online at doi:10.1016/j.joca.2011.04.006.

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