Journal of Biomechanics 47 (2014) 3787–3793

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Is early osteoarthritis associated with differences in joint congruence?

Michele Conconi [a,*], Eni Halilaj [b], Vincenzo Parenti Castelli [a,c], Joseph J. Crisco [b,d]

[a] Health Sciences and Technologies, Interdepartmental Center for Industrial Research (HST-ICIR), Alma Mater Studiorum—University of Bologna, Bologna, Italy
[b] Center for Biomedical Engineering, Brown University, Providence, RI, USA
[c] Department of Industrial Engineering (DIN), Alma Mater Studiorum—University of Bologna, Bologna, Italy
[d] Department of Orthopaedics, Warren Alpert Medical School of Brown University and Rhode Island Hospital, Providence, RI, USA

ARTICLE INFO

Article history:
Accepted 24 October 2014

Keywords:
Carpometacarpal joint
Joint congruence
Osteoarthritis
Etiology
Sex differences

ABSTRACT

Previous studies suggest that osteoarthritis (OA) is related to abnormal or excessive articular contact stress. The peak pressure resulting from an applied load is determined by many factors, among which is shape and relative position and orientation of the articulating surfaces or, referring to a more common nomenclature, joint congruence. It has been hypothesized that anatomical differences may be among the causes of OA. Individuals with less congruent joints would likely develop higher peak pressure and thus would be more exposed to the risk of OA onset. The aim of this work was to determine if the congruence of the first carpometacarpal (CMC) joint differs with the early onset of OA or with sex, as the female population has a higher incidence of OA. 59 without and 38 with early OA were CT-scanned with their dominant or arthritic hand in a neutral configuration. The proposed measure of joint congruence is both shape and size dependent. The correlation of joint congruence with pathology and sex was analyzed both before and after normalization for joint size. We found a significant correlation between joint congruence and sex due to the sex-related differences in size. The observed correlation disappeared after normalization. Although joint congruence increased with size, it did not correlate significantly with the onset of early OA. Differences in joint congruence in this population may not be a primary cause of OA onset or predisposition, at least for the CMC joint.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Osteoarthritis (OA) is a very common and highly disabling disorder (Reginster, 2002; Buckwalter et al., 2004; Lawrence et al., 2008) with a great socioeconomic impact and likely destined to increase even further in the future with aging populations (Kraus, 1997). In particular, the first carpometacarpal (CMC) joint is one of the joints that is most affected by osteoarthritis (Lawrence et al., 1966; Peyron, 1986), showing a significantly higher incidence in women than men (Wilder et al., 2006).

Although the OA terminal condition is the degradation of the articular surfaces, this pathology is no longer considered a disease of cartilage, but rather a global joint disorder, originating from a combination of systemic susceptibility and abnormal mechanical events. Many researchers suggest that cartilage degradation can be correlated with abnormal or excessive articular contact stress (Dekel and Weissman, 1978; Brandt et al., 2008; Radin et al., 1978; Jackson et al., 2004; Fontana et al., 2007). This abnormal contact stress may result both from excessive load acting on a normal joint or from normal loading acting on a weakened articulation: ligament laxity, periarticular muscle weakness, or reduced proprioception may all lead to articular instability, exposing the joint to sudden impulsive loads and finally to high peak pressure (Brandt et al., 2006; McGonagle et al., 2010; Felson et al., 2000).

Since OA is always associated with degeneration of articular surfaces, some researchers hypothesized that anatomical differences may also be among the causes of OA predisposition (North and Rutledge, 1983; Felson et al., 2000; Bredbenner et al., 2010). In particular, investigating the CMC joint of 13 arthritic cadavers (eight

* Corresponding author at: Health Sciences and Technologies, Interdepartmental Center for Industrial Research (HST-ICIR), Alma Mater Studiorum—University of Bologna, Viale Risorgimento 2, 40136, Bologna, Italy. Tel.: +39 51 2093909; fax: +39 51 2093446.
E-mail address: michele.conconi@unibo.it (M. Conconi).

http://dx.doi.org/10.1016/j.jbiomech.2014.10.030
0021-9290/© 2014 Elsevier Ltd. All rights reserved.

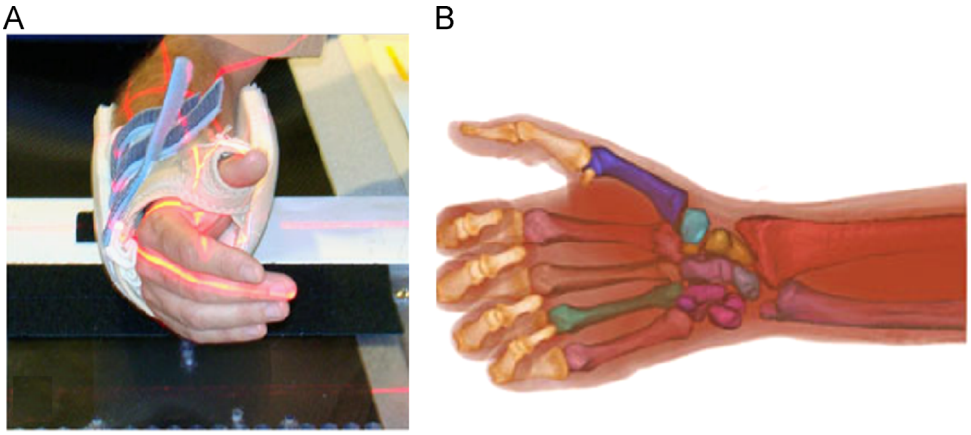

Fig. 1. The scanning neutral positions shown by photograph (A) and respective 3D renderings of the CT scans (B).

females, average 64 year old, five males, average 70 year old, Eaton stage from I to III, Eaton and Glickel, 1987), Ateshian and coworkers (Ateshian et al., 1992) reported significant differences in articular curvatures with sex. The same authors suggested that these geometrical differences may explain the higher predisposition of women to OA. Indeed, as indicated by clinical experience (Sokoloff, 1969; Bullough, 1981) and theoretical computations (Ateshian et al., 1994; Wu et al., 1997), peak contact pressure is affected also by the relative position and shape of the articulating surfaces in contact or, referring to medical terms, to the joint congruence. This refers to the geometric similarity of two articulating surfaces and is clinically taken as representative of the joint capability to distribute an applied load, under the assumption that the better the two surfaces mate each other, the smaller the peak pressure. Decreased congruence, as well as decreased contact areas due to a smaller joint size, may thus lead to increased peak pressures during similar activities and finally increase the risk of osteoarthritis.

Although this hypothesis sounds reasonable and intuitive, there is still no clear evidence indicating whether alterations of joint congruence are simply the effect or also the cause of OA. The aim of this paper is thus to test the hypothesis that individuals with less congruent joint are more exposed to the risk of developing OA.

Based on evidence that bony changes in osteoarthritic joints precede changes in articular cartilage by months or years (Hutton et al., 1986) and the previous studies suggesting that articular shape may be a contributing factor in OA initiation and progression (Felson et al., 2000; Bredbenner et al., 2010; Ateshian et al., 1992; Ateshian et al., 1994; Wu et al., 1997), differences in joint congruence were investigated by analyzing subchondral bone surfaces within a population of asymptomatic and arthritic subjects with early OA through CT scans of their CMC joints. Joint congruence was evaluated with a measure that relies on the Winkler elastic foundation contact model (Conconi and Parenti-Castelli, 2014). This measure has the merit of making the ratio of the applied load to the resulting articular peak pressure a purely geometrical relation. This ratio is size dependent. For this reason, joint congruence is also normalized with respect to the dimension of each individual in order to identify possible differences in joint congruence other than those related to joint size.

Accordingly, the purpose of this study was to determine if joint congruence (Conconi and Parenti-Castelli, 2014) differs with sex, both prior and after normalization with respect to joint size, and to determine if joint congruence differs between asymptomatic subjects and patients with early OA.

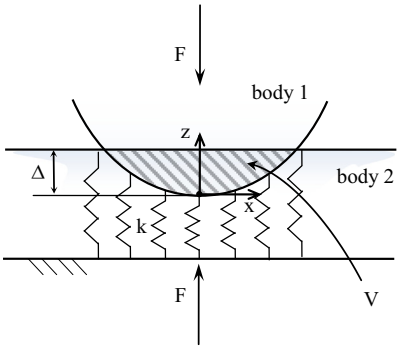

Fig. 2. Schematization of the Winkler contact model.

2. Material and methods

2.1. Subject scanning and procedure

59 Asymptomatic subjects (34 women with a mean ± SD age of 42.3 ± 16.4 and 25 men with a mean ± SD age of 36.8 ± 13.6) and 39 patients with early OA (31 women with a mean ± SD age of 53.9 ± 6.8 and 7 men with a mean ± SD age of 56.3 ± 6) (Eaton Stage I, Eaton and Glickel, 1987) were recruited as part of a larger study on CMC joint biomechanics (Halilaj et al., 2013, 2014a, 2014b, 2014). Radiological inspection confirmed the absence of pathology for the asymptomatic population. After receiving approval from the Institutional Review Board and completing informed consents, the thumb CMC joints in the dominant hands of the asymptomatic subjects and the affected hands of the OA patients were CT-scanned in a braced neutral position (Fig. 1), which was standardized with a modified Rolyan® Original adjustable wrist and thumb spica-splint brace (Patterson Medical, Bolingbrook, Illinois). The brace placed the wrist in approximately 0° flexion/extension and 0° ulnar/radial deviation and the thumb in approximately 0° of flexion/extension and 0° of adduction/abduction. Image volumes were generated with a 16-slice clinical CT scanner (General Electric, Milwaukee, WI), at tube settings of 80 kVp and 40 mA, slice thickness of 0.625 mm, and in-plane resolution of 0.4 mm × 0.4 mm or better. The bones forming the CMC joint, the trapezium (*tpm*) and the first metacarpal (*fmc*), were segmented using commercial software (Mimics®, Materialise, Leuven, Belgium) and 3-D bone models were exported as polygon meshes.

The subchondral surfaces of the trapezium and the metacarpal were manually selected using Geomagic Studio® (Geomagic®, Research Triangle Park, NC) by carefully tracing the visible margins. The relative bone-to-bone distance was evaluated through distance maps (Tersi et al., 2010). The fifth percentile of the distance distribution of the trapezium with respect to the first metacarpal surface was considered as representative of the minimum joint space, in what follows indicated with ε.

Download English Version:

https://daneshyari.com/en/article/871946

Download Persian Version:

https://daneshyari.com/article/871946

Daneshyari.com