Full Length Article

JHS(E)

The Journal of Hand Surgery
(European Volume)
2016, Vol. 41E(7) 732–738

DOI: 10.1177/1753193415622342
jhs.sagepub.com
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Patients with triangular fibrocartilage complex injuries and distal radioulnar joint instability have reduced rotational torque in the forearm

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Abstract

A total of 20 patients scheduled for wrist arthroscopy, all with clinical signs of rupture to the triangular fibrocartilage complex and distal radioulnar joint instability, were tested pre-operatively by an independent observer for strength of forearm rotation. During surgery, the intra-articular pathology was documented by photography and also subsequently individually analysed by another independent hand surgeon. Arthroscopy revealed a type 1-B injury to the triangular fibrocartilage complex in 18 of 20 patients. Inter-rater reliability between the operating surgeon and the independent reviewer showed absolute agreement in all but one patient (95%) in terms of the injury to the triangular fibrocartilage complex and its classification. The average pre-operative torque strength was 71% of the strength of the non-injured contralateral side in pronation and supination. Distal radioulnar joint instability with an arthroscopically verified injury to the triangular fibrocartilage complex is associated with a significant loss of both pronation and supination torque.

Level of evidence: Case series, Level IV.

Keywords

Distal radioulnar joint, forearm rotation torque, triangular fibrocartilage complex, wrist, wrist arthroscopy

Date received: 11th August 2015; revised: 14th November 2015; accepted: 17th November 2015

Introduction

Distal radio-ulnar joint (DRUJ) instability and injury to the triangular fibrocartilage complex (TFCC) are common after distal radial fractures, but their importance is not well understood. More than 40% of displaced distal radial fractures are associated with a TFCC injury (Andersson and Axelsson, 2011; Geissler et al., 1996; Lindau et al., 1997; Richards et al., 1997; Scheer and Adolfsson, 2011). Lindau et al. (2000) demonstrated that instability of the DRUJ is a negative factor in terms of clinical outcome after distal radial fractures in young patients, independent of radiographic findings. Isolated injuries to the TFCC can also occur, for example as a result of a rotational injury to the wrist. In patients with post-traumatic wrist pain but normal standard radiographs, 42% were found to have injuries of the TFCC (Adolfsson, 1994).

Several anatomical structures stabilize the DRUJ, of which the TFCC and especially its foveal insertion is the most important (Haugstvedt et al., 2006). The TFCC is composed of a 'distal component', formed by the ulno-carpal ligament and the distal hammock structure, and of the 'proximal component', which originates from the ulnar fovea and the base of the styloid (Nakamura et al., 1996). Traumatic lesions of the ulnar-sided portion of the TFCC can be critical to the stability of the DRUJ and to forearm function, as these structures are crucial for stability and unrestricted forearm

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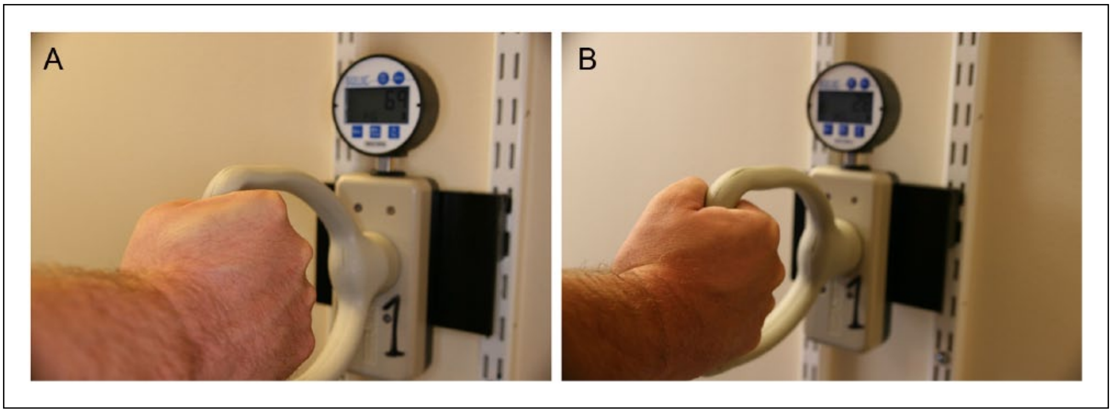

Figure 1. (A) Measurement of peak torque strength in pronation. (B) Measurement of peak torque strength in supination.

rotation. Other stabilizing components of the DRUJ are the anatomical configuration of the distal radius and ulna, the DRUJ and its congruity, the interosseous membrane (Malone et al., 2015), particularly the distal part and the central band, and dynamic muscular stabilizers (extensor carpi ulnaris, flexor carpi ulnaris, pronator quadratus).

Establishing a reliable diagnosis of TFCC injury and DRUJ laxity can be difficult. A recently published systematic review showed low sensitivity, specificities and negative predictive values for scapholunate, lunotriquetral and TFCC injuries for both magnetic resonance imaging and provocative stability tests (Andersson et al., 2015). Arthroscopy is the only reliable method for assessing the severity of ligament injuries of the wrist (Andersson et al., 2015; Hobby et al., 2001), but surgical experience differs considerably between examiners and the inter- and intra-observer reliability of arthroscopic evaluation is low (Loew et al., 2010, 2012).

The hypothesis of this study was that patients with DRUJ instability and TFCC injury would have reduced peak torque on the injured side during both pronation and supination, when compared with the non-injured side.

Methods

The forearm peak rotational torques of 21 consecutive patients who were scheduled for wrist arthroscopy because of clinical signs of TFCC rupture (dorso-ulnar wrist pain and a positive foveal sign) and DRUJ instability were measured pre-operatively. The measurements were performed with a method developed by one of the authors (PA) using a wrist dynamometer supplied with a digital pressure gauge (Model BL-2000, Baseline, White Plains, NY, USA) (Figure 1). The device was calibrated at the SP (Statens Provningsanstalt) Technical Research Institute of Sweden. The precision of measurement of the dynamometer was 0.01 Nm.

Before the study, a reliability test of the measuring device was done by two independent raters. Raters 1 and 2 measured 15 normal individuals without any previous injury or wrist symptoms at three different times with approximately 1 week between the examinations.

An independent observer (a physical therapist), who was blinded to the patients' diagnosis, measured the pre-operative torque according to a standardized protocol, with the patient standing up straight, with the elbow against the waist and in 90° of flexion. Peak supination followed by peak pronation were measured once starting from a neutral position, with the examiner carefully ensuring that the patient did not bring the elbow into abduction or lean the body in any direction. The non-injured side was measured first, and then the injured side. Thereafter, a single surgeon (JKA) examined the TFCC and DRUJ, including clinical tests for DRUJ laxity and the foveal sign test for the TFCC. This latter test is positive when there is tenderness on the palmar aspect of the fovea located proximal to the pisiform and ulnar to the flexor carpi ulnaris tendon. Laxity of the DRUJ was tested with the forearm held in neutral rotation by the examiner, who stabilized the hand and the distal radius with a firm grip to make them one unit. Then the ulna, as the second unit, was forced in a dorsal/palmar direction, relative to the stabilized unit of the hand and radius by the examiner using the other hand (Mrkonjic et al., 2012). The laxity of the DRUJ was compared with that of the uninjured wrist.

During the arthroscopic procedure, intra-articular injuries, such as a TFCC rupture, and other pathological findings were documented using digital images. To check for inter-rater reliability, the intra-articular images taken during surgery were individually scrutinized and assessed for the presence of an injury to the TFCC and its classification by another independent investigator in a standardized manner. This second reviewer was blinded both to the existence of a TFCC

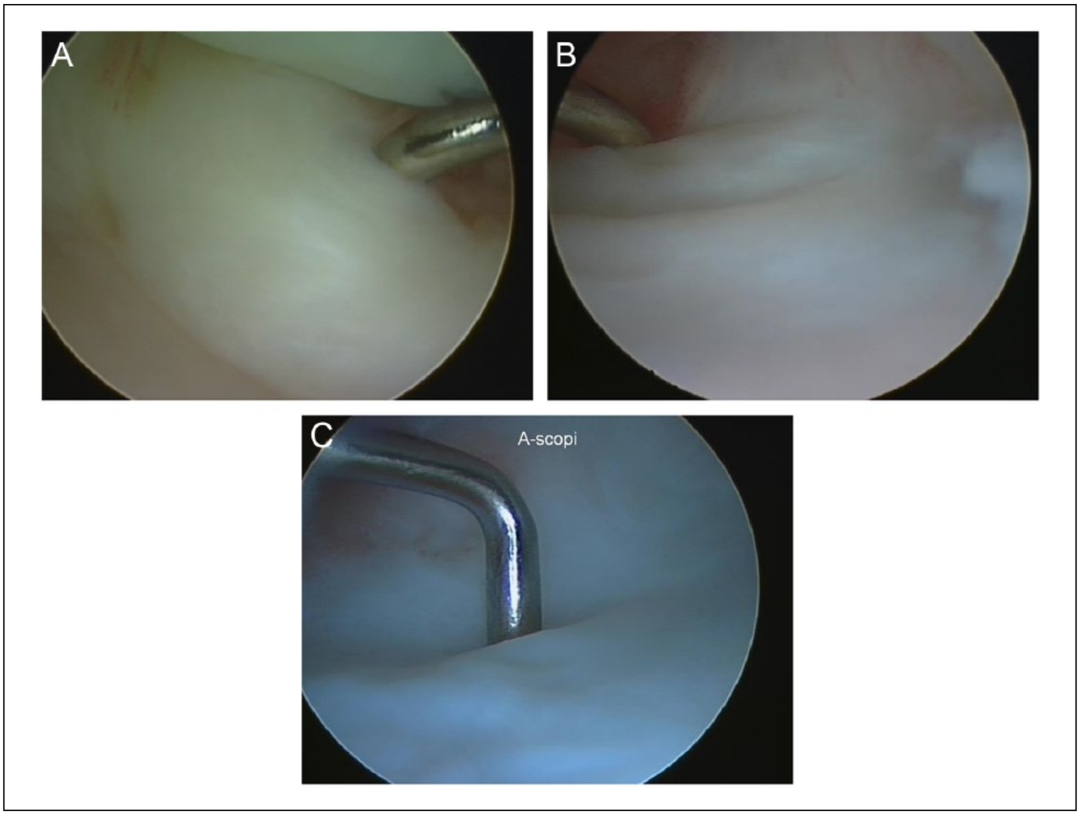

Figure 2. (A) TFCC 1 B injury on the right wrist in a 32-year-old woman. The hook at 2 o'clock is located under the TFCC. (B) Testing the bounce and elasticity (so-called trampoline effect), with the probe at 10 o'clock under the TFCC, on the left wrist in a 17-year-old woman and (C) with the hook above the TFCC, on the left wrist in a 31-year-old woman.

injury and its classification according to Palmer (1989) and any treatment during surgery.

Atzei et al. (2008) have described the radiocarpal 'hook test' to verify a 1-B TFCC injury: with a probe inserted through the 6-R portal, traction is applied to the ulnar-most border of the TFCC. The test is positive if the TFCC can be pulled upwards and radially when the distal and proximal TFCC are detached from the fovea. All TFCC type 1-B injuries in this series were diagnosed during surgery using the hook test (Figure 2(A)) and the so-called trampoline sign, testing the bounce and elasticity of the central portion of the ligament (Weintraub et al., 2007) (Figure 2(B) and (C)).

The study was approved by the ethical review board (EPN), Gothenburg, Sweden (Dnr: 977-12). Informed consent was obtained from each patient.

Statistical analyses

Descriptive data are reported by means and standard deviation (SD).

The intra- and inter-rater reliability of the measurements was determined using the intra-class correlation coefficient (ICC) (2-way mixed model, absolute agreement, single measurements). The ICC is the ratio of the between-subject variability and the between-subject variability plus the within-subject variability. To categorize the level of agreement between ICC values, the classification system proposed by Shrout and Fleiss (1979) was used. ICC values of less than 0.40 represent poor reliability, values between 0.40 and 0.75 represent fair to good reliability and values above 0.75 represent excellent reliability. Bland-Altman plots were used to visualize the reliability according to Bland and Altman (1986).

The agreement between two raters for categorizing the TFCC was analysed as a percentage of their absolute agreement.

For comparisons between injured and non-injured forearm torque, an independent two-sided t-test was performed. A p-value <0.05 was regarded as significant.

Results

Patients

The cohort consisted of eight men and 13 women. One patient was excluded because of inconclusive images of poor quality; they were impossible to use for a secondary review. The mean age was 31 years

(SD 11.3) and their median age was 30 years (range 16–51). None of the patients had any history of previous injuries to the upper extremities in childhood or adolescence or any neuromuscular or degenerative joint diseases. All the patients in the study were secondary referrals to our department, with injuries occurring more than 6 months before examination. Of the 20, 17 had a known history of significant trauma; eight had had a distal radial fracture, of which two had a minor remaining malunion. One of them required a corrective radial osteotomy. The right wrist was affected in five patients and the left in 15. As two patients were left-handed, the frequency of injuries in the non-dominant hand was 65%. Magnetic resonance imaging had been done in 12 patients. TFCC injury was confirmed by magnetic resonance imaging in eight of those 12 patients.

Out of the 20 patients, 18 had a positive foveal sign pre-operatively. All patients proved to have some degree of DRUJ laxity.

Reliability of torque testing

The intra-rater reliability was excellent for both investigators who measured forearm torque in the 15 healthy individuals (ICC = 0.96 (95% CI: 0.93 to 0.97) and ICC = 0.95 (95% CI: 0.93 to 0.97), respectively). The inter-rater agreement was also excellent. The ICC was 0.95 (95% CI: 0.93 to 0.96). The average difference between investigators was 0.22 Nm (SD 0.61) (Figure 3). The ICC was 0.90 in pronation and 0.95 in supination (indicating excellent reliability).

Torque measurements in patients

The average difference between the injured and non-injured sides in pronation was –1.44 Nm, 95% CI: –2.43 to –0.45 ($p = 0.005$). The difference in supination was –1.93 Nm, 95% CI: –3.30 to –0.55 ($p = 0.007$). The mean peak torque in pronation was 3.47 Nm (SD 1.37) on the injured side and 4.91 Nm (SD 1.69) on the non-injured side. In supination, the mean peak torque strength was 4.77 Nm (SD 2.09) on the injured side and 6.70 Nm (SD 2.21) on the non-injured side. The pre-operative peak torque strength on the injured side was 71% on average compared with the non-injured contralateral side in pronation and in supination.

Arthroscopy

Arthroscopy revealed that 18 of 20 patients with DRUJ instability and a clinically assumed TFCC injury proved to have a type 1-B TFCC injury. The other two patients had a type 1-A and a type 2-C TFCC injury, respectively. All 18 patients with a 1B injury in the present series had a repairable complete tear or a repairable proximal tear, respectively class 2 and class 3 injuries according to Atzei et al. (2008). In seven patients, other injuries or pathology were found; partial scapholunate injury ($n = 4$); partial lunotriquetral injury ($n = 1$); chondral lesions ($n = 3$); or synovitis ($n = 4$). In eight patients with a type 1-B TFCC injury, the TFCC also had small central ruptures with or without degenerative signs (Palmer's classification; 2A–2C or 1A).

Agreement between the operating surgeon and the second investigator's assessment of the operative photographs was excellent in terms of diagnosing a TFCC injury and its classification according to Palmer (1989). The absolute agreement was 95% between the surgeon and the second reviewer.

Discussion

This study showed that patients with DRUJ instability and arthroscopically confirmed TFCC injuries have reduced peak torque for both pronation and supination on the injured side compared with the non-injured side. Previous studies have reported that the inter- and intra-observer reliability is relatively low for arthroscopic assessment of wrist ligament injuries (Loew et al., 2010, 2012). In the present study, the inter-rater reliability of diagnosis of TFCC injuries was high, with an absolute agreement of 95%. The fact that the second, blinded reviewer assessed only TFCC injuries and no other injuries obviously played a role in the strong agreement.

The need for a reliable, readily accessible, non-invasive and inexpensive diagnostic tool for diagnosing TFCC injury is obvious. Previous researchers have implied that there could be a correlation between strength in pronation/supination and TFCC injury with DRUJ instability (Lindau et al., 2002). In the present study, we exploited this idea and tested and used a device that accurately measured the torque generated during maximum pronation and supination according to a standardized protocol. Earlier studies have shown that the torque produced varies with arm, body and joint positions and that consistent positioning is vital for reproducible results (Morse et al., 2006; O'Sullivan and Gallwey, 2002; Richards et al., 1996; Savva et al., 2003).

It is known from previous studies that the non-dominant left upper extremity has peak torque values between 85%–95% of the values of the dominant right upper extremity (Matsuoka et al., 2006). Several medical conditions can influence the torque including epicondylitis (O'Sullivan and Gallwey, 2005) and ulnar impaction syndrome (LaStayo and Weiss, 2001). None

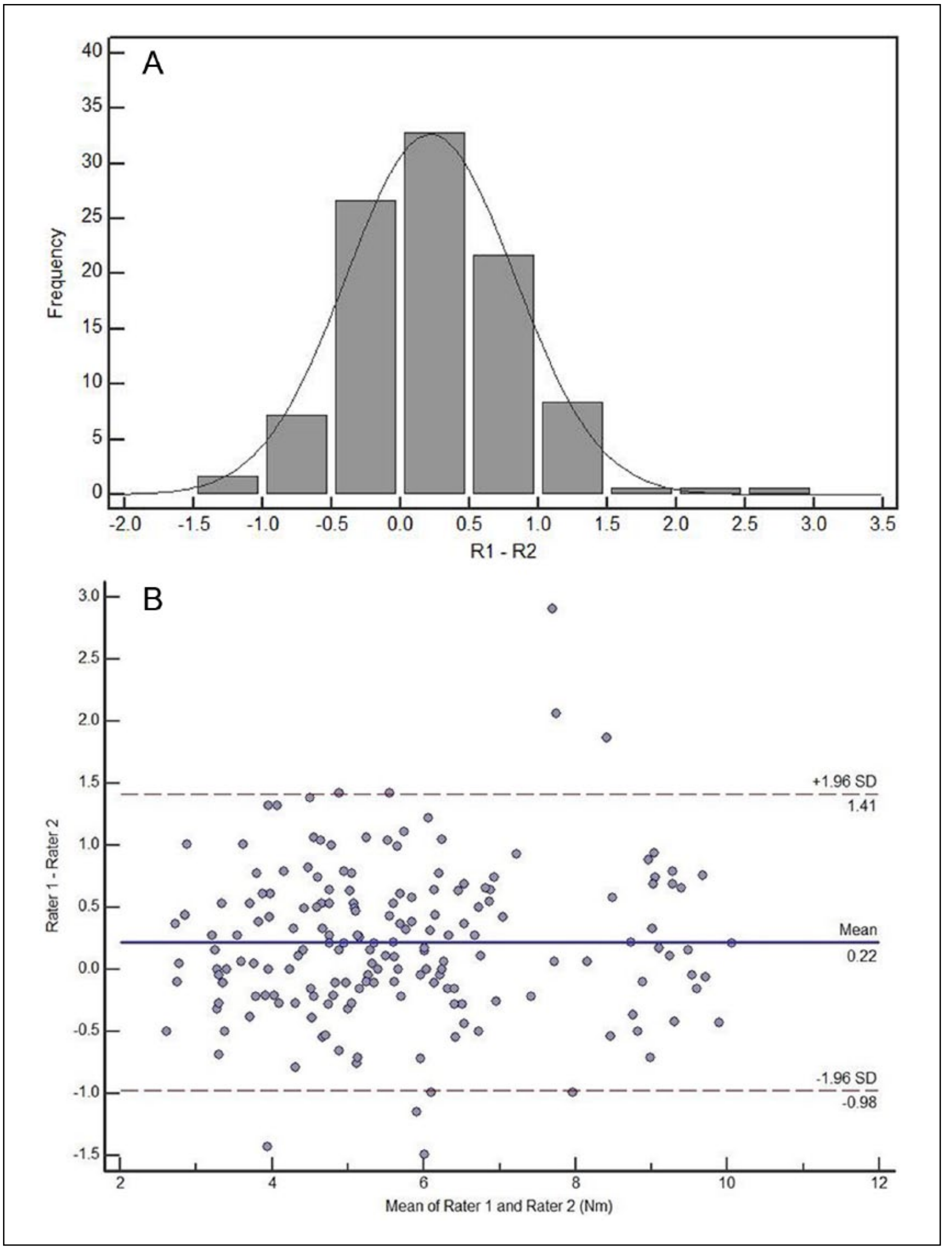

Figure 3. (A) The difference between each pair of ratings for the two raters. The average difference was 0.22 Nm. (B) Bland-Altman diagram showing differences between the two raters plotted against the average of the raters. It also shows the outliers outside the limits of agreement.

of the patients in the present study reported symptoms or demonstrated any clinical signs of these conditions.

Previous investigations have not clearly established a correlation between laxity of the DRUJ after distal radial fractures to loss of strength (Lindau et al., 2002). Correlations of clinical signs and torque values to findings in wrist arthroscopy have not been established before. All the patients in our series had a distinct laxity of the DRUJ and arthroscopically verified total TFCC injuries, 18/20 with 1B injuries. We measured the peak torque strength with the wrist in a neutral position once, with minimal possibility for the patient to activate their dynamic secondary stabilizers. Lindau et al. (2002) measured 20 individuals, six patients with laxity of the DRUJ and 14 with a stable joint. Their measurements were done three times in 30° of ulnar deviation firmly gripping the handle, with a higher possibility for the patients to activate the secondary DRUJ stabilizers, such as the extensor carpi ulnaris muscle.

There are several limitations to this study. Numerous other factors must be considered in relation to the reduced torque values: impaired DRUJ rotation movement; disuse-induced atrophy of forearm rotator muscles; pain or fear of pain with maximum efforts; discomfort and clicking phenomena during forearm rotation; and other concomitant intra-articular injuries. The influence of other associated injuries (ligament, cartilage injuries and synovitis) was not addressed in this study. The surgeon (JKA) was not blinded to the value of the pre-operative peak torque strength. The laxity of the DRU joint was tested manually only by the surgeon (JKA) preoperatively, and not compared with any assessment made by an independent observer. The non-dominant left upper extremity shows overall peak torque values between 85%–95% of the peak torque values of the dominant right upper extremity. In the current study, the dominant wrist was affected in seven patients and the non-dominant in 13, which possibly could affect the significance of the measurement values. However, according to some studies, TFCC injuries are more common on the non-dominant side (Andersson et al., 2014; Terry and Waters, 1998).

The study verified an association between the decrease in torque strength of approximately 30% and arthroscopically diagnosed TFCC injuries. The method can be easily adapted to the standard clinical setting and can now be used as an adjunct to clinical tests and imaging studies. The patients in the study are being followed-up to see whether peak torque strength normalizes after surgical repair of the TFCC.

Acknowledgements

The authors wish to thank Christer Johansson for statistical help.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

This investigation conforms with the University of Gothenburg Human Research Protection Programme guidelines. The study was ethically approved by the ethical review board (EPN), Gothenburg, Sweden (Dnr: 977-12). Informed consent was obtained from each patient.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: funding for this project was provided by the Swedish Research Council Grant 11200 and the University of Gothenburg. This research received no other specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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The Journal of Hand Surgery
(European Volume)
2016, Vol. 41E(7) NP2

DOI: 10.1177/1753193416641886
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Corrigendum on: Andersson JK, Strömberg J, Karlsson J and Fridén J. Patients with triangular fibrocartilage complex injuries and distal radioulnar joint instability have reduced rotational torque in the forearm. J Hand Surg Eur. 2016, 41: 732–738.

The authors apologise for the errors in this published paper. Corrections are as follows:

1) Peter Axelsson should have been added as the second author. The correct author list and affiliation details appear below:

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2) The first sentence in the methods should read:
The forearm peak rotational torques of 21 consecutive patients who were scheduled for wrist arthroscopy because of clinical signs of TFCC rupture (dorso-ulnar wrist pain and a positive foveal sign) and DRUJ instability were measured pre-operatively. The measurements were performed with a method developed by one of the authors (PA) using a wrist dynamometer supplied with a digital pressure gauge (Model BL-2000, Baseline, White Plains, NY, USA) (Figure 1).

3) The acknowledgement should read:

The authors wish to thank Christer Johansson for statistical help.

These errors will be corrected in the print version and the online issue version of this article.