ITALIAN JOURNAL OF PHYSIOTHERAPY

OFFICIAL JOURNAL OF THE ITALIAN SOCIETY OF PHYSIOTHERAPY

VOLUME 3
NUMBER 2
JUNE 2013

SIF
Società Italiana di Fisioterapia

PUBLISHED BY MINERVA MEDICA

ITALIAN JOURNAL OF
PHYSIOTHERAPY

OFFICIAL JOURNAL OF THE ITALIAN SOCIETY OF PHYSIOTHERAPY

ITALIAN JOURNAL OF PHYSIOTHERAPY
Official Journal of the Italian Society of Physiotherapy

Editorial address: Edizioni Minerva Medica - Corso Bramante 83-85 - 10126 Torino (Italy) - Tel. +39 011 67.82.82 Fax +39 011 67.45.02

Business, graphic, typesetting and advertising address: Edizioni Minerva Medica - Corso Bramante 83-85 - 10126 Torino (Italy) - Tel. +39 011 67.82.82 - Fax +39 011 67.45.02 - E-mail: minervamedica@minervamedica.it - Web Site: www.minervamedica.it

Printing: Edizioni Minerva Medica - Tipografia di Saluzzo - Corso IV Novembre 29-31 - 12037 Saluzzo (CN) (Italy) - Tel. +39 0175 24.94.05 - Fax +39 0175 24.94.07

Online annual subscription:
Italy – *Individual:* Online € 90; *Institutional:* Online: Small € 252, Medium € 282, Large € 324, Extra Large € 340.
European Union - *Individual:* Online € 150.00; *Institutional:* Online: Small € 242, Medium € 272, Large € 314, Extra Large € 330.
Outside European Union - *Individual:* Online € 165.00; *Institutional:* Online: Small € 275, Medium € 305, Large € 350, Extra Large € 365.

Subscribers: Payment to be made in Italy: a) by check; b) by bank transfer to: Edizioni Minerva Medica, INTESA SANPAOLO Branch no. 18 Torino. IBAN: IT45 K030 6909 2191 0000 0002 917 c) through postal account no. 00279109 in the name of Edizioni Minerva Medica, Corso Bramante 83-85, 10126 Torino; d) by credit card Diners Club International, Master Card, VISA, American Express. Foreign countries: a) by check; b) by bank transfer to: Edizioni Minerva Medica, INTESA SANPAOLO Branch no. 18 Torino. IBAN: IT45 K030 6909 2191 0000 0002 917; BIC: BCITITMM c) by credit card Diners Club International, Master Card, VISA, American Express.
Notification of changes to mailing addresses, e-mail addresses or any other subscription information must be received in good time. Notification can be made by sending the new and old information by mail, fax or e-mail or directly through the website www.minervamedica.it at the section "Your subscriptions - Contact subscriptions department".

Quarterly publication. Authorisation of the Milan Court no. 140 of March 8, 2011. Entered in the national press register in accordance with art 11 of law 416 dated 5-8-1981 at number 00 148 vol. 2 sheet 377 on 18-08-1982

INSTRUCTIONS TO AUTHORS

The **Italian Journal of Physiotherapy (IJP)** publishes scientific on-line papers on basis sciences and effectiveness studies related to physiotherapy, considered as application of manual therapy and therapeutic exercise in subjects with musculoskeletal disorders and motor impairment. IJP publishes innovative and highly relevant content for both clinicians and scientists and uses a variety of interactive approaches to communicate that content, with the expressed purpose of improving patient care.
Manuscripts may be submitted in the form of editorials, original articles, review articles, case reports, special articles and letters to the Editor. IJP may also invite international leaders of scientific topics related to physiotherapy to submit review articles.
Manuscripts are expected to comply with the instructions to authors which conform to the Uniform Requirements for Manuscripts Submitted to Biomedical Editors by the International Committee of Medical Journal Editors (www.icmje.org). Articles not conforming to international standards will not be considered for acceptance.
Papers should be submitted directly to the online Editorial Office at the Edizioni Minerva Medica website:

www.minervamedica.it

JP will consider for publication manuscripts that have not been published elsewhere, except in abstract form or as part of a published lecture or academic thesis and that it is not under consideration for publication elsewhere. Submission implies that the publication of the manuscript is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, without the written consent of the Publisher. The Authors agree to transfer the ownership of copyright to the IJP in the event the manuscript is published. The journal adheres to the principles set forth in the Helsinki Declaration and states that all reported research concerning human beings should be conducted in accordance with such principles. The journal also adheres to the International Guiding Principles for Biomedical Research Involving Animals recommended by the WHO and requires that all research on animals be conducted in accordance with these principles. The Authors, if necessary, must indicate that the study has been approved by the ethics committee and that patients have given their informed consent. Authors must also indicate whether they have any financial agreement with any organization that were involved in the research by filling the relevant form. Papers must be accompanied by the following authors' statement relative to copyright, ethics and conflicts of interest, signed by all authors:
"The undersigned authors transfer the ownership of copyright to the Italian Journal of Physiotherapy should their work be published in this journal. They state that the article is original, has not been submitted for publication in other journals and has not yet been published either wholly or in part. They state that they are responsible for the research that they have designed and carried out; that they have participated in drafting and revising the manuscript submitted, whose contents they approve. In the case of studies carried out on human beings, the authors confirm that the study was approved by the ethics committee and that the patients gave their informed consent. They also state that the research reported in the paper was undertaken in compliance with the Helsinki Declaration and the International Principles governing research on animals. They agree to inform Edizioni Minerva Medica of any conflict of interest that might arise, particularly any financial agreements they may have with pharmaceutical or biomedical firms whose products are pertinent to the subject matter dealt with in the manuscript".
The authors implicitly agree to their paper being peer-reviewed. All manuscripts will be reviewed by Editorial Board members who reserve the right to reject the manuscript without entering the review process in the case that the topic, the format or ethical aspects are inappropriate. Once accepted, all manuscripts are subjected to copy editing. If modifications to the manuscript are requested, the corrected version should be sent to the online Editorial Office with the modified parts underlined and highlighted. The revised version should be accompanied by a letter with point-by-point responses to the reviewers' comments. Correction of proofs should be limited to a simple check of the printing; it is therefore essential that corrections be kept to an absolute minimum. Proofs must be returned by the deadline specified to the online Editorial Office of the Italian Journal of Physiotherapy. In case of late return the editorial staff of the journal either may correct the proofs on the basis of the original manuscript or delay the publication. Forms for ordering reprints are sent together with the proofs. Rejected articles will not be returned to the author except on request.
Publication of manuscripts is free of charge. For further information about publication terms please contact the Editorial Office of the Italian Journal of Physiotherapy,Edizioni Minerva Medica, Corso Bramante 83-85, 10126 Torino, Italy – Phone +39-011-678282 – Fax +39-011-674502 – E mail: journals6.dept@minervamedica.it

ARTICLE TYPES

Instructions for the types of articles submitted to the journal. The number of figures and tables should be appropriate for the type and length of the paper.

Editorials. Commissioned by the Editor in Chief or the Managing Editor, editorials deal with a subject of topical interest about which the author expresses his/her personal opinion. No more than 1000 words and up to 15 references will be accepted.

Original articles. These should be original contributions to the subject. The text should be 2500-5000 words not including references, tables, figures. No more than 50 references will be accepted. The article must be subdivided into the following sections: *introduction, materials and methods, results, discussion, conclusions*. In the introduction the aim of the study should be clearly summed up. Justify the study, why is it needed. Summarize the rationale for the study or observation. Give only pertinent references, and do not review the subject extensively. Do not include data or conclusions from the work being reported. The materials and methods section should describe in a logical sequence how the study was designed and carried out. Identify the methods, equipment and materials, and procedures in sufficient detail including pertinent references, to allow others to reproduce the study. Describe how the data were analyzed (what hypothesis was tested, what type of study was carried out, how randomization was done, how the subjects were recruited and chosen, provide accurate details of the main features of treatment, of the materials used, of drug dosages, of unusual equipments, of the statistical method. In the results section the answers to the questions posed in the introduction should be given). Describe statistical methods in enough detail to enable knowledgeable readers with access to the original data to verify the reported results. Authors should report and identify the specific statistical test used and the obtained statistical value. When analysing several outcome variables and/or investigating the relationship between many variable consider to use multivariate statistical methods. Specify any general-use computer programs used. The results should be reported fully, clearly and concisely supported, if necessary, by figures, graphs and tables. Present results in logical sequence. Avoid repeating information in text, tables and figures. Restrict tables and figures to those needed to explain arguments and to assess their support. The discussion section should sum up the main results, critically analyze the methods used, compare the results obtained with other published data and discuss the implications of the results. Discuss the limitation of the study. The conclusions should briefly sum up the significance of the study and its future implications. Do not repeat in detail data or other information presented in the Introduction or Result section. It is suggested to the authors to follow the guidelines reported by the CONSORT statement.

Review articles. Review articles should discuss a topic of current interest, outline current knowledge of the subject, analyze different opinions regarding the problem discussed, be up-to-date on the latest data in the literature. The text should be 3000-8000 words not including references, tables, figures. No more than 100 references will be accepted. It is suggested to the authors to follow the guidelines reported by the PRISMA statement. Authors of systematic review articles should: define a clear and clinically relevant research question; retrieve and describe relevant reviews published to date; document their limitations and justify the need for a more comprehensive review; define the search strategy used to identify primary articles; describe the methods used to select primary studies; specify inclusion and exclusion criteria; account for all studies identified by the search and justify exclusions; describe the method of combining study results; discuss variation within and between studies; state their conclusions; compare their conclusions to the literature and current standard of care; outline the limitations of the review; suggest areas for future research.

Case reports. These give a description of particularly interesting cases, for which is justified do not wait to have a greater sample size. Case reports are most valuable if they identify a previously not described finding or phenomenon, or if they describe a therapy that could lead to future research or a change in practice. The text should be 1500-3000 words not including references, tables, figures. No more than 30 references will be accepted. The article must be subdivided into the following sections: introduction, case report or clinical series, discussion, conclusions.

Special articles. These are articles on the history, health care delivery, ethics, economic policy and law concerning physiotherapy. The text should be 2000-7000 words not including references, tables, figures. No more than 50 references will be accepted.

Letters to the Editor. These may refer to articles already published in the journal or to a subject of topical interest that the authors wish to present to readers in a concise form. The text should be 500-1000 words not including references, tables, figures. No more than 5 references will be accepted.

Guidelines. These are documents drawn up by special committees or authoritative sources.

PREPARATION OF MANUSCRIPTS

Text file

The formats accepted are Word and RTF. All submissions should be in English in 12-point Arial, Times, or Times New Roman font. Double-space the text with margins at least 2.5 cm (1 inch). Authors are requested to include line numbers to their manuscript in word prior to submission.
The text file must contain title, authors' details, notes, abstract, key words, text, references and titles of tables and figures. Tables and figures should be submitted as separate files.

Title and authors' details

- Title, with no abbreviations.
- First name, surname of the authors
- Affiliation (section, department and institution) of each author

Notes

- Dates of any congress where the paper has already been presented.
- Name, address, e-mail of the corresponding author;
- Mention of any funding or research contracts or conflict of interest.
- Acknowledgements.
- Word count of the text and the number of figures and tables in the article

Abstract and key words

Articles should include an abstract of between 200 and 250 words structured with the following subheadings: Background, Objective, Study design, Methods, Results, Conclusions. Up to 5 key words or terms should be included for use by referencing sources. Key words should refer to the terms from Medical Subject Headings (MeSH) of MEDLINE/PubMed. No abstracts are required for editorials or letters to the Editor.

Text

Identify methodologies, equipment (give name and address of manufacturer in brackets) and procedures in sufficient detail to allow other researchers to reproduce results. Specify well-known methods including statistical procedures; mention and provide a brief description of published methods which are not yet well known; describe new or modified methods at length; justify their use and evaluate their limits. Units of measurement, symbols and abbreviations must conform to international standards. Measurements of length, height, weight and volume should be given in metric units (meter, kilogram, liter) or their decimal multiples. Temperatures must be expressed in degrees Celsius. Blood pressure must be expressed in millimeters of mercury. All clinical chemistry measurements should be expressed in metric units using the International System of Units (SI). The use of unusual symbols or abbreviations is strongly discouraged. The first time an abbreviation appears in the text, it should be preceded by the words for which it stands.

Language

Please write your text in good English. All accepted manuscripts will be subject to copyediting.

Photographic Consents

A letter of consent must accompany all photographs of subjects in which the possibility of identification exists. It is not sufficient to cover the eyes to mask identity.

References

Cite references in the text by using superscripted Arabic numerals, and number them in the order in which they are cited. Type the reference section double-spaced at the end of the text, following the examples given below. References must be set out in the standard format approved by the International Committee of Medical Journal Editors (www.icmje.org).

JOURNALS

Each entry must specify the author's surname and initials (list all authors when there are six or fewer; when there are seven or more, list only the first six and then "*et al.*"), the article's original title, the name of the Journal (according to the abbreviations used by MEDLINE/PubMed), the year of publication, the volume number and the number of the first and last pages. When citing references, please follow the rules for international standard punctuation carefully.

Examples:
- Standard article.
Sutherland DE, Simmons RL, Howard RJ. Intracapsular technique of transplant nephrectomy. Surg Gynecol Obstet 1978;146:951-2.
- Organization as author
International Committee of Medical Journal Editors. Uniform requirements for manuscripts submitted to biomedical journals. Ann Int Med 1988;108:258-65.
- Issue with supplement
Payne DK, Sullivan MD, Massie MJ. Women's psychological reactions to breast cancer. Semin Oncol 1996;23(1 Suppl 2):89-97.

BOOKS AND MONOGRAPHS

For occasional publications, the names of authors, title, edition, place, publisher and year of publication must be given.

Examples:
- Books by one or more authors
Rossi G. Manual of Otorhinolaryngology. Turin: Edizioni Minerva Medica; 1987.
- Chapter from book
De Meester TR. Gastroesophageal reflux disease. In: Moody FG, Carey LC, Scott Jones R, Ketly KA, Nahrwold DL, Skinner DB, editors. Surgical treatment of digestive diseases. Chicago: Year Book Medical Publishers; 1986. p. 132-58.
- Congress proceedings
Kimura J, Shibasaki H, editors. Recent advances in clinical neurophysiology. Proceedings of the 10th International Congress of EMG and Clinical Neurophysiology; 1995 Oct 15-19; Kyoto, Japan. Amsterdam: Elsevier; 1996.

ELECTRONIC MATERIAL

- Standard journal article on the Internet
Kaul S, Diamond GA. Good enough: a primer on the analysis and interpretation of noninferiority trials. Ann Intern Med [Internet]. 2006 Jul 4 [cited 2007 Jan 4];145(1):62-9. Available from:
http://www.annals.org/cgi/reprint/145/1/62.pdf
- Standard citation to a book on CD-ROM or DVD
Kacmarek RM. Advanced respiratory care [CD-ROM]. Version 3.0. Philadelphia: Lippincott Williams & Wilkins; ©2000. 1 CD-ROM: sound, color, 4 3/4 in.
- Standard citation to a homepage
AMA: helping doctors help patients [Internet]. Chicago: American Medical Association; ©1995-2007 [cited 2007 Feb 22]. Available from: http://www.ama-assn.org/.

Footnotes and endnotes of Word must not be used in the preparation of references.

References first cited in a table or figure legend should be numbered so that they will be in sequence with references cited in the text taking into consideration the point where the table or figure is first mentioned. Therefore, those references should not be listed at the end of the reference section but consecutively as they are cited.

Titles of tables and figures

Titles of tables and figures should be included both in the text file and in the file of tables and figures.

File of tables

Each table should be submitted as a separate file. Formats accepted are Word and RTF. Each table must be typed correctly and prepared graphically in keeping with the page layout of the journal, numbered in Roman numerals and accompanied by the relevant title. Notes should be inserted at the foot of the table and not in the title. Tables should be referenced in the text sequentially.

File of figures

Each figure should be submitted as a separate file. Formats accepted: JPEG set at 300 dpi resolution preferred; other formats accepted are TIFF, PNG, PDF (high quality) and Word (for graphs). Figures should be numbered in Arabic numerals and accompanied by the relevant title. Figures should be referenced in the text sequentially.
Reproductions should be limited to the part that is essential to the paper.
Histological photographs should always be accompanied by the magnification ratio and the staining method.
If figures are in color, it should always be specified whether color or black and white reproduction is required. The cost of color figures will be charged to the Authors.
Optimal dimensions for publication of figures in the journal are:
- 8.6 cm (base) × 4.8 cm (height)
- 8.6 cm (base) × 9 cm (height)
- 17.6 cm (base) × 9 cm (height)
- 17.6 cm (base) × 18.5 cm (height): 1 page.

ITALIAN JOURNAL OF PHYSIOTHERAPY

Vol. 3 June 2013 No. 2

Società Italiana di Fisioterapia

CONTENTS

The new SIF management and the IJP

R. GATTI

School of Physiotherapy, Fondazione Centro San Raffaele, Milan, Italy

The III National Congress of the Italian Society of Physiotherapy (Società Italiana di Fisioterapia, SIF) was held on May 24-25, 2013. The Congress focused on the therapeutic exercise applied to musculoskeletal and neurological impairments. About 200 physiotherapists who attended the Congress expressed appreciation for the scientific level and the relevance of the lectures' contents. Moreover, 50 communications have been presented at the Congress as oral communications or posters and the general opinion has been that the scientific level was high.

I think this was the demonstration of the Italian physiotherapy's growth, for which the SIF is giving an important contribution.

In occasion of the Congress, the SIF members' Annual Meeting has been convened. After three years of life, the aim of the meeting was the election of the new SIF management team. Taking into consideration the results obtained, the SIF members decided to continue with the setting given to the Society by the old management and, as the Society statute does not allow the re-election of the same President, as former Vice President, I have been elected as the new SIF President.

The fact that I am both the Editor in Chief of the SIF scientific journal (IJP) and the President of the Society could not be appropriated. The passed three years demonstrated the importance of role distribution among the members of the management, in order to maintain a high level of motivation and collaboration and the possibility to integrate the activities dedicated to the SIF with the other professional engagements.

Obviously, each decision about my double role has to be taken by the management and I am sure that they will be able to find the best solution, considering first of all the SIF's interests. Anyway, this is the occasion for some considerations about the state of the journal. The scientific level of the publications has always been quite good and this result has been obtained through the collaboration of the Editorial board, composed by international experts in both clinical and scientific aspects of physiotherapy. Especially the three Associate editors Andrew Guccione, Marco Baccini and Matteo Paci have always been present, whenever it was useful. Moreover, the journal has been indexed in Cinahl and we are waiting for other Databases indexings.

The weakest point of the journal is the low number of papers submitted. Until the IJP will not be indexed in greater databases as Scopus, Embase, Medline etc. it will not be able to attract a higher number of submissions. In the same time, a greater number of submitted articles could facilitate the process of indexing.

Probably this difficulty is common at the beginning of the life of all scientific journals. Anyway, I am very confident about the IJP future because Italian physiotherapists are even more involved in scientific activities and consequently the number of submissions is expected to increase. The signals are encouraging, so we only need to keep on working.

Corresponding author: R. Gatti, School of Physiotherapy, Fondazione Centro San Raffaele, Milan, Italy.
E-mail: roberto.gatti@sif-fisioterapia.it

ORIGINAL ARTICLE

Kinematic analysis of 3-dimensional mobilization techniques of the upper cervical spine: a reliability analysis and comparison of techniques

G. SGARBI, S. PROVYN, A. SCAFOGLIERI, P. VAN ROY, E. CATTRYSSE

Department of Experimental Anatomy (EXAN), Vrije Universiteit Brussel, Brussels, Belgium

ABSTRACT

Aim. No previous studies analyzed the three-dimensional kinematic aspects of the upper cervical spine during manual combined mobilizations. The present *in-vitro* study aims to analyze the kinematic behavior of the atlanto-occipital joint during 3D mobilizations and the undesired movements of C1-C2. The comparison between locking and manual fixation techniques is reported, also considering a kinematic analysis of the performed motions. An intra and inter-reliability analysis is also studied.

Methods. Twenty fresh human cervical specimens were studied in a test-retest situation with two examiners, using a Zebris CMS20 ultrasound-based tracking system. Two different 3D- mobilizations (flexion-right axial rotation and flexion-left axial rotation) of the atlanto-occipital joint were performed, comparing segmental manual fixation and segmental locking techniques of C1-C2 segment. The intra- and inter-examiners reliability and kinematics were analyzed.

Results. Although no significant differences between examiners were found, the results do not demonstrate a significant correlation. The manual fixation technique and the direction of axial rotation to the right enables to increase the flexion motion in the atlanto-occipital joint. The manual fixation nor the locking technique influences the axial rotation motion in the atlanto-occipital joint. The cross-correlation parameter demonstrated a contra-lateral pattern between main axial rotation and coupled lateral bending in the atlanto-occipital joint, but an ispi-lateral pattern in the atlanto-axial joint. The main axial rotation was greater than the coupled lateral bending, mainly in the C1-C2 segment.

Conclusion. The use of different segmental manual techniques during complex mobilizations can influence the kinematics of the upper-cervical spine. However, as a reproducibility is low, 3D-kinematic variability is high.
(It J Physiotherapy 2013;3:38-46)

KEY WORDS: Spine - Biomechanics - Posture.

The kinematic analysis of the cervical spine has been studied by several authors using different approaches. Some *in-vivo* studies have attempted to record normal cervical range of motion in different postures,[1] comparing different instrumentations,[2] or analyzing differences between ages and gender.[3]

In some experiments,[4, 5] the three dimensional physiological movements of the upper cervical spine (C0-C1, C1-C2 segments) were recorded. Other authors have focused on the coupling behavior of the occipito-atlanto-axial complex during planar motion, in *in-vitro* as well as *in-vivo* studies.

Controversies remain about the behavior of the coupled motion pattern of the upper cervical spine. Anatomical variation has been proposed as one explanation for the reported contradictions. Injuries and different spinal postures may also influence main and coupled motion pat-

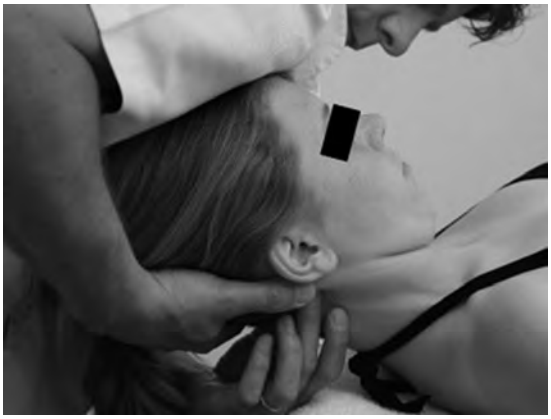

Figure 1.—Manual mobilization of the atlanto-occipital joint with manual fixation of C1.

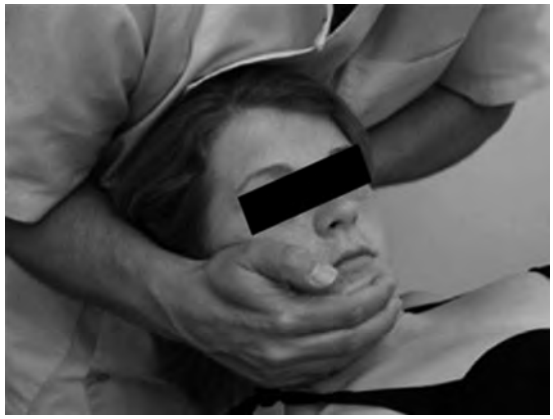

Figure 2.—Manual mobilization of the atlanto-occipital joint with locking of the lower and mid cervical spine.

terns.[6-8] Moreover, the device used during the measurement process and differences associated with *in-vivo* and *in-vitro* specimens [9] may lead to variable results.

In manual therapy the three-dimensional aspect (3D) of joint kinematics are assessed and treated based on a specific concept of motion coupling.[10]

Segmental spinal mobilization is proposed as a way of restricting the desired effect of the intervention to one specific motion segment. It is, however, not know whether and to what extent such a restriction can be achieved. Understanding the segmental three-dimensional kinematics of upper cervical manual mobilization techniques is especially relevant in appreciating the possible risks and effects of such interventions. As previous studies highlighted, the use of different manual techniques can have various effects on the atlanto-occipital joint. In particular the manual fixation technique focuses on the main motion, although the locking technique is useful to reduce the undesired movements of the atlanto-axial joint.[11]

In literature very few studies report on the analysis of segmental ranges of movement of main and coupled motions during manual passive mobilization of the upper cervical spine. Some studies analyzed the 3D aspects of manual planar mobilizations of the atlanto-occipital and atlanto-axial joints,[11-13] comparing different segmental fixation techniques with a regional mobilization. The experiments revealed that segmental mobilizations can reduce coupled motion components associated to the main motion but they did not influence the range of the main motion, suggesting that different techniques could be useful in different situations depending on the desired effects.

Although these experiments gather useful information concerning manual planar mobilization techniques. To date, there are no studies analyzing the 3D- kinematics of three-dimensional non-planar, *i.e.*, combined or complex mobilization of the upper cervical spine.

This study aims to present an *in-vitro* experimental study, conducted by two expert manual therapists, in which the kinematics of the upper cervical spine were recorded during manual three-dimensional mobilization, *i.e.*, combined flexion with axial rotation, in the atlanto-occipital joint. Two different techniques used in manual therapy were compared: segmental manual fixation of the lower segment and segmental 3D-locking technique (Figures 1, 2).

The purpose of this study was threefold: to better understand 1) how different manual techniques can influence the kinematics of the upper cervical spine; 2) the relationship between the three-dimensional main motion and the coupled components; 3) how 3D-mobilizations differ from planar mobilizations and to analyze inter- and intra- therapist reliability of these effects. The methodology of the study has been used previously in similar experiments.

Materials and methods

Specimens

In this experimental study 20 fresh human spinal specimens were included (9 male and 11 female). Each specimen included the occiput, the cervical segments and the first two thoracic vertebrae. The mean age of the specimens was 80 years (± 11 years) with a range 59 to 97.

Room temperature was controlled between 15° and 20° and humidity was above 60% to prevent dehydration of the specimens during the test procedure.

Instruments

A Zebris CMS20 ultrasound-based motion tracking system (Zebris Medical GmbH – Germany) was used in this study.

The accuracy of the system has been studied previously, demonstrating an angular accurancy of <0.2.[14]

Raw data were recorded as ASCII files and kinematic data were computed using Mathcad 14.0 M020 professional software.

Methods

It has been demonstrated that the biomechanical properties of ligaments and tendons do not change due to conservation by freezing.[23, 24] In all specimens the skin, subcutaneous tissue and muscles were taken, leaving the muscular insertions and ligaments intact. This procedure is necessary because, due to the fixation of the ultrasound system on the segments, uncontrolled movements and coupled motions might occur.

Specially fabricated fixation tools were inserted in the parietal part of the occiput (C0), the transverse process of the atlas (C1) and the transverse process of the axis (C2). The transmitters and the receiver of the Zebris system were mounted on these fixation tools. Before starting the mobilizations, the optimal positioning of the device was controlled for every specimen. The specimen was mounted in a supine posture on an examination table to simulate a physiotherapy session. The dissection and the optimal positioning of the fixation tools guaranteed free mobility of the cervical spine through full range of motion in axial rotation, lateral bending, flexion-extension and combined directions.[14]

During the experiment each specimen was manually guided through two mobilizations. First a flexion and right axial rotation mobilization was performed in the C0-C1 segment, and subsequently a flexion and left axial rotation. These two types of mobilization were executed with two different segmental techniques, with the purpose of focusing the movement at the cervical segment that had to be treated. Firstly, in the manual fixation technique, the therapist fixed the axis manually by the posterior arch while mobilizing the head in flexion-axial rotation direction. Secondly, in the locking technique, the inferior cervical spine was brought into a three dimensional end-range position combining flexion, lateral bending and contralateral axial-rotation up to the C1-C2 segment before mobilizing the atlanto-occipital joint.[11] All the mobilization techniques were performed three times consecutively in a test-retest session by two expert manual physiotherapists. Both examiners performed a trial with feedback of the tracking system in a test-retest session on one specimen to optimize concordance between the mobilizing techniques and to get customized with the test set-up.[14] The test-retest order was assigned randomly for the two investigators, who were blinded from the analysis data of the system during testing.

3-D angles of motion

The positional angles used in the present analysis are reproduced from the Zebris-winbiomechanics software. A graphical representation of the calculated angles has been presented by Wang *et al.*[25]

The angles are defined according to a local reference frames based on the transverse processes and anterior tubercle of the atlas in close concordance with guidelines of International Society of Biomechanics (ISB).[26]

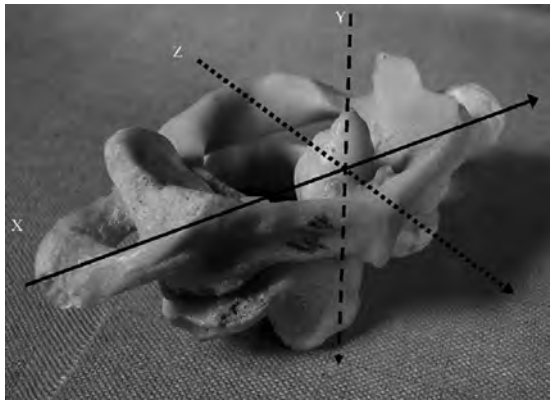

Figure 3.—Bone embedded coordinate system on C1. X-axis: segmental flexion-extension, Z- axis: segmental lateral bending axis, Y-axis: segmental axial rotation axis

Left and right are respectively represented by - and + signs (Figure 3).

Data analysis of motion coupling patterns

Six different parameters were defined to describe the pattern of motion coupling between the main flexion-axial rotation and the coupled lateral bending movement in an objective way.

The starting point was not strictly defined before the execution of the mobilization, therefore the motion was derived from the extreme position reached regarding each axis. This results in three positions: flexion, axial rotation and lateral bending positions, labeled Max X, Max Y, Max Z, respectively.

The Euclidean norm, represented by the formula:

$$\sqrt{x^2 + y^2 + z^2}$$

represents a vector which can be considered a mathematical representation of the overall amount of motion.

The cross-correlation (CC) between the axial rotation and the coupled lateral bending component can be considered the equivalent of a Pearson correlation coefficient.

The ratio between the axial rotation and the coupled lateral bending was defined as the ratio of the extreme positions of axial rotation and lateral bending motions.

Statistical analysis

SPSS software (©SPSS Inc., Chicago, IL, USA, version 19.0) was used for the statistical analysis of results using the 5% significance level ($P<0.05$).

The reproducibility of the results was studied by analysis of differences and correlations between test and retest results of two operators. Parametric techniques were used after controlling data distribution by a Kolmogorov-Smirnoff goodness-of-fit test.

For both segmental mobilization techniques, locking and manual fixation, the differences between paired data of measurements were defined using an analysis of variance (ANOVA) and consecutive paired Student's *t*-test.

The strength of the correlation between parameters in different measurement situations was estimated by the intra-class correlation coefficient (ICC). The classification of this index is included between <0 and 1, where <0 is "poor", 0-0.20 is "slight", 0.21-0.40 is "fair", 0.41-0.60 is "moderate", 0.61-0.80 is " substantial", 0.81-1.00 is "almost perfect" correlation, and negative values demonstrating negative correlations.

Results

Intra- and interexaminers reliability

An ANOVA was performed to analyze differences between the results of the two examiners in the test-retest situation (Table I).

Regarding the atlanto-occipital joint, only significant differences between examiners were demonstrated for the extreme axial rotation position during flexion-right axial rotation with manual fixation (FRM01). On the other hand, more differences between examiners and between repeated executions were demonstrated at the atlanto-axial joint.

Analyzing the variables of the extreme position in the three different directions (Max X, Max Y, Max Z), only three comparisons did not show statistical differences: flexion-right rotation and left axial rotation of C0-C1 with locking technique (FRL 01, FLL 01), and flex-

Table I.—*ANOVA of 3D-mobilizations (test-retest in two examiners).*

Parameters	FRM 01	FLM 01	FRL 01	FLL 01	FRM 12	FLM 12	FRL 12	FLL12
MAX X	0.946	0.339	0.131	0.122	0.400	0.001**	0.035*	0.000**
MAX Y	0.017*	0.167	0.114	0.122	0.668	0.639	0.875	0.649
MAX Z	0.940	0.555	0.259	0.915	0.001**	0.004**	0.139	0.368
EUCL. NORM	0.194	nc	nc	nc	0.002**	0.05*	0.81	0.014*
CC	0.651	0.536	0.615	0.960	0.920	0.261	0.610	0.184
RATIO	0.401	0.813	0.223	0.673	0.242	0.896	0.352	0.898

Max X: extreme position flexion movement; Max Y: extreme position axial rotation movement; Max Z: extreme position lateral bending movement; Eucl. norm: Euclidean norm; CC: cross-correlation between axial rotation and lateral bending motions; Ratio: relative amount between axial rotation and lateral bending motions; FRM: flexion-right axial rotation with manual fixation; FLM: flexion-left axial rotation with manual fixation; FRL: flexion-right axial rotation with locking technique; FLL: flexion-left axial rotation with locking technique; 01: C0-C1 segment, 12: C1-C2 segment.nc: not calculated. *: P≤0.05; **: P≤0.01.

Table II.—*Intra-class correlation coefficients of kinematic parameters.*

Parameters	C01 Right left				C12 Right left			
	Manual lock		Manual lock		Manual lock		Manual lock	
	ICC				ICC			
MAXX	0.62**	0.76**	0.47*	0.15	0.67**	-	-	-
MAXY	-	0.33	0.68**	0.79**	0.30	0.47*	-0.30	0.10
MAXZ	-0.32	-0.31	-0.20	-0.39	-	0.32	-	0.54**
Eucl. norm	0.50*	nc	nc	nc	-	0.72**	-	-
CC	-0.09	0.40	0.35	0.17	0.54**	0.17	0.47*	0.50*
Ratio	0.43*	0.17	-0.15	0.11	-0.13	0.09	-0.42	0.13

ICC: intra-class correlation coefficient; Manual: manual fixation technique; Lock: locking technique, right: right axial rotation, left: left axial rotation Max X: extreme position flexion movement; Max Y: extreme position axial rotation movement; Max Z: extreme position lateral bending movement; Eucl.norm: Euclidean norm; CC: cross-correlation between axial rotation and lateral bending motions; Ratio: relative amount between axial rotation and lateral bending motions; 01: C0-C1 segment; 12: C1-C2 segment; nc: not calculated, - parameters showing statistical significant differences from ANOVA, *: P≤0.05, **: P≤0.01.

ion-left rotation C0-C1 with manual fixation (FLM 01).

In all cases where the single values showed significant differences between examiners the Euclidean norm was calculated to be further analyzed using Student's t-test.

The strength of correlations was estimated by the intra class correlation coefficient (ICC) which varied between 0,43 to 0,79, only showing statistical significance in a limited number of comparisons (Table II).

Max X during flexion left and right rotation mobilization with locking technique and flexion- left rotation with manual fixation in C1-C2 segment (FRL 12, FLL 12, FLM 12) shows no differences for the intra-examiners comparisons, as well as the Euclidean norm, during flexion-right and left axial rotation with manual fixation.

Analysis of differences between techniques

The mean and the standard deviation within examiners were calculated for all the parameters that showed acceptable intra- and interobserver reliability (Table III).

Most of these values present not significant ICC-values. For that reason only a limited number of comparisons between different techniques could be performed using the Student's *t*-test (Table IV).

The analysis of techniques shows a significant difference (P=0.001) of 2.6° in the flexion motion during the manual fixation in the atlanto-occipital joint, and a difference (P=0.02) of 1.6° between the flexion-right axial rotation and flexion-left axial rotation. Otherwise axial rotation movement is not influenced by the type of segmental fixation.

Table III.—*Mean values (SD) of the extreme position of the three direction (in degrees).*

N.=20	Max X	Max Y	Max Z
FRM 01	3.06 (4.5)	-	0.39 (2.2)
FLM 01	1.4 (4.6)	-0.3 (5)	1.7 (2.9)
FRL 01	0.4 (5.7)	1.4 (4.4)	-1.9 (3.4)
FLL 01	-0.7 (4.3)	-0.3 (6.2)	1.2 (3.2)
FRM 12	-0.04 (5.3)	5.3 (5)	-
FLM 12	-	0.5 (3.9)	-
FRL 12	-	23 (11.9)	2.7 (6.3)
FLL 12	-	-21 (8.4)	-1.1 (8.4)

N: number of specimens; SD: standard deviation; Max X: extreme position flexion movement; Max Y: extreme position axial rotation movement; Max Z: extreme position lateral bending movement; FRM: flexion-right axial rotation with manual fixation; FLM: flexion-left axial rotation with manual fixation; FRL: flexion-right axial rotation with locking technique; FLL: flexion-left axial rotation with locking technique; 01: C0-C1 segment; 12: C1-C2 segment, -:statistical significant values in the ANOVA test, the mean was not calculated.

Table IV.—*Manual* vs. *locking fixation technique, right rotation* vs. *left rotation during manual fixation (Student's* t-*test/ C0-C1 segment).*

	Mean (SD)	Sign
Manual *vs*. locking		
Max X01: FRM *vs.* FRL	2.6 (2.9)	0.001*
Max Y01: FLM *vs*. FLL	-0.02 (3.6)	0.976
Right *vs.* left rotation		
Max X01: FRMvsFLM	1.6 (2.9)	0.02*

Manual: manual fixation technique; Locking: locking technique; right: right axial rotation movement; left: left axial rotation movement; SD: standard deviation; Sign: significant, *:P≤0.05, Max X: extreme position flexion movement; Max Y: extreme position axial rotation movement; FRM: flexion-right axial rotation with manual fixation; FLM: flexion-left axial rotation with manual fixation; FRL: flexion-right axial rotation with locking technique; FLL: flexion-left axial rotation with locking technique; 01: C0-C1 segment; 12: C1-C2 segment. *: P≤0.05.

Cross-correlation

The means and standard deviation of CC were calculated for negative and positive values separately.

The mean CC-values of atlanto-occipital joint movements tend to be generally negative demonstrating a contra-lateral coupling between axial rotation and lateral bending motion components, while in the atlanto-axial joint it is generally a positive value demonstrating an ipsilateral coupling pattern (Figure 4).

The mean CC-values for the C0-C1 segment vary from -0.55 to -0.90 and from 0.53 to 0.93.

Cross-correlation values for the C1-C2 segment vary from -0.05 to -0.83 and from 0.39 to 0.81.

Ratio

As for the cross-correlation parameter, the means and standard deviation of the ratio between segmental axial rotation and segmental lateral bending motion components were calculated for the test-retest data. The values for contra-lateral and ipsi-lateral coupling specimens were calculated separately.

Ratio's for C0-C1 segment vary from -0.7 (0.44) to -5.6 (13.9) and from 0.6 (0.48) to 11.5 (34.9).

At the C1-C2 segment ratios vary from -1.6 (0.6) to -13.4 (20.2) and from 1.6 (0.8) to 31.8 (64.7).

The extreme position of the axial rotation motion component exceeds the extreme position of coupled lateral bending, mainly in the C1-C2 segment.

Discussion

The purpose of the study was to analyze the kinematic behavior of the atlanto-occipital joint of two different three-dimensional mobiliza-

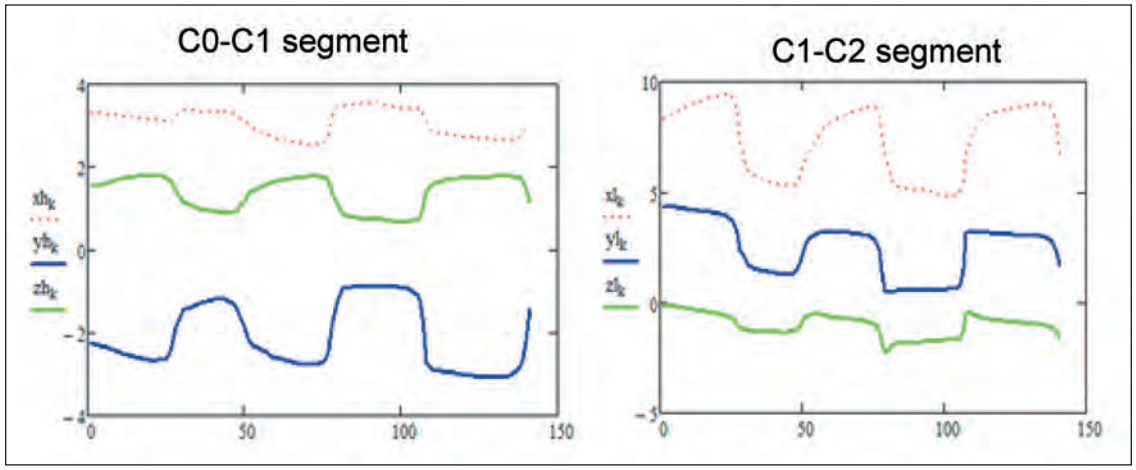

Figure 4.—Motion coupling pattern during flexion-left axial rotation with manual fixation technique in C0-C1 segment (specimen 173/Mathcad-graph). A) Contralateral combination of axial rotation and lateral bendig; B) ipsilateral combination of axial rotation and lateral bendig. xhk: flexion-extension axis; yhk: axial rotation axis; zhk: lateral bending axis; k: sampling size 20Hz.

tions, flexion-right axial rotation and flexion-left axial rotation, comparing two different segmental manual techniques to fix the atlanto-axial joint. However, before comparing techniques inter- and intra-therapist reproducibility had to be analyzed.

Reproducibility of manual and more specifically segmental mobilization techniques remains a debatable matter. Previous studies [14] showed differences in intra-examiner reproducibility between observers.

In this experiment low level of intra- and inter-examiners reproducibility was demonstrated. One might suppose that a higher level of experience and familiarity with the applied techniques could increase the inter-examiner reliability level. However, this was not demonstrated from the results as no higher test-retest reproducibility could be demonstrated for one examiner over the other.

Mobilizations were performed on the C0-C1 segment, whereas the lower segment C1-C2 was fixed. Thus, the attention of the examiners was pointed on the mobilized segment. This in turn might explain partly why the reproducibility results were lower on the atlanto-axial segment.

Although relative minor differences between consecutive registrations were observed, the ICC's are not statistically significant in the majority of comparisons, varying from 0.43 to 0.79, *i.e.*, from moderate to substantial. This result might be related to the fact that the occipito-atlanto-axial complex exhibits the highest total range of motion when compared with other cervical segments,[9] and also by the fact that there may be less control of the mobilized segment by the therapist during a 3D mobilization, with respect the execution of a planar mobilization.

The analysis of differences between the two different segmental fixation techniques, on one hand, and between opposite direction of axial rotation movement on the other hand, shows respectively a mean difference of 2.6° and 1.6°. However, the axial rotation movement is not influenced by the type of segmental fixation in the C0-C1 segment.

Regarding the extreme positions reached in the three motion directions during different types of mobilization, it seems that the coupled lateral bending motion in C0-C1 segment is not influenced by the locking nor by the manual fixation technique (0.39° to 1.9°), while the manual fixation technique seems to reduce the axial rotation motion in the C1-C2 segment (0.5°-5.3° in manual fixation *versus* 21°-23° in locking technique). This might be explained by the nature of the fixation. By fixing the posterior arch of C1 between index and thumb, the examiner seems to be well capable of controlling the axial rotation in the atlanto-axial joint.

This confirms the results of a previous

study [11] which showed a reduction of associated axial rotation and lateral bending motions using the manual fixation technique without influencing the main of flexion-extension motion component in the C0-C1 segment, and a reduction of all movement component in the atlanto-axial joint with the locking technique.

Moreover previous studies [12] also observed a reduction of coupled lateral bending and flexion-extension motion during an axial rotation mobilization using a manual segmental fixation technique. In the same study,[12] during a lateral bending mobilization of C1-C2 segment, the manual fixation technique reduced the effect on the coupled flexion-extension component. This study, according to previous articles, helps the manual therapist to choose among different techniques, according to the effect he wants to obtain on the cervical segment: reducing the undesired movements on lower cervical segments or focusing on the main three-dimensional motion.

The relationship between the axial rotation and the coupled lateral bending components is described by the cross correlation (CC) analysis. It seems that the CC in the atlanto-occipital joint tends to be a negative value, representing a contra-lateral coupled lateral bending, while in the atlanto-axial joint there is a tendency towards a positive value, showing an ispi-lateral coupled lateral bending motion.

The contra-lateral pattern of axial rotation with lateral bending in C0-C1 segment confirms the findings of previous studies,[6, 7, 9, 12, 15-19] but this does not occur for the C1-C2 segment in the present study. In general in the literature, a contra-lateral pattern of coupled lateral bending is observed at the atlanto-axial joint during planar main axial rotation or main flexion-extension movement.

In agreement with other studies,[6, 8, 13, 22] in this experiment the ratio showed a larger extreme axial rotation position than the extreme lateral bending position both in the ispi-lateral and contra-lateral coupling specimens, mainly at the C1-C2 segment. This can be explained by the fact that the major motion component taking place in the C1-C2 segment is axial-rotation.

There are many differences between the previous studies [11, 12] and the present experiment. First of all the number and the type the of specimens, 6 embalmed versus 20 fresh specimens. Secondly the previous studies analyzed only the intra-examiner reproducibility of one observer. The acceptable intra-examiner reproducibility and significance in the ICC values permitted to perform a more extensive comparison between techniques. Finally, the differences between planar and combined mobilization. During all previous studies that analyzed the upper-cervical spine, only planar movements were performed, and very few studies analyzed the effect of manual mobilization techniques. This could explain the complexity and the differences of the results for such complex mobilization techniques.

Conclusions

The results show a low intra- and inter-examiners reliability in the C0-C1 segment, as well as in the lower C1-C2 segment. This is mainly demonstrated from the low ICC-values.

The complexity of the upper cervical spine anatomy, the complexity of the mobilization techniques and the relative great mobility of the upper-cervical segments compared to the mid cervical spine, could influence the reproducibility of the 3-dimensional kinematics of segmental complex mobilizations.

A manual fixation technique can increase the main flexion motion, without affecting the axial rotation motion. Moreover, the direction of the axial-rotation motion can influence the main flexion motion in the atlanto-occipital joint.

A contra-lateral coupled lateral bending motion in the C0-C1 segment was observed, in agreement with previous studies, in contrast with an ipsi-lateral coupled lateral bending in the C1-C2 segment. The ratio shows a greater axial rotation motion compared to the coupled lateral bending, especially in the C1-C2 segment both for ipsi-lateral and contra-lateral coupling specimens.

The results of this *in-vitro* study suggest that the use of different segmental manual techniques during complex mobilizations could partly re-

sult in different kinematics of the upper-cervical spine, although the specific effect may vary due to intra- and inter- examiner variability.

Further *in-vivo* studies are warranted and may validated these results.

References

1. Edmondston SJ, Henne SE, Loh W, Ostvold E. Influence of cranio-cervical posture on three-dimensional motion of the cervical spine. Manual Therapy 2005;10:44-51.
2. Gelalis ID, De Frate LE, Stafilas KS, Pakos EE, Kang JD, Gilbertson LG. Three-dimensional analysis of the cervical spine motion: reliability of a computed assisted magnetic tracking device compared to inclinometer. Eur Spine J 2009;18:276-81.
3. Trott PH, Pearcy MJ, Rusron SA, Fulton I, Brien C. Three-dimensional analysis of the active cervical motion: the effect of the age and gender. Clin Biomech 1996;11:201-6.
4. Panjabi MM, Dvorak J, Duranceau J, Yamamoto I, Gerber M, Rauschning W, Bueff HU. Three-dimensional movements of the upper cervical spine. Spine 1988;13:726-30.
5. Karthu JO, Parkkola RK, Komu ME, Kormano MJ, Koskinen SK. Kinematic magnetic resonance imaging of the upper cervical spine using a novel positioning device. Spine 1999;24:2046-56.
6. Panjabi MM, Oda T, Crisco JJ, Dvorak J, Grob D. Posture affects motion coupling patterns of the upper cervical spine. J Orthop Res 1993;11:525-36.
7. Panjabi MM, Dvorak J, Crisco JJ, Oda T, Wang P, Grob D. Effects of alar ligament transection on upper cervical spine rotation. J Orthop Res 1991;9:584-93.
8. Panjabi MM, Dvorak j, Crisco JJ. Flexion, extension, and lateral bending of the upper cervical-spine in response to alar ligament transections. Journal of Spinal Disorders 1991;4:157-67.
9. Cook C, Hegedus E, Showalter C, Sizer Jr PS. Coupling behavior of the cervical spine: a systematic review of the literature. J Manipulative Physiol Ther 2006;29:570-5.
10. Cattrysse E, Provyn S, Kool P, Clarys JP, Van Roy P. Morphology and kinematics of the atlanto-axial joints and their interaction during manual cervical rotation mobilization. Man Ther 2011;16:481-6.
11. Cattrysse E, Baeyens JP, Clarys JP, Van Roy P. Manual fixation versus locking during upper cervical segmental mobilization. Part 1: an in-vitro three-dimensional arthrokinematic analysis of manual flexion-extension mobilization of the atlanto-occipital joint. Manual Therapy 2007;12:342-52.
12. Cattrysse E, Baeyens JP, Clarys JP, Van Roy P. Manual fixation versus locking during upper cervical segmental mobilization: Part 2: an in- vitro three-dimensional arthokinematic analysis of manual axial rotation and lateral bending mobilization of the atlanto-axial joint. Man Ther 2007;12:353-62.
13. Cattrysse E, Baeyens JP, Kool P, Clarys JP, Van Roy P. Does manual mobilization influence motion coupling patterns in the atlanto-axial joint? J Electromyogr Kinesiol 2008;18:838-48.
14. Cattrysse E, Provyn S, Kool P, Gagey O, Clarys JP, Van Roy P. Reproducibility of kinematic motion coupling parameters during manual upper cervical axial rotation mobilization: a 3-dimensional in-vitro study of the atlanto-axial joint. J Electromyogr Kinesiol 2009;19:93-104.
15. Panjabi MM, Crisco JJ, Vasavada A, Oda T, Cholewicki J, Nibu K, Shin E. Mechanical properties of the human cervical spine as shown by three-dimensional load-displacement curves. Spine (Phila Pa 1976) 2001;26:2692-700.
16. Ishii T, Mukai Y, Hosono N, Sakaura H, Nakajima Y, Sato Y, Sugamoto K, Yoshikawa H. Kinematics of the upper cervical spine in rotation: in- vivo three-dimensional analysis. Spine 2004;29:E139-44.
17. Dugailly PM, Sobczak S, Sholukha V, Van Sint Jan S, Salvia P, Feipel V *et al*. In-vitro 3D-kinematics of the upper cervical spine: helical axis and simulation for axial rotation and flexion extension. Surg Radiol Anat 2010;32:141-51.
18. Dugailly PM, Sobczak S, Moiseev F, Sholukha V, Salvia P, Feipel V *et al*. Musculoskeletal modeling of the suboccipital spine: kinematics analysis, muscle lengths, and muscle moment arms during axial rotation and flexion extension. Spine (Phila Pa 1976) 2011;36:E413-22.
19. Harrison DE, Harrison DD, Troyanovich SJ. Three-dimensional spinal coupling mechanics: Part I. A review of the literature. J Manipulative Physiol Ther 1998;21:101-13.
20. Goel VK, Clark CR, Gallaes K, Liu YK. Moment-rotation relationships of the ligamentous occipito-atlanto-axial complex. J Biomech 1988;21:673-80.
21. Oda T, Panjabi MM, Crisco JJ 3rd. Three-dimensional translational movements of the upper cervical spine. J Spinal Disord 1991;4:411-9.
22. Ishii T, Mukai Y, Hosono N, Sakaura H, Fujii R, Nakajima Y *et al*. Kinematics of the cervical spine in lateral bending: in-vivo three-dimensional analysis. Spine (Phila Pa 1976) 2006;31:155-60.
23. Panjabi MM, Krag M, Summers D, Videman T. Biomechanical time-tolerance of fresh cadaveric human spine specimens. Journal of Orthopaedic Research 1985;3:292-300.
24. Wilke HJ, KrishChack S, Claes LE. Formalin fixation strongly influences biomechanical properties of the spine. Journal of Biomechanics 1996;29:1629-31.
25. Wang FS, Teng CC, Lin KH. Measurement of the cervical range of motion pattern during cyclic neck movement by an ultrasound-based motion system. Manual Ther 2005;10;68-72.
26. Wu G, Siegler S, Allard P, Kirtley C, Leardini A, Rosenbaum D *et al*. ISB recommendation on definitions of joint coordinate system of various joint motion-part 1: ankle, hip and spine. J Biomech 2002;35:543-8.

Corresponding author: G. Sgarbi, Department of Experimental Anatomy (EXAN), Vrije Universiteit Brussel, Brussels, Belgium.
E-mail: sgarbigi@gmail.com

ORIGINAL ARTICLE

Inter-tester reliability of determining glenohumeral joint accessory motion and humeral head position

S. L. EDMOND [1], J. D'ANNUNZIO [2], N. PARIS [2]

[1]University of Medicine Dentistry NJ, School of Health Related Professions, Doctoral Program in Physical Therapy, Newark, NJ, USA; [2]Caldwell Therapy Center, West Caldwell, NJ, USA

ABSTRACT

Aim. The manual examination of glenohumeral joint accessory motion and humeral head position are components of the examination of the shoulder joint. Quantifying inter-tester reliability of these measures provides insight into their clinical usefulness. Furthermore, there is a need to investigate the hypothesis that humeral head position affects the reliability of glenohumeral joint accessory motion measurements.

Methods. Two therapists examined both shoulders of 40 subjects with unilateral shoulder pain for glenohumeral anterior, posterior and inferior glides, and humeral head position. Inter-tester reliability was calculated for each of these measures, and separately for glenohumeral glides when therapists agreed on humeral head position.

Results. Kappa scores for glenohumeral glides were less than 0.30, whereas the Kappa coefficient for humeral head position was 0.55. Kappa scores improved to 0.56 and 0,46 respectively for anterior and posterior glides when testers agreed on humeral head position.

Conclusion. The inter-tester reliability of glenohumeral joint accessory motion was poor for all glides when humeral head position was not accounted for, whereas it was moderate for humeral head position. When humeral head position was taken into consideration, anterior and posterior glide reliability coefficients improved, but only to moderate levels. *(It J Physiotherapy 2013;3:47-54)*

KEY WORDS: joints - Shoulder joint - Manipulation, orthopedic.

Joint mobilization/manipulation is a common manual intervention used to treat patients with shoulder conditions. It has been shown to be effective in managing patients with impingement syndrome,[1-4] adhesive capsulitis [4-7] and nonspecific shoulder conditions.[8]

A glenohumeral joint accessory motion examination is essential for diagnosing glenohumeral joint hypermobility [9, 10] or instability,[4, 12, 13] and is a prerequisite for administering joint mobilization/manipulation interventions performed to increase accessory motion at the glenohumeral joint.[9, 10, 14] Several methods of manually examining joint accessory motion have been proposed. Kaltenborn [9] described 2 commonly used methods in his text, titled "Manual Mobilization of the Joints". One of these 2 methods for examining accessory joint mobility entails gliding one of the articulating bones in a direction parallel to the flattened out concave joint surface. In the case of the glenohumeral joint, the humerus is glided in 3 different directions in relation to the glenoid: posterior to anterior ("anterior glide"), anterior to posterior ("posterior glide"), and superior to inferior ("inferior glide"). During the execution of the glide, the therapist makes a judgment regarding whether motion is normal, hypomobile or hypermobile. These grades are based on the amount of excursion compared with a 'normal' joint, as well as the quality of the end feel. An accessory motion judged to have decreased excursion and an end

feel that is more firm than expected is graded hypomobile, whereas a motion with greater than expected excursion accompanied by an end feel that is less firm than what is considered normal is graded hypermobile. Kaltenborn[9] suggested that therapists with less experience rely on direct comparisons with normal joints to make these determinations. Most therapists determine accessory joint mobility by comparing the accessory motion of an affected joint with the same motion on the unaffected side.[13, 15]

One prerequisite for determining the usefulness of a diagnostic test is quantifying the extent to which a measurement is reproducible, or reliable. We were able to identify 4 prior studies[11-13, 16] in which the reliability of the determination of glenohumeral joint accessory motion without the use of instrumentation in un-anaesthetized subjects was reported.

In 3 of these studies,[11-13] subjects were asymptomatic, whereas in the 4th study[16] 8 of 18 subjects were asymptomatic. The 10 symptomatic subjects in this latter study were diagnosed with a variety of shoulder musculoskeletal disorders, however the investigators did not distinguish between asymptomatic and symptomatic subjects in their analyses. Patients with shoulder pain seen in musculoskeletal rehabilitation clinics have shoulder impairments that are likely to be different from those seen in healthy subjects, and reliability coefficients therefore likely vary between these 2 groups. Since the population of interest to rehabilitation therapists consists of patients with symptomatic joints, determining the test reliability of commonly used examination procedures in a population of symptomatic subjects is essential for understanding the clinical usefulness of these examination procedures.

In 2 of the aforementioned studies in which only asymptomatic subjects were included, subjects were athletes,[11, 12] and study results only addressed the reliability of normal vs. hypermobile judgments. Patients seen for conservative management of shoulder conditions are not necessarily athletes, and are typically evaluated for both hypermobility and hypomobility. Identifying the test reliability of subjects who are likely to present with the range of joint accessory motion impairments commonly seen in outpatient clinics is also an essential component of interpreting test results in the clinical setting.

In all 4 studies, intra-tester reliability coefficients were reported. Three of the 4 studies [11, 13, 16] also reported inter-tester reliability. In many outpatient clinics, patients are often seen by more than one therapist. Arguably, treatment of patients seen by more than one therapist will be more consistent and more accurately address the true impairment if therapists agree on accessory motion examination results. There is a need to determine the inter-tester reliability of shoulder accessory motion in subjects with symptomatic shoulders who are being seen in outpatient clinics for conservative management of their shoulder symptoms.

During the physical examination of a patient with shoulder pain, clinicians often palpate the humeral head to determine if it is correctly positioned in relation to the acromion.[17-19] This evaluation procedure is performed by identifying the location of the humeral head relative to that of the acromion.[17-19] Typically, this examination procedure is performed to determine if anterior positioning of the humeral head could be contributing to shoulder pain,[17] specifically impingement syndrome.[18, 19] Lin *et al.*[20] suggested that the position of the humeral head might influence the results of accessory motion testing. For example, if the posterior capsule is hypomobile and the anterior capsule is hypermobile, then this asymmetry could cause the humeral head to be positioned more anterior in relation to the acromion than what is considered 'centered'. This condition could result in a difference in joint excursion from that which would occur if the humeral head is correctly positioned in relation to the acromion. If this is the case in a reasonable percentage of patients with shoulder conditions, then addressing humeral head position during an accessory motion examination should improve accessory motion judgments.

One prerequisite to establishing the validity of this hypothesis is identifying the reliability of determining humeral head position. Two different investigators evaluated the reliability of the determination of humeral head position in 3 separate articles.[17-19] Subjects consisted of

healthy athletes in 2 studies,[17-18] whereas in the 3rd study [19] patients with a provisional diagnosis of impingement syndrome or rotator cuff disease were included. In all 3 studies,[17-19] measurements were made from a photograph taken while palpating the shoulder structures. One study protocol also stated that a custom made device was used to position the shoulder.[17] Inter-tester reliability was reported in 2 of these studies,[17, 18] whereas in 2 studies, intra-tester reliability was reported.[17, 19]

Instrumentation, such as photography and positioning devices, is often not available or practical in the clinical setting. Most clinicians therefore rely on manual palpation techniques to evaluate humeral head positioning. To our knowledge, no study has evaluated the inter-tester reliability of the manual determination of humeral head positioning in subjects receiving conservative treatment for symptomatic shoulders.

We hypothesized that reliability could be adversely affected by humeral head positional impairments; for example, if the first test procedure for joint accessory motion produced a change in the position of the humeral head in relation to the acromion, thus changing the perception of joint accessory motion during the second accessory motion test procedure. To our knowledge, no study has evaluated the inter-tester reliability of the manual determination of humeral head positioning in patients with shoulder pain, or the effect of agreement in relation to humeral head position on the determination of shoulder accessory joint motion.

This study had 2 purposes. The first aim was to determine the inter-tester reliability of glenohumeral joint anterior, posterior and inferior glide accessory motion testing and humeral head position without the use of instrumentation in subjects with shoulder pain seen in the outpatient musculoskeletal rehabilitation setting. Secondly, we aimed to determine whether humeral head positioning has an effect on the reliability of these examination procedures. In relation to this 2nd aim, we hypothesized that the reliability of determining glenohumeral accessory motion would improve when both therapists agreed on the position of the humeral head.

Materials and methods

Both shoulders of 40 subjects with unilateral shoulder symptoms who were referred to an outpatient therapy clinic for evaluation and management of their shoulder condition between September 2004 and July 2008 were included in this study. Potential subjects with bilateral shoulder symptoms were excluded because in a typical testing procedure, an uninvolved shoulder is used for comparison purposes.[13,15] Potential subjects were also excluded if they were less than 18 years of age; or if they had a history of shoulder surgery, osteoporosis, a shoulder fracture within the 8-week period prior to initiating therapy, or a delayed or non-union shoulder fracture. Subjects were also excluded if they were judged by the first evaluating therapist to have a hot, swollen or red shoulder joint. All subjects who met the aforementioned inclusion/exclusion criteria agreed to participate and completed data collection.

The University of Medicine Dentistry New Jersey Institutional Review Board approved this study. All study-related activities were carried out in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 2000. All subjects signed informed consents, and anonymity and confidentiality was preserved.

Testers consisted of one physical therapist (JD) and one occupational therapist (NP), each with more than 20 years experience evaluating and treating patients with musculoskeletal conditions. In relation to patients with upper extremity musculoskeletal conditions, they worked in the same clinic, shared similar practice patterns and frequently shared patients. We therefore believe that it is unlikely that differences in the determination of shoulder joint accessory motion and humeral head position were due to differences in education.

Before initiating the study, the testers developed a standard protocol for determining glenohumeral accessory motion and humeral head positioning. (Appendix A) Glenohumeral joint motion was graded “hypomobile”, “normal”, or “hypermobile”, for each of the 3 glides, whereas humeral head position was graded “anterior”, “centered”, or “posterior”. We did not formally

consider end feel in our determination of joint accessory motion, since end feel judgments have been shown to decrease the reliability of the determination of glenohumeral joint motion in prior studies.[11,13]

Each subject was instructed to lie on his or her back with both shoulders exposed. Depending on scheduling considerations, subjects were examined first by either one of the 2 therapists. The affected shoulder was evaluated first, so that the therapist could assess for the presence of a red, hot, or swollen joint, as these were exclusion criteria for participation in the study. The therapist first palpated the affected shoulder to make a determination regarding the relative position of the humeral head in relation to the acromion. This therapist then moved the humerus in an anterior, posterior, and inferior direction in random order, and assessed the amount of excursion. The procedure was repeated on the unaffected shoulder. A second therapist repeated each of these procedures immediately after the first therapist completed these procedures. The second therapist was blinded to the results of the examination performed by the first therapist. All additional examination procedures were deferred until after both therapists had completed these examination procedures.

Statistical analysis

Data were analyzed using SAS version 9.2. Kappa scores were calculated for all subjects for each of the 3 shoulder accessory motions and for humeral head position. Separate Kappa scores were calculated for each of the 3 shoulder accessory motions in which only those subjects for whom both testers agreed on humeral head position, and only those subjects for whom both testers agreed that the humeral head was correctly positioned in relation to the acromion were included.

Results

Subjects were between the ages of 36 and 82 years, with a mean age of 57. Twenty-eight of the 40 subjects were female, and 18 had right-sided pain. A summary of the test results for glenohumeral glides and humeral head position is provided in Table I.

Kappa scores for all 40 subjects, for the 31 subjects with whom the therapists were in agreement regarding humeral head position, and for the 12 subjects with whom both therapists determined that humeral head position was centered, are reported in Table II. When all subjects were analyzed, for each of the 3 shoulder motions, inter-tester reliability was poor, ranging from K=0.26-0.27, whereas the reliability of palpating the position of the humeral head was K=0.55. Accessory motion Kappa scores improved to more acceptable levels for anterior (K=0.56) and posterior (K=0.46) glides when only subjects for whom both therapists agreed on humeral head position were included in the analyses. When comparing anterior and posterior glides under conditions in which clinicians agreed on humeral head position with the same glide when clinicians disagreed on humeral head position, Kappa scores were markedly higher when clinicians agreed. Improvements did not occur for inferior glide assessments when humeral head position was considered (K=0.27). Additional improvements did not occur consistently when only subjects with whom the therapists agreed that the humeral head was centered in relation to the acromion were included; how-

Table I.—*Summary of the test results for glenohumeral glides and humeral head position.*

	Anterior glide	Posterior glide	Inferior glide	Humeral head position
Therapist #1	Hypomobile N.=20	Hypomobile N.=25	Hypomobile N.=30	Anterior N.=23
	Normal N.=20	Normal N.=14	Normal N.=9	Centered N.=17
	Hypermobile N.=0	Hypermobile N.=1	Hypermobile N.=1	Posterior N.=0
Therapist #2	Hypomobile N.=23	Hypomobile N.=23	Hypomobile N.=23	Anterior N.=23
	Normal N.=16	Normal N.=15	Normal N.=16	Centered N.=16
	Hypermobile N.=1	Hypermoble N.=2	Hypermobile N.=1	Posterior N.=1

Table II.—*Kappa coefficients (95% confidence intervals) and percent agreement for inter-tester reliability of anterior, posterior and inferior glides, and humeral head position.*

	Anterior glide	Posterior glide	Inferior Glide	Humeral head position
All subjects (N.=40)	K=0.27 (-0.02, 0.55) 63%	K=0.26 (-0.03, 0.56) 63%	K=0.27 (0.00, 0.53) 65%	K=0.55 (0.30, 0.80) 78%
Subjects in which both therapists agreed on humeral head position (N.=31)	K=0.56 (0.28, 0.83) 74%	K=0.46 (0.14, 0.79) 74%	K=0.27 (-0.03, 0.58) 65%	
Subjects in which both therapists disagreed on humeral head position (N.=9)	K=-0.60 (-1.00, -0.15) 0.11%	K=-0.40 (-0.92, 0.12) 22%	K=0.27 (-0.19, 0.73) 67%	
Subjects in which both therapists agreed that the humeral head position was centered (N.=12)	K=0.50 (0.08, 0.92) 75%	K=0.33 (-0.17, 0.83) 50%	K=0.51 (0.07, 0.94) 75%	
Subjects in which both therapists disagreed on humeral head position or agreed that it was not centered (N.=28)	K=0.13 (-0.23, 0.48) 57%	K=0.24 (-0.11, 0.59) 57%	K=0.20 (-0.06, 0.47) 61%	

ever confidence intervals for these analyses were wide.

Discussion

Based on the interpretation of Kappa scores proposed by Landis & Koch,[21] the inter-tester reliability of glenohumeral glides were fair to poor (Kappa scores of 0.40 and below), whereas Kappa scores for humeral head positioning were consistent with moderate agreement (Kappa scores between 0.41 and 0.60). The inter-tester reliability of anterior and posterior glides improved to moderate levels when testers were in agreement regarding the position of the humeral head, suggesting that judgments related to humeral head positioning affect the reliability of the assessment of these glenohumeral glides. Inferior glide reliability coefficients did not improve when therapists were in agreement regarding humeral head position, perhaps because this technique is less affected by the position of the humeral head.

We were able to identify 3 other studies in which the inter-tester reliability of the examination of glenohumeral joint accessory motion, performed without the use of instrumentation was calculated.[12-13,16] Results from these 3 studies also demonstrated unsatisfactory inter-tester reliability, (Table III) indicating that inter-tester reliability is too low to make comparisons between therapists in clinical practice. Several reasons for poor reliability have been reported in the literature. These include failure to standardize the test position,[12-13,20] differences in scapular fixation across trials,[20] variability in the forces imparted to produce movement,[11-13] the subjective nature of the interpretation of the test result,[12, 13] and differences in the amount of muscle relaxation from one test to the next.[11-13, 20] Lin *et al.*[20] also suggested that humeral head position could affect reliability.

In our study, we developed a standardized test procedure, and both testers trained together before initiating the study. This protocol did not address scapular fixation, nor did it standardize the amount of force implemented to produce movement or the interpretation of the amount of joint movement. However, we did standardize test position and evaluate for the effect of humeral head position. Possibly, reliability could improve further if these other issues identified by prior investigators were addressed in our test procedure; however, standardizing test procedures to address these issues would require instrumentation.

Our standardized protocol also did not address muscle spasm or guarding. The possibility that muscle spasm or guarding could affect the determination of joint accessory motion is sup-

Table III.—*Prior studies investigating the reliability of glenohumeral joint accessory motion of un-anaesthetized subjects without the use of instrumentation.*

	Subjects	Testers	Inter-tester Reliability	Intra-tester Reliability	Glide	Scale
Levy [11]	43 asymptomatic athletes, 86 shoulders	4 physicians	K=0.05-0.07	K=0.06-0.30	Anterior, Posterior and Inferior (an axially applied 10 lb. weight was first used to center the humeral head in the glenoid fossa)	1 – 3 for hypermobility not incorporating end feel
Van Duijn [16]	18 subjects, 10 with a history of shoulder dysfunction	3 physical therapists	ICC= 0.52	ICC=0.53-0.88	Inferior	7 point grading scale ranging from ankylosed to unstable not incorporating end feel
Ellen-beck-er [12]	8 asymptomatic baseball pitchers, 16 shoulders	1 physical therapist	none	ICC=0.50	Anterior	5 point grading system for hypermobility incorporating end feel
Ellen-beck-er [13]	15 asymptomatic subjects	4 physicians and 3 physical therapists	K=0.09 K=0.21	K=0.34 K=0.53	Anterior	4 point grading system for hypermobility incorporating end feel 2 point grading system not incorporating end feel

Table IV.—*Prior studies investigating the reliability of humeral head position.*

	Subjects	Testers	Inter-tester Reliability	Intra-tester Reliability	Instrumentation	Scale
Bryde[17]	31 asymptomatic subjects	2 therapists	ICCs=0.48-0.56	ICCs=0.5-0.86	Instrumentation to hold arm in position. Measurements were taken from a photograph	Measured in millimeters
Mc Kenna[18]	15 asymptomatic junior elite swimmers	3 physical therapists	ICCs=0.49 - 0.68	None	Measurements were taken from a photograph	Measured in millimeters
Mc Kenna[19]	26 subjects with a provisional diagnosis of impingement syndrome or rotator cuff disease	1 radiologist and 1 physical therapist	None	ICC=0.85-0.91	Measurements were taken from a photograph	Measured in millimeters

ported by a study by Farber *et al.*,[22] in which they reported that over 15% of subjects with shoulder instability failed to relax enough to allow a joint motion examination to be performed. In the clinical setting, many practitioners would response to this situation by implementing techniques to reduce muscle spasm or guarding before evaluating joint accessory motion; however our protocol did not allow for these interventions. Spasm or guarding, if present during the 1st examination, could change as a result of the testing performed by the first therapist, impacting on the second therapist's determination of test results.

One additional consideration is that the amount of accessory motion might have changed (increased) as a result of the testing performed by the first therapist. A visual inspection of the data, however, suggests that this was not the case. Finally, in the clinical setting, the determination of accessory motion is often affected by other evaluation findings that are considered in conjunction with those obtained during accessory motion testing and palpation procedures, such as the reported mechanism of injury, the presence of pain or apprehension during accessory motion testing or the observation of generalized joint laxity. In our study, we did not account for these other examination findings in our determination of accessory motion and humeral head

position. Further studies designed to determine if the inter-tester reliability of glenohumeral joint accessory motion testing can be improved should consider humeral head position, but should also address these additional issues.

In our study, reliability was acceptable for the determination of humeral head position. Three other investigators evaluated the reliability of this measurement.[17-19] In all of these studies, instrumentation was used and humeral head position was measured in millimeters; therefore ICCs (Intraclass Correlation Coefficients) were reported (Table IV). Reliability measures for these studies are therefore not directly comparable with ours. Two investigators reported that reliability coefficients were highest when the subject was measured in the sitting position,[17, 19] whereas our measurements were taken with the subject in supine. Our measurements might have been more accurate had we positioned the subject in sitting; however this would have required the subject change position during the testing procedure to evaluate accessory motion, thereby potentially affecting the subject's ability to relax.

Our study had several limitations. First, the order of testing of the 2 therapists was not randomly assigned. Additionally, prevalence issues might have affected our accessory motion Kappa scores, as only a few subjects were judged to have hypermobile accessory motion or a humeral head that was posteriorly positioned. The low prevalence of these examination categories would cause Kappa coefficients to be artificially lowered,[23] thus the reliability of accessory motion and humeral head position might be higher than suggested by our statistical results.

Conclusions

Inter-tester reliability was poor, but improved to moderate levels for anterior and posterior glides when testers agreed on the position of the humeral head. Similar improvements were not seen for the measurement of mobility in an inferior direction. Glenohumeral joint anterior and posterior motion should be examined only after the therapist examines for glenohumeral joint positioning.

References

1. Conroy DE, Hayes KW, The effect of joint mobilization as a comprehensive treatment for primary shoulder impingement syndrome. J Orthop Sports Phys Ther 1998;28:3-14.
2. Bang MD, Deyle GD. Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. J Orthop Sports Phys Ther 2000;30:126-37.
3. Senbursa G, Baltaci G, Atay A. Comparison of conservative treatment with and without manual physical therapy for patients with shoulder impingement syndrome: a prospective, randomized clinical trial. Knee Surgery Sports Traumatol Arthrosc 2007;15:915-21.
4. Kelley MJ, McClure PW, Leggin BG. Frozen shoulder: evidence and a proposed model guiding rehabilitation. J Orthop Sports Phys Ther 2009;39:135-48.
5. Nicholson GG. The effects of passive joint mobilization on pain and hypomobility associated with adhesive capsulitis of the shoulder. J Orthop Sports Phys Ther1985;6:238-46.
6. Buchbinder R, Youd JM, Green S, Stein A, Forbes A, Harris A *et al.* Efficacy and cost-effectiveness of physiotherapy following glenohumeral joint distension for adhesive capsulitis: a randomized trial. Arthritis Care Res 2007;57:1027-37.
7. Jewell DV, Riddle DL, Thacker LR. Interventions associated with an increased or decreased likelihood of pain reduction and improved function in patients with adhesive capsulitis: a retrospective cohort study. Phys Ther 2009;89:419-29.
8. Teys P, Bisset L, Vicenzino B. The initial effects of a Mulligan's mobilization with movement technique on range of motion and pressure pain threshold in pain-limited shoulders. Manual Therapy 2008;13:37-42.
9. Kaltenborn FM. Manual mobilization of the joints. ed.6. Olaf Norlis Bokhandel, Norway; 2006.
10. Edmond SL. Mobilization/manipulation, extremity and spinal techniques. Second edition. St. Louis: Elsevier; 2006.
11. Levy AS, Lintner S, Kenter K, Speer KP. Intra- and Interobserver reproducibility of the shoulder laxity examination. Am J Sports Med 1999;27:460-3.
12. Ellenbecker TS, Mattalino AJ, Elam E, Caplinger R. Quantification of anterior translation of the humeral head in the throwing shoulder Manual assessment versus stress radiography. Am J Sports Med 2000;28:161-7.
13. Ellenbecker TS, Bailie DS, Mattalino AJ, Carfagno DG, Wolff MW. Brown SW. et al Intrarater and interrater reliability of a manual technique to assess anterior humeral head translation of the glenohumeral joint. J Shoulder Elbow Surg 2002;11:470-5.
14. Maitland GD. Peripheral Manipulation. Third edition. London: Butterworth–Heinemann Ltd.; 1991.
15. Gerber C, Ganz R. Clinical assessment of instability of the shoulder (with special reference to anterior and posterior drawer tests). J Bone Joint Surg Br 1984;66:551-6.
16. van Duijn AJ, Jensen RH. Reliability of inferior glide mobility testing of the glenohumeral joint. J Man Manip Ther 2001;9:109-14.
17. Bryde D, Freure J, Jones L, Werstine M, Briffa NK. Reliability of palpation of humeral position in asymptomatic shoulders. Man Ther 2005;10:191-7.
18. McKenna L, Straker L, Smith A. The inter-tester reliability of humeral head position in junior swimmers. Phys Ther Sport 2009;10:97-100.
19. McKenna L, Straker L, Smith A. The validity and intratester reliability of a clinical measure of humeral head position. Man Ther 2009;14:397-403.
20. Lin H-T, Hsu A-T, An K-N, Chien JC, Kuan T-S, Chang G-L. Reliability of stiffness measured in glenohumeral joint and its application to assess the effect of end-range mobilization in subjects with adhesive capsulitis. Man Ther 2008;13:307-16.

21. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1997;33:159-74.
22. Farber AJ, Castillo R, Clough M, Bahk M, McFarland EG. Clinical assessment of three common tests for traumatic anterior shoulder instability. J Bone Joint Surg Am 2006;88-A):1467-74.
23. Sim J, Wright CC. The Kappa statistic in reliability studies: use, interpretation and sample size requirements. Phys Ther 2005;85:257-68.

Acknowledgements.—We gratefully acknowledge the therapists and staff at Caldwell Therapy Center for their help in recruiting subjects and collecting data.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Received on _____. - Accepted for publication on July 2, 2013.

Corresponding author: S. L. Edmond, University of Medicine Dentistry NJ, School of Health Related Professions, Doctoral Program in Physical Therapy, 65 Bergen St Suite 714B, Newark, NJ 07101-1709, USA. E-mail: edmondsl@umdnj.edu

APPENDIX A

Description of the protocol used to determine accessory motion and humeral head position.

The patient was positioned supine on a treatment table with a pillow under the head and a round bolster under the knees. Before testing, the examiner checked the pillow under the patient's head and repositioned it as needed to allow unrestricted movement.

The examiner first determined the position of the humeral head relative to the acromion and in comparison to the uninvolved side. The examiner then tested for accessory motion. Using a large goniometer, the examiner positioned the humerus in approximately 40 degrees in the scapular plane and performed each of the 3 accessory motion glides. The examiner did not attempt to change the position of the humerus at any point during the testing procedure. The procedures are described below.

Humeral Head Position: The examiner first placed one hand around the acromion and clavicle on the affected side. With her other hand, the examiner then palpated for humeral head position by placing the fingers over the anterior aspect and thumb over the posterior aspect of the humeral head. She repeated this procedure on the non-involved side. From the information obtained by palpating these structures and comparing the relative position of these landmarks on both affected and unaffected shoulders, the examiner made a determination regarding whether the humeral head was positioned correctly in relation to the acromion, or whether it was positioned anterior or posterior. If the relevant landmarks of both shoulders were symmetrical, then the therapist concluded that the humeral head was centered. Any perceived difference was considered to constitute an impairment in humeral head position. If the humeral head was determined to be closer to the anterior acromion and clavicle, then the therapist concluded that the humeral head was positioned anteriorly. Conversely, if the humeral head was determined to be closer to the posterior acromion, then the therapist concluded that the humeral head was positioned posteriorly.

Anterior Glide: The examiner first placed one hand on the anterior aspect of the acromion and clavicle on the affected side to stabilize the scapula. The arm was positioned against the examiner's ribcage with the elbow slightly flexed, and the humerus abducted to approximately 40 degrees in the scapular plane. The examiner's other hand supported the upper arm on the posterior and proximal surface. The examiner then glided the humerus in an anterior direction. For comparison purposes, the same procedure was then performed on the unaffected shoulder. Using the information obtained from these procedures, the examiner then determined whether the motion on the affected shoulder was decreased, equal to, or increased compared with the unaffected side.

Posterior Glide: The examiner first placed one hand under the scapula on the affected side to stabilize the scapula. The arm was positioned against the examiner's ribcage with the elbow slightly flexed, and the humerus abducted to approximately 40 degrees in the scapular plane. The examiner's other hand grasped the upper arm on the anterior and proximal surface. The examiner then glided the humerus in a posterior direction. For comparison purposes, the same procedure was then performed on the unaffected shoulder. Using the information obtained from these procedures, the examiner then determined whether the motion on the affected shoulder was decreased, equal to, or increased compared with the unaffected side.

Inferior Glide: The examiner first placed one hand on the neck of the scapula on the affected side to stabilize the scapula. The arm was positioned against the examiner's ribcage with the elbow slightly flexed, and the humerus abducted to approximately 40 degrees in the scapular plane. The examiner's other hand supported the upper arm on the lateral and proximal surface. The examiner then glided the humerus in an inferior direction. For comparison purposes, the same procedure was performed on the unaffected shoulder. Using the information obtained from these procedures, the examiner then determined whether the motion on the affected shoulder was decreased, equal to, or increased compared with the unaffected side.

REVIEW

Modifications of spatial-temporal parameters during gait after total knee arthroplasty: a systematic review

R. FIORENTINI [1], S. MAGGIONI [1], M. RESTELLI [1], S. FERRANTE [1, 2], M. MONTICONE [1]

[1]Physical Medicine and Rehabilitation Unit, Salvatore Maugeri Foundation, Institute of Care and Research (IRCCS), Scientific Institute of Lissone, Milan, Italy; [2]Neuroengineering and Medical Robotics Laboratory, Bioengineering Department, Politecnico di Milano, Italy

ABSTRACT

Successful total knee arthroplasty (TKA) is expected to lead to pain relief, better physical performances and an enhanced quality of life. Achieving a physiological gait pattern is also considered an important treatment goal and walking parameters are increasingly investigated during physical assessment after TKA. The aim of this systematic review was to examine how spatial-temporal gait parameters actually change after TKA. The databases of Medline, Cinahl, Embase, Pedro and the Cochrane Library were searched for English language full-text articles comparing TKA patients and controls on the basis of gait analysis. The methodological quality of each study was assessed by using the Downs and Black's checklist. Only the main spatial-temporal values of gait were considered because they can be measured by means of more accessible and cheaper equipment than opto-electronic systems, and are easier to contextualise in clinical practice. A total of 121 references were retrieved, and five articles were selected. Although the study protocols lacked common features, and there were discrepancies in the comparisons of patients and controls, we found that spatial-temporal gait parameters improved after surgery, but not always significantly; when compared to healthy control groups, patients undergoing TKA did not achieve the same gait patterns; and interlimb differences remained after surgery, probably as a consequence of maladaptive strategies adopted before TKA. Understanding how these parameters change after TKA is important in clinical practice as it is expected to improve post-surgical treatment and to avoid exaggerated articular loading with respect to osteoarthritis progression. *(It J Physiotherapy 2013;3:55-63)*

Key words: Arthroplasty, replacement, knee - Arthroplasty, replacement, knee - Review literature as topic.

Knee osteoarthritis (OA) is the most common joint disorder in industrialised countries. Data from a recent survey indicate that the age-standardised prevalence of radiographic knee OA is between 19.2% and 27.8% in subjects aged >45 years, and approximately 37% in those aged >60 years; the age-standardised prevalence of symptomatic knee OA is 16.7% among subjects aged >45, and higher among subjects aged >60 years.[1]

Total knee arthroplasty (TKA) is a cost-effective means of reducing pain, improving function, and enhancing the quality of life of patients with OA, within orthopaedic literature.[2-4] It has been estimated that the demand for primary TKA procedures will increase from 450,000 in 2005 to 3.5 million by 2030,[5] mainly because of population aging and the obesity epidemic.[1, 2]

Studies on gait analysis have raised doubts that, after TKA, subjects may not achieve walking patterns comparable to that of age-matched healthy controls, one or more years after surgery.[6-11] This may be caused by the presence of the "stiff-knee pattern", which consists in prolonged activity of lower limbs muscles and reduced knee flexion during the load absorption phase.[12] Also, abnormal muscular co-contractions around the knee have been found after TKA as compensatory

mechanism aimed at providing a better control of knee kinematics during stance phase.[13]

The majority of the validated assessment developed for patients with TKA due to knee OA are self-administered questionnaires that evaluate functional impairments subjectively.[10, 14] However, functional outcome scores may not strictly correlate with walking ability, and it has been recommended that gait analysis should be used in order to obtain an objective assessment,[9, 10, 14, 15] because it provides quantitative measures of spatial-temporal parameters that can help to identify the mechanisms causing gait disturbances and understand compensatory gait strategies. Walking evaluations are also important as pathological gait mechanics and asymmetric joint patterns increase weight bearing on non-operated knees and predispose to OA progression.[15, 16]

However, how spatial-temporal parameters during gait change after TKA have not yet clearly defined, and the aim of this study was to investigate these modifications by means of a systematic review of the existing literature.

Materials and methods

The study was approved by our hospital's Institutional Review Board.

Study selection criteria

Studies were considered eligible for review if they: 1) involved patients who had undergone TKA mainly because of OA; 2) included a pre-surgery gait analysis; 3) compared TKA patients with unimpaired controls; 4) collected spatial-temporal gait data; 5) provided original raw data; and 6) were written in English. These criteria were chosen in order to allow the findings of the studies to be compared with a minimum of confounding factors. There were no limitations concerning the date of publication. All of the potentially eligible studies were evaluated by three authors (RF, SM, MR) without considering the results. The selected studies were then reviewed by all of the authors of this paper, with any disagreement concerning eligibility being resolved by discussion.

Table I.—*Search strategy.*

Search N.	Strategy
1	Arthroplasty, replacement, knee [Mesh]
2	Total knee replace*
3	Total knee arthroplasty
4	1 or 2 or 3
5	Biomechanic*
6	Kinematic*
7	Kinetic*
8	Gait analysis
9	5 or 6 or 7 or 8
10	Walk*
11	Gait
12	Ambulat*
13	10 or 11 or 12
14	4 and 9 and 13

* it means that the authors searched all of the words with these specific beginning.

Search strategy

The search for articles was completed in December 2011. The databases of Medline, Cinahl, Embase, Pedro and the Cochrane Library were searched for full-text articles using combinations of the following key words: "arthroplasty", "replacement", "knee", "total knee replace*", "total knee arthroplasty", "biomechanic*", "kinematic*, "kinetic*", "gait analysis", "walk*", "gait" and "ambulat*" (Table I).

In order to look for additional articles of interest, we evaluated the "related articles" option of PubMed and hand-searched the bibliographies of the selected studies.

Methodological quality

Downs and Black's checklist [17] was chosen as a mean of evaluating the quality of each study on the basis of the findings of the review by McClelland *et al.*,[7] and applied using only the criteria relevant to assess potential sources of bias in non-randomised trials. The criteria were as follows: item 1, *is the hypothesis/aim objective of the study clearly described?*; item 2, *are the main outcomes to be measured clearly described in the Introduction or Methods section?*; item 3, *are the characteristics of the patients included in the study clearly described?*; item 5, *are the distributions of principal confounders in each group of subjects to*

be compared clearly described?; item 6, *are the main findings of the study clearly described?*; item 7, *does the study estimates of the random variability in the data for the main outcomes?*; item 12, *were those subjects who were prepared to participate representative of the entire population from which they were recruited?*; item 16, *if any of the results of the study were based on "data dredging", was this made clear?*; item 18, *were the statistical tests used to assess the main outcomes appropriate?*; item 20, *were the main outcome measures used accurate (valid and reliable)?*; item 25, *was there adequate adjustment for confounding in the analyses from which the main findings were drawn?*; item 27, *did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?*.

If the item was clearly addressed, it was given a positive mark; if not, it was given a negative mark. If an item was mentioned but not completely addressed, it was given a "partial" mark.

Spatial-temporal parameters

We chose to restrict our investigation to spatial and temporal parameters because they can be measured by means of cheaper and more accessible equipment than opto-electronic systems, and are more easily contextualised in clinical practice.[18]

The reviewed studies used various spatial (*e.g.*, stride length, step length and step width) and temporal parameters (*e.g.*, cadence, stride time, step time, double-limb support, single/double support, stance phase and swing phase), as well as spatial-temporal gait speed. In order to compare the results of the studies, we decided to consider only gait speed, cadence, stride length and stride time as these were the most frequently analysed parameters (Table II for full definitions).[19]

Table II.—*Definition of gait parameters.*[19]

Parameter	Definition
Gait speed	The distance covered in a given amount of time
Stride length	The distance between successive points of initial contact of the same foot.
Cadence	Steps per minute
Stride time	The time for the completion of a right and a left step

Results

The overall search identified 121 articles, of which five [20-24] were selected on the basis of our inclusion criteria. The step by step selective process is reported in details in Figure 1.

Table III shows their main characteristics.

There were differences in the gait analysis protocols, although all of them had the subjects walk at their preferred speed.[20-24] The controls in the study of Smith *et al.*[22] were asked to walk at a slow, medium and fast pace, and the data closest to the patient group were used for comparative purposes. In the studies by Sukru Solak *et al.,* Yi-ming *et al.* and Smith *et al.*[20-22] spatial-temporal gait parameters were assessed during level walking, whereas the participants in Mandeville's studies [23, 24] also crossed obstacles [23] and ascended stairs [24] (but we only recorded the level walking parameters). In most of the studies, the subjects were instructed to walk along a 10-metre walkway for the gait assessment,[21, 23, 24] whereas Sukru Solak *et al*. used a 4.6-meter walkway.[20] In Mandeville's studies, the patients were barefooted,[23, 24] whereas those in the study of Smith *et al*. wore their usual footwear with low heels.[22]

There was also a difference in the number of walking tests used for gait assessment. One study used a minimum of five and a maximum of eight tests,[22] and Mandeville *et al*. used up to five tests depending on each subject's tolerance.[23, 24] The use of several tests allowed the subjects to become accustomed to the experimental protocol.

Methodological quality

Table IV summarises the results of the methodological quality assessment. All of the papers clearly described the aim of the study, the chosen outcome measures, and the patients' characteristics. Most studies clearly described their main findings, and showed appropriate statistical analyses, including measures of random variability, although power calculations were not showed and only one study [22] took into account confounding factors. None provided evidence that the subjects were representative of the target population.

Analysis of spatial-temporal parameters

Table V shows the results of each of the included study in terms of mean values and standard deviations of the selected gait parameters obtained both by experimental and by the control groups at different timepoints. When appropriate statistical analyses were found,[22-24] the significant differences between groups and within different timepoints were also registered.

Most relevant trends of gait parameter are specified as follows:

— gait speed. In comparison to preoperative data, all of the patients improved gait speed but at different timepoints. The studies which analysed more of one assessment point showed the patients maintained the attained results.[21, 22] Only Yi-ming's did not reach age-matched healthy controls;[21]

— cadence. All of the studies which analysed cadence showed an increase in TKA patient at different timepoints; the TKA groups of Sukru Solak and Yi-Ming's studies [20, 21] maintained this improvement over time. Sukru Solak and Smith's patients [20, 22] reached age-matched healthy controls values;

— stride time. All of the studies which analysed stride time found an improvement after TKA at different timepoints and all of the patients reached age-matched healthy controls values.[20, 22, 23] The TKA group of Sukru Solak's study maintained these improvements over time.[20]

Figure 2 shows the parameters analysed in each study, with the columns indicating the values of each parameter at the different timepoints.

Discussion

Despite some methodological shortcomings and the small number of the studies included,

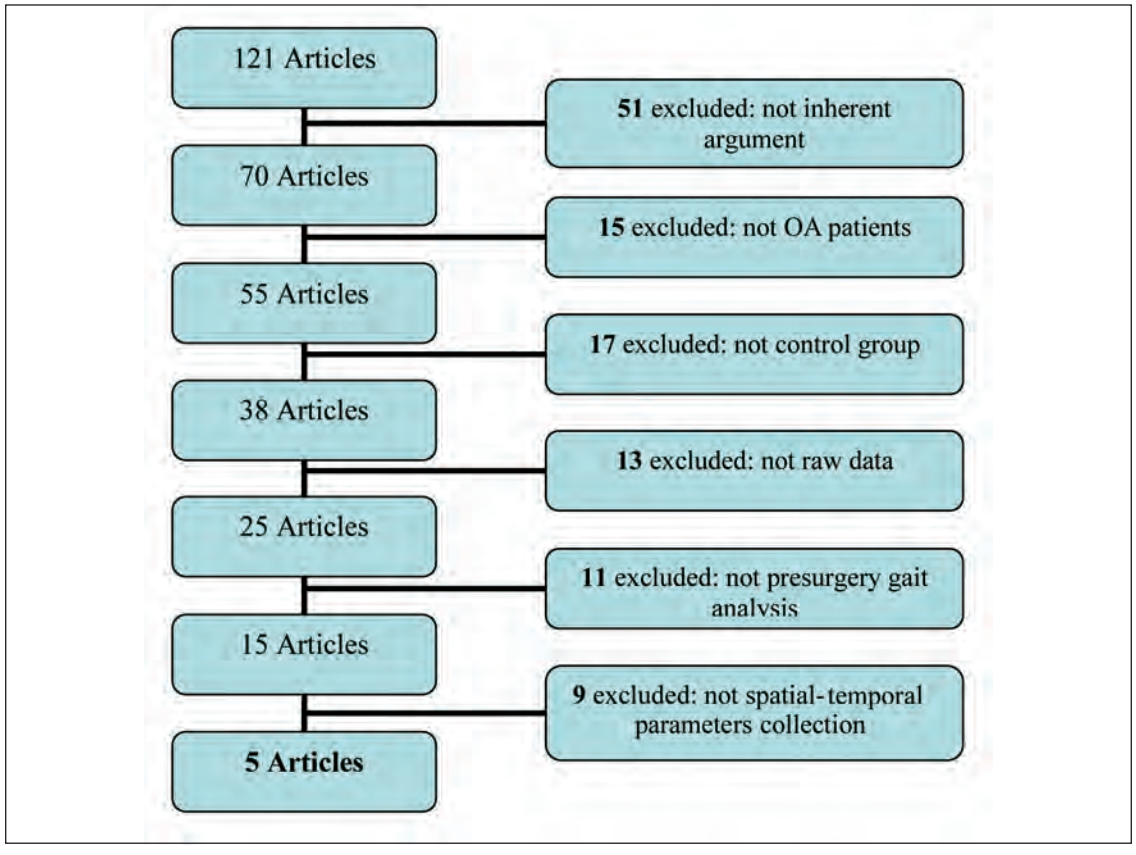

Figure 1.—Flowchart of included articles.

Table III.—*Characteristics of the groups included in the reviewed studies.*

Study	Groups	Participants	Age (years)	Assessments	Analysed parameters	Statistics
Sukru Solak [20]	TKA	N.=24 women	67 (57-78)	3 assessments: – before TKA – 1 year after TKA – 2 years after TKA	Cadence, stride length, stride time	Paired *t* test to evaluate within- group changes; independent sample t test to evaluate between-group changes
Yi-Ming. [21]	Controls	N.=12 women	65 (59-73)	1 assessment	Velocity, cadence, stride length	ANOVA to evaluate within-group changes
	TKA with patella resurfacing	N.=26 (16 women, 10 men)	67±7.94	3 assessments: – before TKA – 3 months after TKA – 1 year after TKA		
	TKA without patella resurfacing	N.=25 (14 women, 11 men)	66±6.11	3 assessments: – before TKA – 3 months after TKA – 1 year after TKA		
Smith AJ. [22]	TKA	N.=34	69±7	2 assessments: – before TKA – 12-18 months after TKA	Velocity, cadence, stride length, stride time	Paired t test to evaluate within- group changes, p = 0.017; repeated measure ANOVA to evaluate between- group changes
	Controls	N.=20	67±7 years	1 assessment		
	Controls	N.=12 women	65 (59-73)	1 assessment		
Mandeville [23]	TKA	N.=21 (15 women, 6 men)	63.7±7.56	2 assessments: – before TKA – 6 months after TKA	Velocity, stride length stride time	Repeated measure ANOVA to evaluate within- and between-group effects p = 0.0125 (Bonferroni's correction)
	Controls	N.=22 (14 women, 8 men)	62.7±4.26	2 assessments: – 6 months between assessments		
Mandeville [24]	TKA	N.=21 (15 women, 6 men)	62.6 (50-70)	2 assessments: – before TKA – 6 months after TKA	Velocity, stride length,	ANCOVA to evaluate within- and between-group effects (covariate = walking velocity) p = 0.0125 (Bonferroni's correction)
	Controls	N.=21 (16 women, 5 men)	62.7 (50-70)	2 assessments: – 6 months between assessments		

Table IV.—*Assessment of methodological quality.*

Downs and Black criteria [17]	Item 1	Item 2	Item 3	Item 5	Item 6	Item 7	Item 12	Item 16	Item 18	Item 20	Item 25	Item 27
First author [reference]	Clear aim	Outcomes described	Patients described	Confounders described	Main findings clearly described	Measures of random variability	Subjects represent population	Planned analysis	Appropriate statistics	Accurate outcome measure	Adjustment for confounders	Power calculation
Sukru Solak [20]	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No
Yi-Ming [21]	Yes	Yes	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Smith [22]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No
Mandeville [23]	Yes	Yes	Yes	Partially	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Mandevillle [24]	Yes	Yes	Yes	Partially	Yes	Yes	No	Yes	Yes	Yes	Yes	No

Table V.—*Values gait parameters of each studies.*

SUKRU SOLAK [20]				
Parameters	Pre-op	1 year post-op	2 years post-op	Healthy
Cadence (step/min)	96±6	100±6	100±6	106 ±3,5
Stride Length (m)	0.89±0.08	0.99±0.04	0.98±0.06	1.03±0.02
Stride time (s)	1.2±0.13	1.05±0.18	1.05±0.13	0.99±0.08

YI-MING [21]							
Parameters	Patella resurfacing			Patella non resurfacing			Healthy
	Pre-op.	3 months post-op	1 year post-op	Pre-op.	3 months post-op	1 year post-op	
Gait speed (m/s)	0.52±0.10	0.92±0.08	0.91±0.11	0.56 0.10±	0.89±0.12	0.86±0.13	1.01±0.14
Cadence (step/min)	86.97± 15.85	99.46±8.36	99.60±7.66	86.52±14.49	94.17±10.19	94.68±9.39	101±11
Stride Length (m)	0.90±0.21	1.08±0.16	1.08±0.14	0.88±0.17	1.03±0.12	1.05±0.13	1.14±0.12

SMITH [22]			
Parameters	Pre-op	1 year post-op	Healthy
Gait speed (m/s)	0.97±0.16	1.05±0.12 *	1.08±0.14
Cadence (step/min)	101.0±12.9	103.0±8.8 *	101.3±11.8
Stride Length (m)	1.15±0.13	1.22±0.13 *	1.26±0.12

MANDEVILLE [23]				
Parameters	Pre-op	6 months post-op	Healthy baseline	Healthy 6 months later
Gait speed (m/s)	0.94±0.38 #	1.06±0.32 *,#	1.14±0.37	1.21±0.3
Stride Length (cm)	109.6±28.8 #	117.1±24.2 *, #	125.4±28.3	129.1±23.1
Stride time (s)	1.20± 0.28	1.12±0.18 *	1.11±0.28	1.08±0.17

MANDEVILLE [24]				
Parameters	Pre-op	6 months post-op	Healthy baseline	Healthy 6 months later
Gait speed (m/s)	0.89±0.04 #	1.05±0.03 *,#	1.14±0.04	1.21±0.03
Stride Length (cm)	104.55 ±3.03 #	115.54±2.48 *,#	125.87±2.99	129.11±2.42

* significantly different within assessments of the TKA patients (P<0.0125); # significantly different between groups (P<0.0125)
Pre-op=pre-operatively; Post-op=post-operatively.

the findings of this review show that the spatial-temporal gait parameters of TKA patients improve after surgery, but do not necessarily attain the values of healthy age-matched controls.

Comparison of the studies included in this review [20-24] allows to identify the main characteristics of the gait of TKA patients. All of the studies showed improvements in pre-TKA gait patterns at each follow-up time, but there were differences between the patients and controls. In both Mandeville's studies,[23, 24] none of the spatial-temporal parameters reached the level of the control group six months post-operatively, similarly the patients of YI-Ming's study [21]did not reach the level of the control group in less than one year; but after 12 months, in Smith *et al.*'s. study [22] the results in the TKA group were similar to those observed in the respective control group; on the contrary, Sukru Solak's study [20] did not reach the values observed in the respective control group even one and two years after surgery. Hence, walking spatial-temporal parameters at baseline seem important determinants of post-surgical estimates in order to achieve a physiological gait pattern. Moreover, although the improvements in spatial-temporal variables may indicate enhanced locomotor ability following surgery, six months may be too short to resolve the symptoms and reach control gait speed.[25] In highly impaired subjects, this would be consistent with the antalgic gait adopted by patients with knee OA in an attempt to reduce compression at the knee during the stance phase in response to pain, as described by Kaufman *et al.*[26]

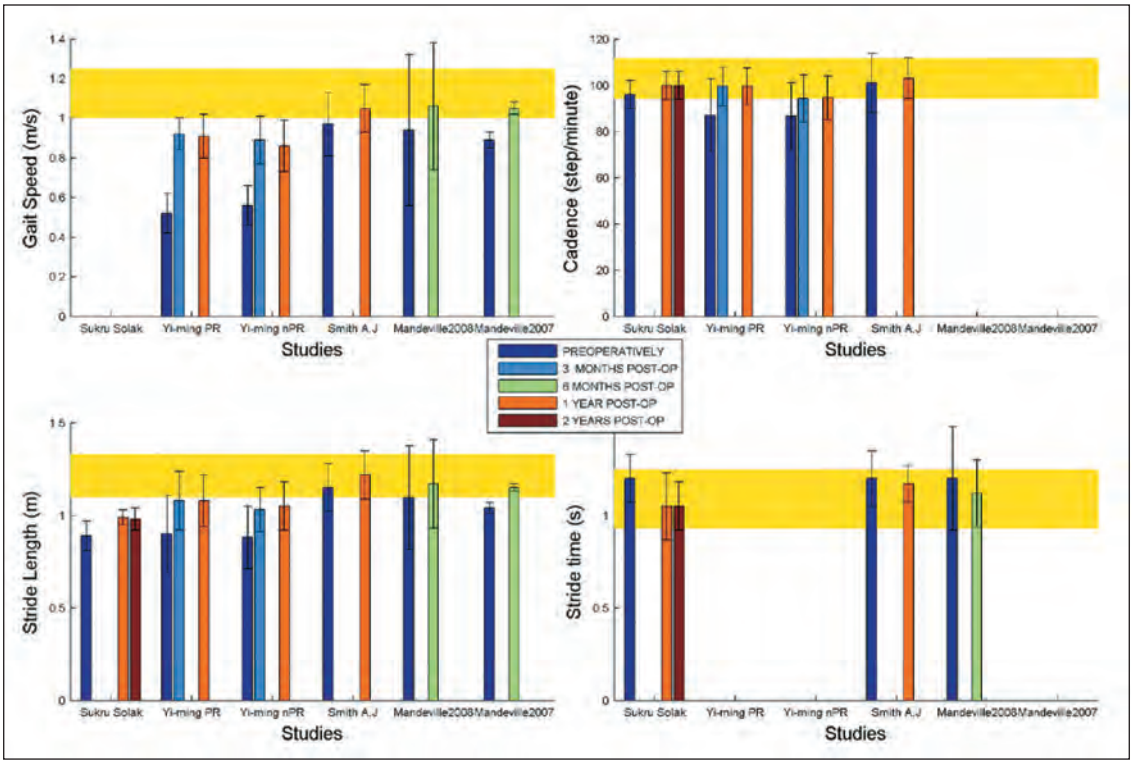

Figure 2.—Mean values and standard deviations of velocity (A), cadence (B), stride length (C) and stride time (D) attained by the TKA and control groups in the different studies. The columns indicate the values of each parameter at the different timepoints. The shaded horizontal area shows the values obtained by the control groups: the lower limit is the mean value of the different studies minus standard deviation, and the upper limit the mean value plus standard deviation.

Also Otsuki *et al.* has suggested that changes in the gait parameters of OA patients reflect a gait pattern that prevents pain and reduces load on the knee,[27] and Sukru Solak *et al.*[24] attributed the normalisation of their patients' gait parameters to the relief of knee pain one year after TKA. It is also remarkable to note that the improvement obtained after one year does not change after two years.[24]

Interestingly, Mandeville *et al.* found little knee moment support during walking, which suggests that deficits in muscle activation and atrophy of the quadriceps persist for six months.[20, 21] It is possible that TKA patients use their involved knee as a strut rather than a damping element when supporting the body during gait both before and after surgery; the greater contribution of the TKA hip extensor to moment support may compensate for the diminished contribution of the knee extensor during level walking. Beth *et al.* found that TKA candidates showed a significant preoperative deficit in quadriceps muscle activation that partially resolved 33 months after surgery, although significant impairment continued.[28]

Yi-Ming also evaluated the effects of different TKA interventions, and analysed the differences in gait parameters between patients with and without a resurfaced patella,[21] and found no significant between-group difference after one year. This finding has also been reported by two other authors:[29, 30] in Pollo *et al.*[29] no significant differences were found in the biomechanics of walking, stair climbing, or chair rising between patients after TKA with and without a resurfaced patella; in the same way, Smith *et al.*'s study concluded that there were no clinically relevant differences in level walking gait between total knee arthroplasty performed with or without patellar resurfacing.

Limitations of the study

The main limitations are the small number of studies considered (due to our strict inclusion

criteria) and the fact that they were difficult to compare because they analysed different variables and used different timepoints. Furthermore, some of the variables were described in only one study. Hence, the results should be interpreted with caution as the selected studies show methodological shortcomings, partially limiting the interpretation of the findings.

It is therefore necessary to conduct further controlled studies analysing pre- and post-TKA data at the same times in order to be able to draw more definite conclusions concerning the changes in walking parameters.

Clinical and research suggestions

Spatial-temporal gait parameters change after TKA and normalise after more than one year only in some cases. Hence, understanding how these parameters change after TKA is important in clinical practice as it is expected to improve treatment planning. It would be advisable to focus rehabilitation after TKA also for the re-acquisition of correct gait cycle pattern, balance and neuromotor control in order to shorten the time needed to recover a physiological gait.[31, 32] However, evidence on this topic is still inadequate, and it would be interesting to investigate whether different rehabilitation protocols lead to different changes in spatial-temporal gait parameters.

Three of the selected studies [20-22] in this review analysed spatial-temporal parameters by computing the mean value of the right and left legs; however, as most cases of TKA are one-sided, it is more important to know the difference between the two in order to understand the symmetry of the patients' gait. It is suggested that future studies should also investigate the changes in step symmetry.

Finally, identifying and correcting gait impairments frequently found after TKA may help preventing excessive articular loading and promoting better load distribution at other joints of the lower extremities with respect to progression of multi-articular OA.[33]

References

1. Zhang Y, Jordan JM. Epidemiology of osteoarthritis. Rheum Dis Clin North Am 2008;34:515-29.
2. Jones CA, Beaupre LA, Johnston DWC, Suarez-Almazor ME. Total joint arthropasty: current concepts of patient outcomes after surgery. Rheum Dis Clin North Am 2007;33:71-86.
3. Jones DL, Westby MD, Greidanus N, Johanson NA, Krebs DE, Robbins L *et al*. Update on hip and knee arthroplasty: current state of evidence. Arthritis and Rheum 2005;53:772-80.
4. Yoshida Y, Mizner RL, Pamsey DK, Snyder-Mackler L. Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time. Clin Biomech 2008;23:320-8.
5. Mandeville D, Osternig LR, Lantz BA, Mohler CG, Chou LS. A multivariate statistical ranking of clinical and gait measures before and after total knee replacement. Gait Posture 2009;30:197-200.
6. Ouellet D, Moffet H. Locomotor deficits before and two months after knee arthroplasty. Arthritis and Rheum 2002;47:484-493.
7. McClelland JA, Webster KE, Feller JA, Menz HB. Knee kinematics during walking at different speeds in people who have undergone TKR. The Knee 2011;18:151-5.
8. Catani F, Ensini A, Belvedere C, Feliciangeli A, Benedetti MG, Leardini A *et al*. In vivo kinematics and kinetics of a bi-cruciate substituting total knee athroplasty: a combined fluoroscopic and gait analysis study. J Orthopaed Res 2009;27:1569-75.
9. Webster KE, Wittwer JE, Feller JA. Quantitative gait analysis after medial unicompartimental knee arthroplasty for osteoarthritis. J Arthroplasty 2003;18:751-9.
10. Liebensteiner MC, Herten A, Gstoettner M, Thaler M, Krismer M, Bach CM. Correlation between objective gait parameters and subjective score measurement before and after total knee arthroplasty. The Knee 2008;15:461-6.
11. Hatfied GL, Hubley-Kozey CL, Wilson JLA, Dunbar MJ. The effect of total knee arthroplasty on knee joint kinematics and kinetics during gait. J Arthroplasty 2011;26:309-18.
12. McGuinty G, Irrgang JJ, Pezzullo D. Biomechanical considerations for rehabilitation of the knee. Clin. Biomech 2000;15:160-6.
13. Benedetti MG, Catani F, Bilotta TW, Marcacci M, Mariani E, Giannini S. Muscle activation pattern and gait biomechanics after total knee replacement. Clin Biomech 2003;18:871-6.
14. Ornetti P, Maillefert JF, Laroche D, Morisset C, Dougados M, Gossec L. Gait analysis as a quantifiable outcome measure in hip or knee osteoarthritis: A systematic review. Joint Bone Spine 2010;77:421-5.
15. Levinger P, Webster KE, Feller J. Asymmetric knee loading at heel contact during walking in patients with unilateral knee replacement. The Knee 2008;15:456-60.
16. Alnahdi AH, Zeni JA, Snyder-Mackler L. Gait after unilateral total knee arthroplasty: frontal plane analysis. J Orthop Res 2011;29:647-52.
17. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality of both randomised and non-randomised studies of health care interventions. J Epidemiol Commun H 1998;52:377-84.
18. Bilney B, Morris M, Webster K. Concurrent validity of the GAITRite® walkway system for quantification of the spatial and temporal parameters of gait. Gait Posture 2003;17:68-74.
19. Neumann DA. Kinesiology of walking. Chapter 15. In: Lower extremity (Section IV). In: Kinesiology of the musculoskeletal system. Foundations for rehabilitation. St Louis, MO: Elsevier Mosby; 2010. p. 527-31.
20. Sukru Solak A, Kentel B, Ates Y. Does bilateral total knee arthroplasty affect gait in women? J Arthroplasty 2005;20:745-50.
21. Yi-Ming X, Yue-Hong B, Jun Z, Qing-Tian L, Juan L. Gait analysis in primary total knee arthroplasty with and without

patellar resurfacing: a randomized control study. J. Shanghai Jiaotong Univ (Sci) 2010;15:632-6.
22. Smith AJ, Lloyd DG, Wood DJ. Pre-surgery knee joint loading patterns during walking predict the presence and severity of anterior knee pain after total knee arthroplasty. J Orthop Res 2004;22:260-6.
23. Mandeville D, Osternig LR, Chou LS. The effect of total knee replacement surgery on gait stability. Gait Posture 2008;27:103-9.
24. Mandeville D, Osternig LR, Chou LS. The effect of total knee replacement on dynamic support of the body during walking and stair ascent. Clin Biomech 2007;22:787-94.
25. Andriacchi TP. Evaluation of surgical procedure and/or joint implants with gait analysis. Instr Course Lect 1990;39:343-50.
26. Kaufman KR, Hughes C, Morrey BF, Morrrey M, An KN. Gait characteristics of patients with knee osteoarthritis. J Biomech 2001;34:907-15.
27. Otsuki T, Nawara K, Okuno M. Quantitative evaluation of gait pattern in patients with osteoarthrosis of the knee before and after total knee arthroplasty. Gait analysis using a pressure measuring system. J Orthop Sci 1999;4:99-105.
28. Berth A, Urbach D, Awiszus F. Improvement of voluntary quadriceps activation after total knee arthroplasty. Arch Phys Med Rehabil 2002;83:1432-6.
29. Pollo FE, Jackson RW, Koëter S, Ansari S, Motley GS, Rathjen KW. Walking, chair rising, and stair climbing after total knee arthroplasty: patellar resurfacing versus nonresurfacing. Am J Knee Surg 2000;13:103-8.
30. Smith AJ, Lloyd DG, Wood DJ. A kinematic and kinetic analysis of walking after total knee arthroplasty with and without patellar resurfacing. Clin Biomech 2006;21:379-86.
31. Akodu AK, Giwa SO, Akinbo SR, Ahmed UA. Physiotherapy in the management of total knee arthroplasty: a review. Nig Q J Hosp Med 2011;21:99-105.
32. Minns Lowe CJ, Barker KL, Dewey M, Sackley CM Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials. BMJ 2007;335:812.
33. Block JA, Shakoor N. Lower limb osteoarthritis: biomechanical alterations and implications for therapy Curr Opin Rheumatol 2010;22:544-50.

Acknowledgements.—We would like to thank Kevin Smart for his help in preparing the English version of the manuscript.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Received on January 17, 2013 - Accepted for publication on June 14, 2013.

Corresponding author: R. Fiorentini, via Monsignor Bernasconi 16, 20035 Lissone, Milan, Italy. E-mail: roberta.fiorentini@fsm.it

Rethinking the management models for people with back pain: identifying physiotherapists as case managers for mechanical, non-inflammatory disorders

M. BACCINI, A. LENZINI

Unit of Functional Rehabilitation, Azienda Sanitaria di Firenze, Florence, Italy

Dear Editor,

Musculoskeletal disorders are a relevant cause of disability and, because of their high prevalence, constitute a major health problem in industrialised societies. Back pain and low-back pain (LBP), in particular, show epidemic proportions.[1] A recent review [2] found that, based on data from 165 studies providing estimates for 54 countries, the median prevalence according to the prevalence period was 15, 32.1, 37.4 and 42 for point, 1-month, 1-year and lifetime prevalence, respectively. Moreover, the economic burden of LBP is enormous and appears to be growing over years.[3]

At the SIF Congress 2013, Anthony Delitto showed that a large amount of the economic burden of LBP derives from high-priced exams, that are in most cases useless, and from interventions that have been clearly demonstrated to be not effective. Delitto suggested that the main reason for continuing to prescribe such exams and interventions for people with LBP may actually be the economic interest of providers. He also showed that a change in the health care services organization for LBP, with a central role of physiotherapists in LBP management, yields to a significant reduction of the burden, though the proportional cost for physiotherapy increases. New management models have been successfully experimented also in Northern Europe.[4-6] The need to rethink management models and front line care for people with back pain is, therefore, imperative and is also acknowledged by clinicians.[7]

The question is: what about Italy? In Italy the state of affairs is clearly similar to the one described by Delitto, or even worse, with a high number of imaging exams improperly prescribed and of non evidence-based treatments routinely delivered by health services, in particular by private services. At present, clinical pathways for people with musculoskeletal conditions are not standardised. Frequently, general practitioners refer their patients to the orthopedic specialist regardless of the presence of indications for surgery, and several patients are first referred to the rheumatologist or the pain specialist. When patients are referred to physiotherapy services, frequently they are not cared for in a reasonably short time and treatments delivered for similar conditions may greatly differ among rehabilitation centers. Moreover, the involvement of different professionals occurs in a disorderly manner, with unnecessary duplications of visits.

To improve cares for musculoskeletal disorders, in 2011 the Azienda Sanitaria di Firenze (a local Health Unit in Florence) started the OPTIMUS (OPTImized MUSculoskeletal care pathways) project, aimed at experimenting the suitability and the effectiveness of an innovative clinical pathway for people with these conditions. The study involved 12 general practitioners and a number of specialists and physiotherapists. Six general practitioners referred all their patients with a musculoskeletal condition to a single physiotherapy service at the "Piero Palagi" hospital, except for cases where an inflammatory pathology was suspected. In that case, patients were referred to the rheumatologist through a fast-track pathway. Patients referred by these practitioners constituted the experimental group (EXP). Patients with musculoskeletal pain referred by the other six general practitioners, who acted as controls (CNTR), were evaluated with the same outcome measures as the experimental group but were treated with the usual care for their condition. All participants were assessed at baseline and 3 and 6 months later through telephone interviews. Outcome measures were: 1) use of drugs; 2) the Short Form-36 (SF-36), a health-related quality of life scale validated in the Italian language;[8] 3) the Measure Yourself Medical Outcome Profile (MYMOP) patient-generated questionnaire, assessing the severity of symptoms, their impact on function and general wellbeing.[9] At the 3- and 6-month follow-up two further questionnaires were administered, to evaluate the perceived global outcome and patients' satisfaction. The main novelty of the OPTIMUS project is the identification of the physiotherapy professional as the "case manager" for people with mechanical, non-inflammatory musculoskeletal pain. For EXP group patients referred to the

physiotherapy service, in fact, physiotherapists could choose to administer a direct intervention or just to give advices for self-management and/or propose practising a regular physical activity, or even to ask for a specialist's consultation when needed. Moreover, briefings with specialists to discuss complex or not-responding cases were scheduled weekly.

Out of 246 patients enrolled, 216 were in the EXP group and 40 in the CNTR group. As expected, back pain (low-back pain or neck pain) was the most prevalent condition (EXP: 65%, CNTR: 60%). At present, 115 patients with back pain completed the follow-up periods, 97 in the EXP group and 18 in the CNTR group. The difference in groups sample sizes is largely due to a very low rate of referral by general practitioners of CNTR group. We briefly summarise here the results in this subgroup of patients.

At baseline, there were no differences between the EXP and CNTR groups as regards age, gender, use of drugs, MYMOP and SF-36 scores. Data from the first and second follow-up showed that patients in the EXP group improved more than controls. In more details, patients in the EXP group, compared to controls, had a greater improvement in several physical sections of SF-36 at 3 months ($P<0.005$) and at 6 months ($P<0.05$), a greater reduction of pain and activity limitations and a greater increase in general wellbeing at 3 and at 6 month ($P<0.001$), and used less drugs at 6 months ($P<0.05$). Moreover, groups significantly differed in the perceived global outcome at both follow-ups ($P<0.001$): at 3 months 58% of patients in the EXP group and 24% of controls stated their symptoms were resolved or much improved and these percentages were similar at 6 months (58% compared to 22%); at 3 months, none in the EXP group but 24% of controls referred a worsening in their symptoms, whereas at 6 months these percentages were 4% and 17%, respectively. Finally, patients in the EXP group were significantly more satisfied than controls with the intervention ($P<0.001$, at both follow-ups). Cost-effectiveness analyses are yet under investigation, but patients in the EXP group performed a very small number of imaging exams and were rarely referred to specialists.

Data presented support the efficacy of a management model for back pain that allows general practitioners to have quickly accesses for their patients to the appropriate health services (physiotherapy or specialists visits) and that identifies the physiotherapist as the case manager for people with mechanical, non-inflammatory musculoskeletal pain. In our opinion, the model should be widely applied but at present both political and cultural obstacles likely hinder its large diffusion in health care services organization.

References

1. Deyo RA. Low-back pain. Sci Am 1998;279:48-53.
2. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F *et al*. A systematic review of the global prevalence of low back pain. Arthritis Rheum 2012;60:2028-37.
3. Delitto A, George SZ, Van Dillen LR, Whitman JM, Sowa G, Shekelle P *et al*.; Orthopaedic Section of the American Physical Therapy Association. Low back pain. J Orthop Sports Phys Ther 2012;42:A1-57.
4. Maddison P, Jones J, Breslin A, Barton C, Fleur J, Lewis R *et al*. Improved access and targeting of musculoskeletal services in northwest Wales: targeted early access to musculoskeletal services (TEAMS) programme. BMJ 2004;329:1325-7.
5. Leemrijse CJ, Swinkels ICS, Veenhof C. Direct access to physical therapy in the Netherlands: results from the first year in community-based physical therapy. Phys Ther 2008;88:936-46.
6. Salisbury C, Foster N, Bishop A, Calnan M, Coast J, Hall J *et al*. "PhysioDirect" telephone assessment and advice services for physiotheraphy: protocol for a pragmatic randomized controlled trial. BMC Health Serv Res 2009;9:136.
7. Hartvigsen J, Foster NE, Croft PR. We need to rethink front line care for back pain. BMJ 2011;342:d3260.
8. Apolone G, Mosconi P. The Italian SF-36 Health Survey: translation, validation and norming. J Clin Epidemiol 1988;51:1025-36.
9. Paterson C. Measuring outcome in primary care: a patient-generated measure, MYMOP, compared to the SF-36 health survey. BMJ 1996;312:1016-20.

Corresponding author: M. Baccini, Unit of Functional Rehabilitation, Azienda Sanitaria di Firenze, Florence, Italy. E-mail: marco.baccini@asf.toscana.it.