ITALIAN JOURNAL OF PHYSIOTHERAPY

OFFICIAL JOURNAL OF THE ITALIAN SOCIETY OF PHYSIOTHERAPHY

VOLUME 3
NUMBER 1
MARCH 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 March 2013 No. 1

Società Italiana di Fisioterapia

CONTENTS

EDITORIAL

The rehabilitation of subjects with stroke: common points of different rehabilitative approaches

A. TETTAMANTI

San Raffaele Scientific Institute, Milan, Italy

Reading the editorial published on the last number of the Italian Journal of Physiotherapy about the "wishes for the future of therapeutic exercise" I was really interested in a statement in which the author highlights how "an overview of scientific literature in both musculoskeletal and neurological physiotherapy allows to detect different approaches for the same clinical condition" and "the comparison between these approaches does not affirm a clear superiority of one to others".[1]

One of the possible explanation given by the author is that until now we does have not detected the physiological basis of the therapeutic effect. Therefore the connection between therapeutic exercise and physiological concepts exists but is still unclear and different approaches could share some aspects that are still unknown. In support of this hypothesis the author cites different kinds of treatments for musculoskeletal disorders that could share the same physiological basis for their effectiveness.

In my opinion this could be the same for neurorehabilitation. In fact by analyzing the literature one can find some common points in apparently different therapeutic approaches.

Stroke is one of the major causes of disability in industrialized countries and rehabilitation is one of the fundamental components of care of stroke subjects.[2, 3]

The recovery is composed of various parts: spontaneous recovery, linked to processes of restitution, and motor re-learning, based on substitution processes and compensation.[4]

The motor re-learning is promotable through the modulation of cortical neuroplasticity.[5-7]

The existing literature on the topic is wide. The problem becomes how to select the best treatment for the patient. The idea of approaching literature based solely on the best scientific evidence available leads to a sort of dead end. In fact, by consulting the most authoritative meta-analysis the difficulty to discriminate the appropriate treatment (best practice) increases.[3,8] In fact, many treatments are effective, there is often no clear superiority of one treatment over another and often the clinical trials themselves are designed so that the experimental group does not perform a treatment of comparable intensity with the experimental one.

But then: is it possible to identify the best treatment? This question unfortunately, or fortunately, does not have a real answer. The proposal would therefore be to avoid choosing a regimen over another but to choose the more effective shared parts of the treatments and to put them together to create the best one for that patient. Hence, the idea is to go looking for the common points of the different approaches.

A clear example of how these "common points" are actually the basis of the approaches proposed in the literature comes from robotic-assisted arm training. The recent Cochrane review [9] shows that if we evaluate the use of the upper limb in activities of daily living, there is good evidence that shows how the training with electromechanical or robotic assistance is superior to conventional treatment . The question now should be: what leads to this result; what are the differences between the standard treatment and robot-assisted treatment?

This question is also raised by the authors themselves, who have published an article comparing the robot-assisted arm training with a standard treatment and with a treatment of the same intensity of the robotic group.[10] Their hypothesis is that the intensity of treatment, higher in robotics that in the usual care, is the reason that leads to a big result in the robotic group.

The results are that both in the scale of evaluation of motor function, both in assessing the reduction of overall activity, the intensity seems to be the variable that affects the outcome of the treatment. In fact, the robotic group and the high intensity group obtained exactly the same results. This article shows how the "milestone" of the matter could be the intensity of treatment.

A second example is the action observation training (AOT), based on observation of videos depicting subjects who perform functional gestures and the subsequent repetition of the same gesture by the patient.

The neural substrate which underlies the effectiveness of this rehabilitation is the Mirror Neuron System. The result of the first clinical trial carried out on subjects post-stroke shows how this training is an effective technique for the recovery of motility of the upper limb.[11]

All cognitive facilities have in common the multimodality of treatment. In fact, it combines the motor action with an important cognitive and multisensory stimulation thus facilitating re-motor learning.[12]

Examples of multimodal training are the cognitive facilitations, such as AOT, mental practice, or the mirror therapy.

In view of the above reasoning, it is therefore possible do detect some points that are common to many approaches described in the literature for the rehabilitation of post-stroke subjects. They could be summarized in some fundamental aspects, such as the specificity of the training proposed, which should be focused to the type of deficient gesture and the context in which this action will be used by the subject. Another point is the relevance for the subject and the relevance of the gesture proposed as training from a functional point of view: the gesture should be focused on actions that are commonly used in daily life. These must be "transitive" and purposeful, aimed at achieving a goal. Another common and essential feature is the intensity of the treatment, intended as the level of difficulty and as repetition of the activity or action that we want to train. The last point I would like to highlight is multimodality, also known as multi-sensory stimulation.

These points could be taken into consideration when choosing the appropriate treatment for our poststroke subjects.

References

1. Gatti R. Wishes for the future of therapeutic exercise. IJP 2012;2:119-20.
2. Bonita R, Mendis S, Truelsen T, Bogousslavsky J, Toole J, Yatsu F. The global stroke initiative. Lancet Neurol 2004;3: 391-3.
3. Langhorne P, Sandercock P, Prasad K. Evidence-based practice for stroke. Lancet Neurol 2009;8:308-9.
4. Kwakkel G, Kollen B, Lindeman E. Understanding the pattern of functional recovery after stroke: facts and theories. Restor Neurol Neurosci 2004;22:281-99.
5. Pekna M, Pekny M, Nilsson M. Modulation of neural plasticity as a basis for stroke rehabilitation. Stroke 2012;43: 2819-28.
6. Warraich Z, Kleim JA. Neural plasticity: the biological substrate for neurorehabilitation. PM R 2010;2:S208-19.
7. Johansson BB. Current trends in stroke rehabilitation. A review with focus on brain plasticity. Acta Neurol Scand 2011;123:147-59.
8. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet2011;14:1693-702.
9. Mehrholz J, Hädrich A, Platz T, Kugler J, Pohl M. Electromechanical and robot-assisted arm training for improving generic activities of daily living, arm function, and arm muscle strength after stroke. Cochrane Database Syst Rev 2012;6:CD006876.
10. Lo AC, Guarino PD, Richards LG, Haselkorn JK, Wittenberg GF, Federman DG et al. Robot-assisted therapy for long-term upper-limb impairment after stroke. N Engl J Med 2010;362:1772-83.
11. Ertelt D, Small S, Solodkin A, Dettmers C, McNamara A, Binkofski F *et al.* Action observation has a positive impact on rehabilitation of motor deficits after stroke. Neuroimage 2007;36(Suppl 2):T164-73.
12. Johansson BB. Multisensory stimulation in stroke rehabilitation. Front Hum Neurosci 2012;6:60.

Received on ???? - Accepted for publication on ????.
Corresponding author: . Tettamanti, San Raffaele Scientific Institute, Milan, Italy. tettamanti.andrea@hsr.it

Biomechanical and electromyographic analysis of stepping down during ongoing gait

F. POZZI [1], G. M. GUTIERREZ [2]

[1]Biomechanics and Movement Science Program, University of Delaware, Newark, DE, USA; [2]Department of Physical Therapy, Steinhardt School of Culture, Education, and Human Development, New York University, New York, NY, USA

ABSTRACT

Aim. Stepping down during ongoing gait represents a common functional activity. At ground contact, the leading leg has to absorb the energy released during the descent making it more complex than level ground gait. The aim of this study was to yield a biomechanical description of stepping down during ongoing gait through the analysis of kinematic, kinetic, and EMG data in young, healthy individuals.

Methods. Eight healthy subjects (4 male/4 female, 25.8±4.5 years, 1.68±0.07m height, 67.09±9.93kg weight) were recruited for the study. A custom made 9m long walkway was built with a 15cm step to simulate a street curb. Subjects were instructed to walk barefoot at a self-selected speed on the elevated walkway, step down onto the lower walkway, and keep walking until the end of the platform. Only kinematic, kinetic and EMG data from the leg used to step down (leading leg) were reported.

Results. All subjects used a toe landing strategy. During the swing phase prior to touchdown, plantarflexion movement, combined with co-activation of the plantar and dorsiflexors were found at the ankle joint. Following ground contact, knee flexor and extensor activation were observed.

Conclusion. The EMG activity, along with the kinematic and kinetic patterns, found at the ankle and knee joints indicated that both joints contribute to absorb energy after ground contact. *(it j physiotherapy 2013;3:3-10)*

Key words: Ankle - Knee - Gait.

During everyday life, we are often challenged to step down from a height while walking. People that live in urban settings perform this functional activity several times daily when crossing streets, as they step down from street curbs while they walk through a typical metropolitan environment. Single steps are often present in home settings as well. Thus, improving performance during this activity is an important functional goal of rehabilitation, as it may affect the autonomy of patients after discharge from rehabilitation programs.

While walking on an elevated surface, the body has higher potential energy. As the body center of mass descends to a lower level, this potential energy is transformed into kinetic energy.[1, 2] Thus, at foot contact, the linear and angular momenta are higher compared to level ground gait.[1, 2] The leading leg has to control these higher momenta, absorb part of the energy released during the descent, and partially use some of this energy to promote forward motion.[1, 2] Additionally, during stepping down foot clearances are small, foot placement is close to the step edges and the single limb support phase is longer.[3] For these reasons, descending a step while walking is a challenging scenario and represents a common cause of falls in the older population.[4]

During the approach phase, individuals must quickly adjust the step length on the raised surface to land the foot close to the height change. Furthermore, their leading leg contacts the ground farther away from the step. These adaptations allow performance of the task without hesitation, loss of movement fluency, or loss of walking speed.[3, 5, 6] At foot contact, two landing strategies have been observed: heel and toe landing.[2] Heel landing is preferred when negotiating a small step at high speed, while toe landing is preferred when the step is higher and the speed lower.[7] The foot contacts the ground earlier during toe landing, which helps reduce the body's descent velocity. Additionally, the leading leg absorbs energy at the ankle joint using the plantarflexor muscles.[2] The negative work at the ankle and proximal joints appeared to occur sequentially. This may indicate that failing to absorb energy at the ankle can be overcome by increasing energy absorption at the proximal joints.[2] Failure to appropriately absorb and transform the potential energy and control the momenta can cause a loss of balance,[2] which is especially problematic during unexpected height changes.[1]

While kinematic and kinetic data have been reported during stepping down in ongoing gait, no study analyzed the concomitant muscle activation of the leading leg. Understanding the muscle activation patterns of the leading leg will give important insight on the activation patterns used to complete a step down task. Therefore, the purpose of this study is to quantify the EMG activity, along with kinematics and kinetics, of the leading leg during stepping down in ongoing gait.

Materials and methods

Participants

Eight subjects (4 male/4 female, 25.8±4.5 years, 1.68±0.07m height, 67.09±9.93kg weight) were recruited for the study. The study was approved by the University's Institutional Review Board, and each participant gave informed consent. Subjects had to be between 18 and 35 years of age for inclusion in the study. Subjects were excluded from the study if they reported: 1) cardiovascular, pulmonary, neuromuscular, and/or musculoskeletal diseases, disorders, or conditions; 2) surgery in the lower limbs within the past year; 3) musculoskeletal injuries within the past 6 months; and 4) drug and/or alcohol consumption within 24 hours prior to testing that might interfere with motor performance. A custom questionnaire was used to collect demographic information and screen for exclusion criteria.

Instrumentation

Before testing, ten individual reflective markers and six clusters of three reflective markers were attached bilaterally to the lower limbs. Five Qualisys ProReflex cameras (Qualisys AB Inc., Gothenburg, Sweden) tracked the 3-dimensional position in space of the reflective markers at 120Hz. Virtual markers on specific anatomical landmarks were digitized using a custom made digitizing wand in the Visual3D software (version 4.0, C-Motion, Inc., Germantown, MD, USA) using the real-time streaming function of Visual3D. The locations of the markers, clusters, and virtual markers are presented in Figure 1.

A custom made 9 m long walkway was built with a 15 cm step to simulate a street curb (Figure 2). Two force plates (Kistler Inc., Winterthur, Switzerland) were embedded in the lower

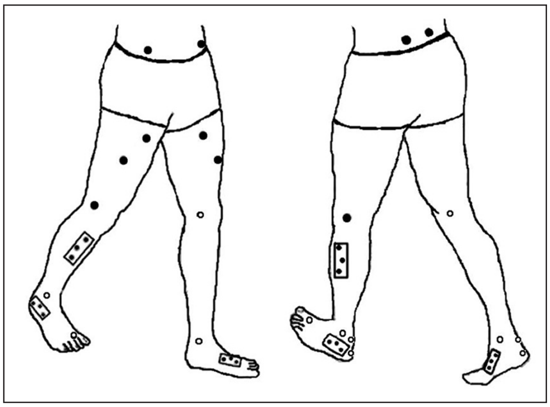

Figure 1.—A representative diagram of the tracking marker locations, including: 10 individuals reflective markers (solid dots; placed bilaterally on the ASIS, PSIS, anterior thigh (2), and lateral femoral condyle); six 3-reflective-marker clusters (squares with 3 dots; placed bilaterally on the anterior shank, lateral calcaneous, and first metatarsal); and 12 virtual markers digitized in relation to the physical markers (empty dots; located bilaterally on the medial femoral condyle, medial and lateral malleoli, inferior and superior aspect of the calcaneus, and 2nd metatarsal head). These markers were used to build six-degree of freedom models of the pelvis, thighs, shanks, and feet, as well as to track those segments during the dynamic task.

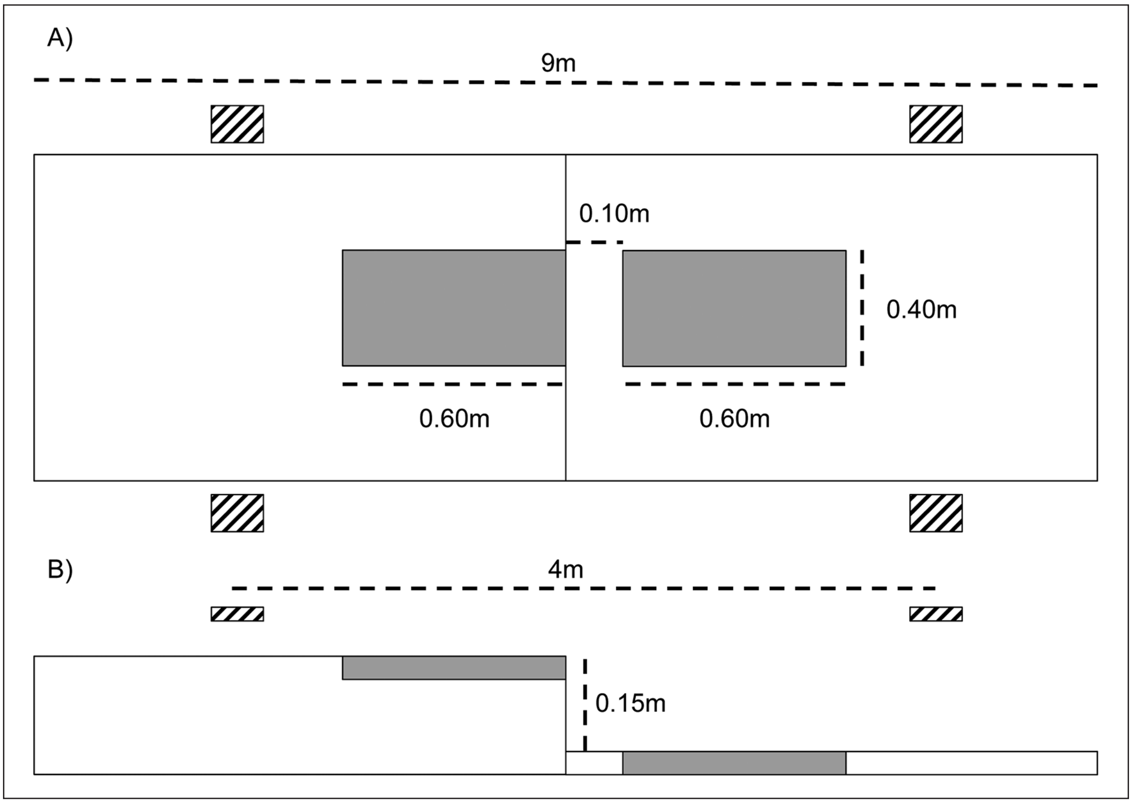

Figure 2.—Superior (A) and lateral (B) view of the walkway (total length 9m). The walkway was built in halves, such that one half could be elevated by 0.15m. Two force plates (dark gray rectangles) were embedded into the walkway. Two pairs of timing gates (diagonal lines) were placed approximately 4m apart and used to measure walking speed. (Figure not to scale)

and upper walkway and used to acquire ground reaction force data during the step down transition at 1200Hz.

The activity of the peroneus brevis (PB), peroneus longus (PL), tibialis anterior (TA), medial gastrocnemius (MG), biceps femoris (BF), rectus femoris (RF), and vastus medialis (VM) muscles of the leading leg was collected using a Bagnoli-8 EMG system (Delsys Inc., Boston, MA, USA). The skin on the electrode placement sites was shaved, abraded, and cleaned with an alcohol pad.[8] Bipolar surface EMG electrodes [DE 2.1 Single Differential Surface EMG Sensor, Delsys, Inc.; Sensor Contacts – 2 silver bars, 10 mm long, 1 mm diameter; Contact Spacing – 10 mm; CMRR – 92 dB (typical), 84 dB (minimum)] were attached on the belly of those muscles parallel to the direction of the muscle fibers.[8] The ground electrode was placed directly over the spinous process of C_7. A manual muscle test was performed to check for correct placement and to minimize crosstalk between muscles. An elastic wrap secured the electrodes and reduced the movement artifact. The EMG signals were acquired at a sampling rate of 1200 Hz and with a gain of 1000x (frequency response 20±5 – 450±50 Hz [80 dB/decade], System Noise [RTI]<1.2 IV [RMS] for the specified bandwidth).

Experimental procedure

Subjects were instructed to walk at self-selected speed on the elevated walkway, step down onto the lower walkway, and keep walking until the end of the platform. The leg used to step down (leading leg) was determined by coin flip. Subjects performed three practice trials where self-selected speed was measured using two optical timing gates (Polaris, FarmTek Inc., Wylie, TX, USA). After resting for one minute, subjects performed three trials where kinematic, kinetic and EMG data were collected simultaneously. Trials were discarded and performed again if subjects did not contact the force plates cleanly, visually targeted the force plates, and/or if speed exceed ±5% of the pre-determined self-selected speed.

Statistical analysis

Raw kinematic and analog (ground reaction force and EMG) data were imported into Visual3D for the analysis. Six-degree of freedom models for the pelvis, thigh, shank, and foot were built using real and digitized markers in Visual3D. Coordinate reference systems for each segment in the model were created in Visual3D, which were then applied to the dynamic trials. The position data of all reflective markers were smoothed using a low-pass, 2nd order, zero-lag Butterworth filter with a cutoff frequency of 7Hz. Joint rotations and angular velocities were calculated using a Cardan sequence to describe the movement of the leading leg during the step down trials. Although the pelvis segment was created, the markers on the pelvis were obstructed during the data collection on numerous occasions. Thus, hip kinematic and kinetic data were not included in the analysis.

The ground reaction force signals were smoothed using a low-pass, 2nd order, zero-lag Butterworth filter with a cutoff frequency of 20Hz. Using the inverse dynamics algorithm of Visual3D, moments and power at the ankle and knee joints were calculated. Kinetic data were normalized to body weight (BW). All reported joint moments were external joint moments.

EMG signals were band-pass filtered (2nd order, zero-lag Butterworth filter with cutoff frequencies of 20-450Hz), rectified, and smoothed (low-pass, 2nd order, zero-lag Butterworth filter with cutoff frequency of 7Hz). The maximal muscle activation over all step down trials was used to normalize the EMG signal between subjects.

Data were averaged over the three trials for each subject. Data were collected on the leading leg, thus the swing phase preceded the stance phase. An inspection of the data revealed that the swing phase was longer compared to level ground gait and accounted for about 47% of the gait cycle, which is evident considering that the leading leg has to travel more space before contacting the lower level. As a result, the data are presented over stride divided in 100% of swing and 100% of stance. Due to the nature of the study, only descriptive statistics were calculated and will be presented.

Results

The average walking speed was 1.16±0.08 m/s and all subjects used a toe landing strategy

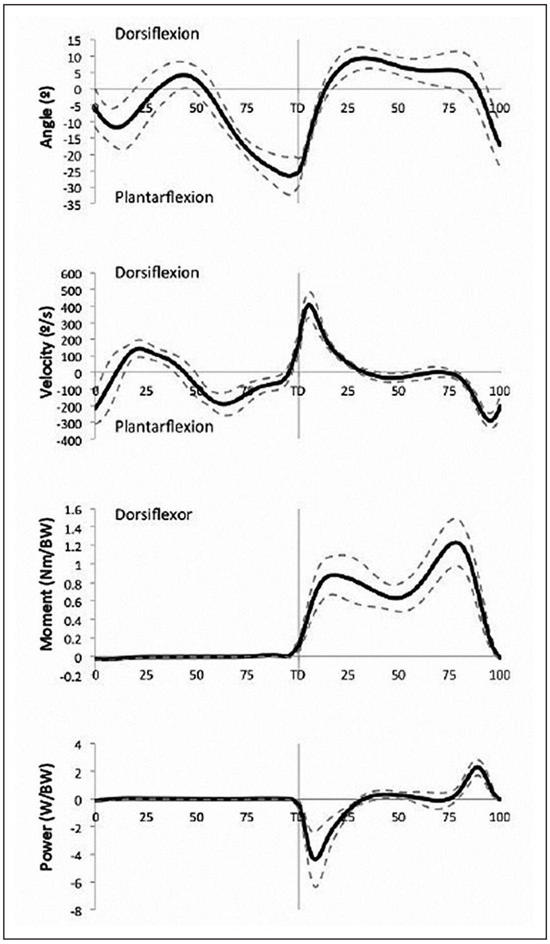

Figure 3. Joint rotation angles, velocities, moments, and powers (mean [solid line] ± SD [dashed line]) for the ankle joint in the sagittal plane during the swing (100%; between 0 and TD) and stance phases (100%; between TD and 100). The vertical line represents TD.

to complete the task. The ankle and knee joints presented with larger motion and higher energy absorption in the sagittal plane compared to the frontal and transverse planes.

During the last 50% of swing, the ankle moved into plantarflexion and reached ~25° of plantarflexion at touchdown (TD; Figure 3). Furthermore, all muscles analyzed increased their activation, and an absolute peak of MG activation was observed before TD with co-activation of the TA muscle (Figure 4). During the first 25% of the stance phase, the ankle moved into dorsiflexion and the peak velocity of this movement was ~400°/s. High dorsiflexor moment and negative power were found in the sagittal plane at the ankle. The knee presented with a kinematic and kinetic pattern similar to the ankle joint (flexion movement [peak velocity ~180°/s], flexor moment, and negative power [Figure 5]). The activation of the MG decreased following TD, while the RF and VM muscles sharply increased their level of activation.

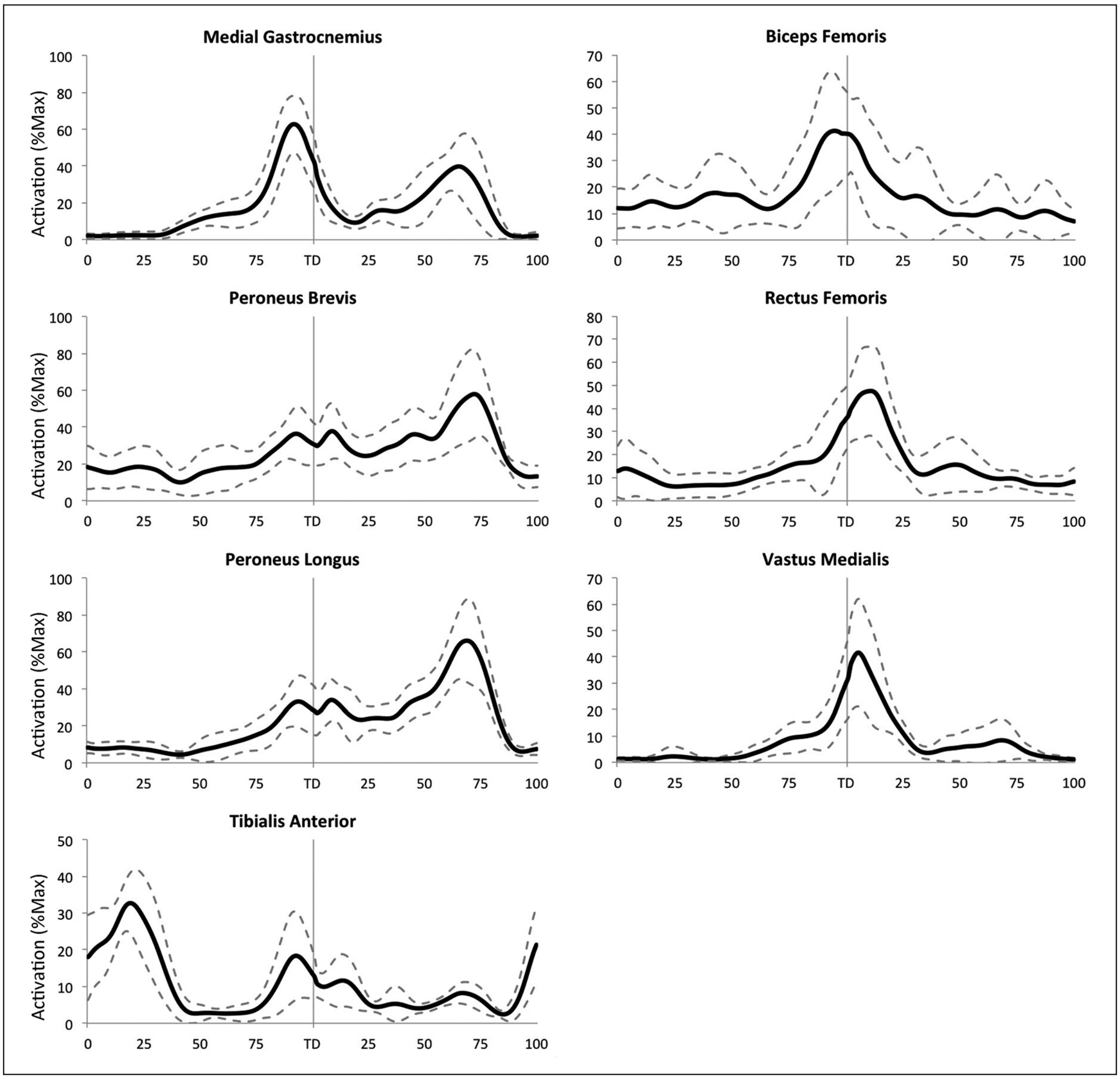

Figure 4.—EMG activation (mean [solid line] ± SD [dashed lines]) during the swing (100%; between 0 and TD) and stance phases (100%; between TD and 100). The vertical line represents TD. Values are normalized to the maximal activation during the step down trials.

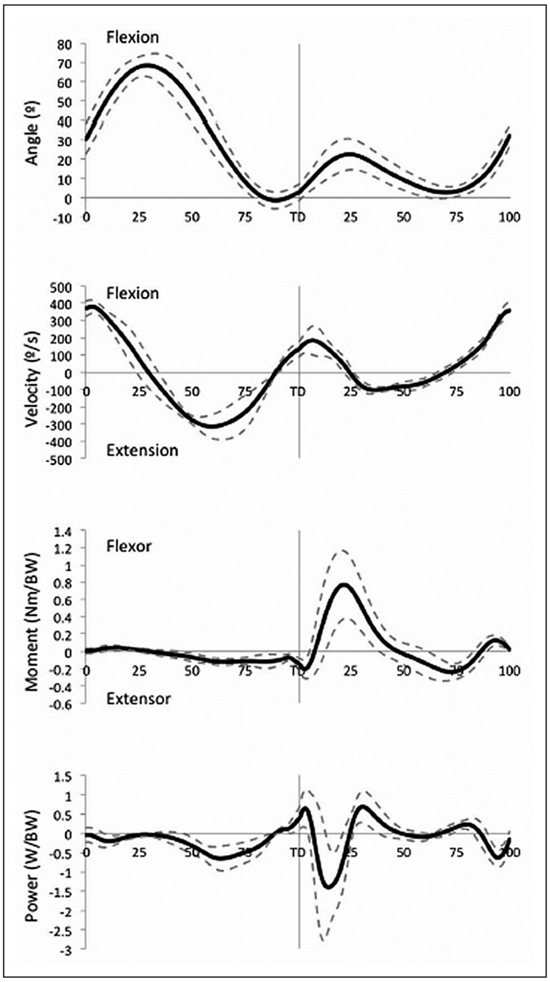

Figure 5.—Joint rotation, velocities, moments, and powers (mean [solid line] ± SD [dashed line]) for the knee joint in the sagittal plane during the swing (100%; between 0 and TD) and stance phases (100%; between TD and 100). The vertical line represents TD.

Discussion

Stepping down during ongoing gait represents a complex functional activity. The leading leg needed to control the descent of the center of mass and absorb the energy released during the descent.[1, 2, 9] When toe landing, the plantarflexors and knee extensor EMG patterns found in this study, reinforced the evidence that both ankle and knee joints contribute to energy dissipation during stepping down in ongoing gait.

Fine modifications of the leading leg's kinematic strategies and EMG patterns, are needed to safely perform the task. During the beginning of the swing (from 0 to ~50% of swing), the ankle joint of the leading leg sustained dorsiflexion movement along with TA activity, which is similar to level ground gait.[10] However, starting at ~50% of swing, the kinematic and EMG patterns at the ankle are altered compared to level ground gait. Specifically, the ankle moved into plantarflexion, the TA was silent, and starting at ~75% of the swing phase, all muscles analyzed increased their activation. These modifications seemed to occur in anticipation of ground contact (feed-forward mechanism) to control the higher moments and release of potential energy.[1, 2] Similar adjustments have been observed in activities that required comparable functional demands on the ankle, such as stair descent.[11, 12] During the first 25% of stance, passive movement at the ankle and knee joints and concomitant activation of the antagonist muscles (plantarflexors at the ankle and extensor at the knee) were observed. This suggested lengthening of the musculo-tendinous complex, which allowed for energy absorption. When all energy was absorbed (after ~25% of stance), the movement and muscle activation at the ankle became similar to level ground gait, as suggested by the contraction of the plantarflexor during mid-stance and the contraction of the TA, dorsiflexion movement and knee flexion during the subsequent pre-swing.[10]

The MG muscle presented with high preparatory activity (just prior to TD), with co-activation of the TA, and reduction of the plantarflexion movement. This suggests that the contraction of the MG most likely generated muscle stiffness, as proposed by Gallhofer *et al.*,[13] rather than contributing to plantarflexion movement. Increasing muscle stiffness enhanced the ability of muscles to absorb energy.[14] Additionally, high preparatory activity might be related to the speed of ankle dorsiflexion movement after TD. During drop jump performed on a sledge, Ishikawa & Komi [15] found that the preparatory activity of the MG and vastus lateralis increased with the height of the drop and consequently with the drop velocity. The fact that: 1) high preparatory activity of the MG was found during stepping down in ongoing gait (average velocity

1.16±0.08m/s), but not in stair descent (average velocity 0.53±0.07m/s);[9, 11] and 2) high angular velocity after TD were associated with high preparatory activity, seemed to follow with the observation made by Ishikawa & Komi:[15] high preparatory activity is needed to absorb energy during high speed eccentric movements.

The knee served a similar function in stepping down as it does in level ground gait.[10] Sagittal plane motion in the knee is needed for advancement, stability of the body, and minimizing center of mass displacement. The sagittal plane kinematics in stepping down during ongoing gait were similar to level ground gait.[10] However, due to the release of potential energy, the kinetics were altered relative to level ground gait. Specifically, there was a higher flexor moment in early to mid-stance with concomitant negative sagittal plane power, which suggests energy absorption. This change in kinetics necessitated an altered activation of the knee musculature. Specifically, there was higher amplitude of activity in the BF and VM muscles during their normally timed activation at TD, which is likely due to additional support requirements indicated by the change in sagittal plane moment and power. The RF is typically silent during heel strike in level ground gait, however there was a strong burst of activity at TD in stepping down. This might be due to the additional stabilization and support requirements at the knee or hip.

To allow subjects to carry out kinematic and EMG patterns they would have naturally developed to descend a step in daily activity, we did not impose a landing strategy (*i.e.*, toe *vs.* heel). Since the landing strategy is determined by numerous factors (age, approaching speed, and curb height),[7] the walkway reproduced the standard height for a street curb.[16] We believe that all of these helped subjects performing the task as naturally as possible. However, although the height of the curb and the self-selected speed helped reproduce a standard functional motor task, they are considered limitations of the study. In daily life, curb height can be variable, which may generate different kinematics, kinetics and EMG patterns compared to our observation. Additionally, subjects walked barefoot, which was done in an effort to reduce the variability between footwear, as well as to more accurately track the movement of the foot. However, it does not represent an everyday walking style. The shoes may also promote heel landing by dissipating the impact force generated at landing. Future study should aim to investigate the effect of shoes on the biomechanics of stepping down in ongoing gait. The role of the hip and trunk, as well as the concomitant muscle activation, should also be addressed.

Conclusions

Stepping down in ongoing gait represents a normal, but challenging functional activity. When toe landing, the ankle moved into plantarflexion during the swing phase. Furthermore, high EMG activation of the plantarflexors was found prior to ground contact. These movements and EMG strategy allowed the ankle to absorb energy after ground contact. The kinematic and EMG pattern at the knee (flexion movement and high extensor EMG) indicated that this joint contributed to energy dissipation following ground contact.

References

1. van Dieen JH, Spanjaard M, Konemann R, Bron L, Pijnappels M. Balance control in stepping down expected and unexpected level changes. J Biomech 2007;40:3641-9.
2. van Dieen JH, Spanjaard M, Konemann R, Bron L, Pijnappels M. Mechanics of toe and heel landing in stepping down in ongoing gait. J Biomech 2008;41:2417-21.
3. Lythgo N, Begg R, Best R. Stepping responses made by elderly and young female adults to approach and accommodate known surface height changes. Gait Posture 2007;26:82-9.
4. Berg WP, Alessio HM, Mills EM, Tong C. Circumstances and consequences of falls in independent community-dwelling older adults. Age Ageing 1997;26:261-8.
5. Begg RK, Sparrow WA. Gait characteristics of young and older individuals negotiating a raised surface: implications for the prevention of falls. J Gerontol A Biol Sci Med Sci 2000;55:M147-154.
6. Crosbie J, Ko V. Changes in the temporal and distance parameters of gait evoked by negotiation of curbs. Aust J Physiother 2000;46:103-12.
7. van Dieen JH, Pijnappels M. Effects of conflicting constraints and age on strategy choice in stepping down during gait. Gait Posture 2009;29:343-5.
8. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol 2000;10:361-74.
9. Cluff T, Robertson DG. Kinetic analysis of stair descent: Part 1. Forwards step-over-step descent. Gait Posture 2011;33:423-8.
10. Perry J, Burnfield J. Gait analysis: normal and pathological

function. Second edition. Thorofare, NJ: SLACK Incorporated; 2010.
11. McFadyen BJ, Winter DA. An integrated biomechanical analysis of normal stair ascent and descent. J Biomech 1988;21:733-44.
12. Protopapadaki A, Drechsler WI, Cramp MC, Coutts FJ, Scott OM. Hip, knee, ankle kinematics and kinetics during stair ascent and descent in healthy young individuals. Clin Biomech 2007;22:203-10.
13. Gollhofer A, Strojnik V, Rapp W, Schweizer L. Behaviour of triceps surae muscle-tendon complex in different jump conditions. Eur J Appl Physiol 1992;64:283-91.
14. Ishikawa M, Komi PV, Grey MJ, Lepola V, Bruggemann GP. Muscle-tendon interaction and elastic energy usage in human walking. J Appl Physiol 2005;99:603-8.
15. Ishikawa M, Komi PV. Effects of different dropping intensities on fascicle and tendinous tissue behavior during stretch-shortening cycle exercise. J Appl Physiol 2004;96:848-52.
16. Kirschbaum J, Axelson P, Longmuir P, Mispagel K, Stein J, Yamada D. Chapter 7. Curb Ramps. Design Sidewalks and Trails for Access: Part II of II, best practices design guide. Washington (DC): Department of Transportation, Federal Highway Administration; 2001 [Internet]. Available at http://www.fhwa.dot.gov/environment/sidewalk2/sidewalks207.htm [cited 2013, Mar 1].

Part of these data were presented during the 12th Annual Graduate Research Student Seminar at the Combined Section Meeting of the American Physical Therapy Association, Chicago, IL, USA, 2012.
Conflicts of interest.—The authors have no conflict of interest to declare.

Received on October 25, 2012 - Accepted for publication on March 1, 2013.

Corresponding author: F. Pozzi, 301 Mckinly Laboratory, University of Delaware, Newark, DE 19713 USA. E-mail: fpozzi@udel.edu

Description of the cervical manipulative technique in the scientific literature

C. CASTELNUOVO [1], M. BARBERO [2], G. ZITO [3]

[1]Private Practitioner, Milan, Italy; [2]Department of Health Sciences, University of Applied Sciences and Arts of Southern Switzerland, SUPSI, Manno, Switzerland; [3]School of Physiotherapy, University of Melbourne, Melbourne, Australia

ABSTRACT

Aim. Vertebral manipulation is a technique commonly used in the treatment of people suffering disorders of the vertebral column. Recently this form of treatment has received increasing attention from authors and researchers in the field of manual therapy. As these techniques become more widely used, it is important that clinicians treating the cervical spine know how to administer them appropriately. Publications must contain accurate descriptions of the technical details of these techniques and criteria for their use if they are to assist clinicians. The aims of this paper were to scrutinize the description of the cervical manipulative techniques in clinical trails and to propose a set of elements to describe these techniques.

Methods. A systematic review of the literature was conducted searching the major databases. All studies that included cervical manipulation in the treatment of neck pain, cervicogenic headache and cervical radiculopathy were included. An evaluation matrix including 8 items has been used to scrutinize the cervical manipulative techniques included in the studies.

Results. Thirty-two studies fulfilled the inclusion criteria and were reviewed. According to our evaluation matrix only 5 articles provide detailed information about the manipulation technique applied in the studies.

Conclusion. The level of details provided by the authors is still not satisfactory. Journals publishing articles in the field of manipulative therapy should impose higher standards on authors with regard to description of techniques.
(it j physiotherapy 2013;3:11-19)

Key words: Manipulation, spinal - Neck pain - Musculoskeletal manipulations.

The term "manipulation" is used to describe a number of different techniques in the field of musculoskeletal rehabilitation, making it difficult to distinguish one technique from the other. When reference is made to "manipulation" in the scientific journals, it is often necessary to seek additional information to distinguish the "authentic" manipulation technique, a high velocity low amplitude passive movement applied to a joint, from other manual therapy techniques.[1] The scientific community has placed increased emphasis on this therapeutic approach because its efficacy in the management of some musculoskeletal disorders is supported by encouraging results.[2-11] It is, therefore, necessary to accurately describe the techniques used in the literature in order to foster better intraprofessional and interprofressional communication.[12]

In keeping with the overgrowing propagation of evidence based practice in clinical practice, it is essential to support the effective transfer of acquired knowledge.[13] As there is a paucity of specific descriptions of the manipulative techniques, it would be useful to develop an internationally acceptable nomenclature for the techniques.[14]

The ability to clearly and unambiguously describe this intervention, irrespective of its source or the author's professional background, is necessary if clinicians are to apply the clinical research findings into practice. Inconsistency in the technical language has been identified as the biggest obstacle hindering widespread integration of manual therapy in the field of physiotherapy practice and education.[15] Again as Flynn *et al.* stated: "It is increasingly evident that the lack of precision in the description of techniques has become more than a problem, it is an obstacle to both the analysis of the methodology and ultimately interpretation of the results".[16]

In February 2007 the Academy of Orthopaedic Manual Physical Therapists (AAOMPT) established a Task Force with the aim of standardizing the terminology in the field of manual therapy, including manipulative techniques. The ultimate goal of this task force was to create a model for manual techniques that could be accepted internationally and used in the physiotherapy community.[12]

The aims of this paper are to consider the reproducibility of the cervical manipulation studied in selected clinical trials based on the description provided and to propose a series of elements that describe the most important facets of the cervical manipulation technique.

Materials and methods

PubMed database

Searches were conducted on October 20, 2011 on the database PubMed for randomized controlled trials (RCT) and clinical trials (CT) indexed from 2000 onwards that included the use of cervical manipulative techniques on subjects affected by neck pain, cervicogenic headache or cervical radiculopathy.

PEDro database

Given the specialized nature of the database which focuses on rehabilitation, and to avoid restricting the research, key words "cervical AND manipulation" were used. The search was limited to "clinical trial" articles indexed from 2000 to October 31, 2011 ensuring that the articles satisfied the same requirements of the research articles on the PubMed database.

Selection of the studies

Two reviewers independently assessed the abstracts of 136 titles yielded from the search. They read the available abstracts online and a selection of the articles that complied with the established inclusion criteria. Studies were considered if the use of the cervical manipulative technique for the treatment of neck pain, cervicogenic headache or cervical radiculopathy could be identified from the abstract. In the event of disagreement, the full article was retrieved and re-examined by both reviewers. The results were discussed until a satisfactory conclusion was reached. Of the136 retrieved articles from the search in the two databases, 33 were deemed appropriate for this task, and 32 publications were included following the reading of the full text (Figure 1).

Evaluation of the articles

Because there was no existing validated quality evaluation matrix relating to the accuracy of description of manipulative techniques on the cervical spine, a quality checklist was developed by the authors (Table I) considering the "Model for Standardizing Manipulation Terminology in Physical Therapy Practice".[17] The evaluation matrix of the articles was developed to identify the different elements inherent in the manipulative techniques proposed in the studies (Figure 2). There were a total of 8 elements. One point was assigned for each positive element. A score of 8 indicated that a wide-ranging amount of useful information about the application of the technique was presented. Scores close to zero indicated scant detail in the description. The elements reflected, according to the authors of this work, useful details that would enable good reproducibility of a manipulative technique described in a trial.

The proposed elements included: choice of articular level manipulated, handling (point of contact/placement of thrusting hand/locking/set up), patient position, operator position, thrust, indicators of success, dosage, references. To meet the criterion and obtain a positive score, the element had to contain the minimum amount of information that was agreed upon by the reviewers.

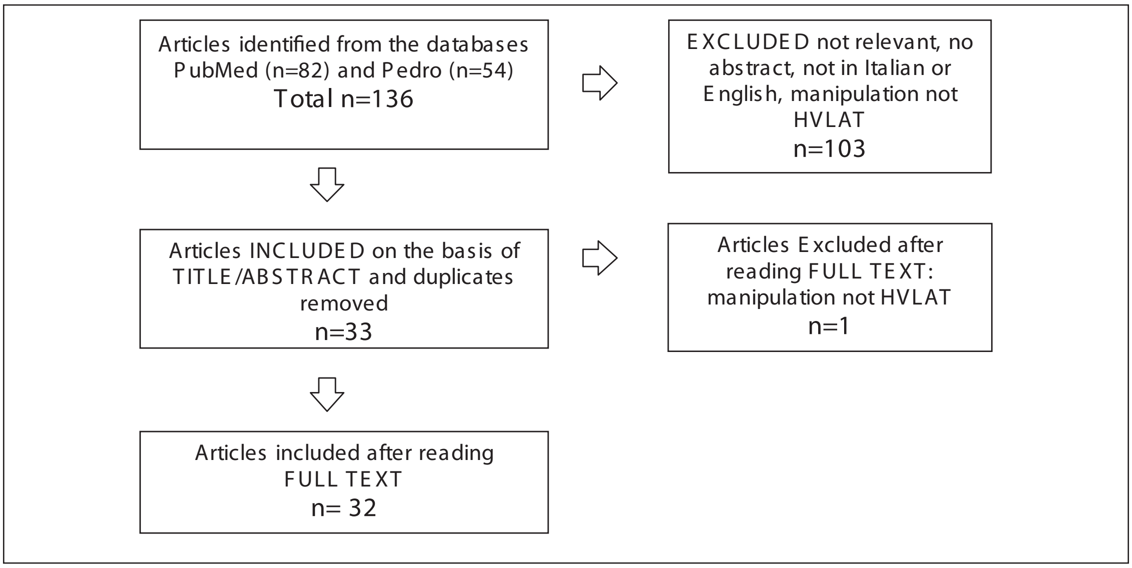

Figure I.—Flow chart: literature search and selection of articles.

Table I.—*Evaluation matrix.*

Choice of articular level manipulated	The criterion is satisfied if the articular level to be manipulated is explicitly mentioned. The criterion is not satisfied if the region of the neck is described broadly (cervical manipulation, upper cervical manipulation etc.)
Handling	The criterion is satisfied if the exact point of contact of the thrusting hand on the vertebra is mentioned, the part of the hand that will impart the thrust and the set-up and lock position.
Patient position	The criterion is satisfied if the position of the patient's cervical spine are described along with any movements and/or adjustments required to place him/her in the pre-manipulative position.
Operator position	The criterion is satisfied if the position of the therapist during the application of the manipulative technique is described
Thrust	The criterion is satisfied if the details about the direction and the manner in which the manipulative techniques will be performed are described
Indicator of success	The criterion is satisfied if the author provides details of the procedure or the criterion that confirms success of the technique. Or else they define whether the technique is successful or not.
Dosage	The criterion is satisfied if details are given regarding frequency or the number of times the manipulation is administered.
References	The criterion is satisfied if reference is made in the bibliography or in the text to the original description to where the technique is described

Criteria are reported in the Table I.

The reviewers independently assessed the information in the articles and rated them according to the agreed criteria based. In some publications the authors used photographic material and provided links to video material on the web pertaining to the techniques. In these cases it was decided to assign a negative score to the technical element indicated, unless the information was also provided in writing.

Results

Of the 32 studies included, none achieved the maximum score from our evaluation matrix (Table II). The highest score of 7/8 was achieved in 5 studies,[18-22] a score less than 3 in 21 studies,[23-43] and a score between 3 and 7 in 6.[44-49] To describe the use of the vertebral manipulative thrust techniques, the authors frequently refer to alternative terminology, often associated with to

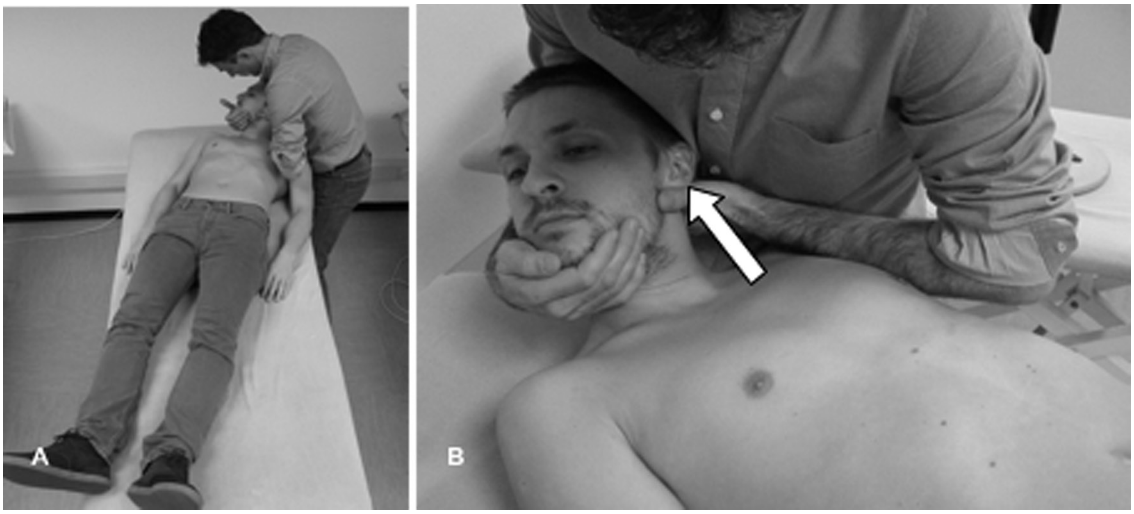

Figure 2.—An example of a high velocity, low amplitude thrust technique of the left atlanto-occipital joint. A) The patient lies supine, diagonally across the table with the head over the edge. The operator stands at the side of the table at the head end; B) the patient's head is cradled with the operator's right forearm and the chin is grasped lightly with the right hand. The cervical spine is placed in flexion, left lateral flexion and right rotation. The force to distract the atlanto-occipital joint is applied in a cephalic direction with the thrusting knuckle (palmar aspect of the 2nd metacarpophalangeal joint) of the left hand on the left occipital condyle.

the background of the operator. Terms used include CMT (chiropractic manipulative therapy), TJM (thrust joint manipulation), SMT (spinal manipulative therapy), HVLAT (high-velocity low-amplitude techniques), CSM (chiropractic spinal manipulation), and adjustment. In some articles reference was made to techniques that have a more precise name such as toggle recoil, diversified, lateral break.

In 16 studies out of 32 [18-22, 24, 26, 27, 37, 39, 42, 43, 45-47, 49] the authors satisfactorily justify their selection of a particular vertebral level to manipulate. Findings on palpatory examination and on assessment of accessory cervical movements were considered sufficient as long as they were reported in the publication.

"Handling" referred to the positioning of the hands of the therapist, the point of contact, the fixation of the segments of the eventual locking of the joint. To obtain a positive score, the authors of this review resolved that at least 2 of the following pieces of information should be detailed: where the hand that applies the manipulative thrust makes contact with the neck and which part of the hand imparts the locking, fixation (setup) and eventual manipulative thrust. Eight studies [18-22, 45, 46, 48] out of 32 provided sufficient detail on the techniques in their studies.

Four studies [18-21] provided sufficient information regarding both the positioning of the patient and the positioning of the therapist. Another 4 studies mention only the position of the patient.[22, 44, 45, 47]

In 5 studies the authors provided photographs [18-21, 41] or link to a videoclip [41] to help describing the technique more fully.

Specifics regarding the direction of the thrust (rotary, in traction) are provided in 9 studies [18-22, 41, 44, 45, 48] out of 32. Only 5 studies [18-22] refer to a popping sound as an indicator of success in manipulating a particular articular level. This element was considered positive even if the author explained that the pop was not a criterion for the successful performance of the manipulation.

With regard to the dosage with which patients are manipulated, most of the authors either indicated a certain frequency or the basis on which they administered the manipulation. Two studies [33, 39] reported insufficient details, providing only the duration of the treatment period.

Finally, in seven,[22, 34-36, 45, 47, 49] a specific article or text was cited for details of the manipulative technique. Where this was not provided, or in the presence of a generic reference, the element was considered to be negative.

TABLE II.—*Evaluation matrix of the selected articles. In column 2, "name of the technique" refers to the most accurate wording the authors used in referring to the manipulative technique in the study.*

Author and year	Name of the technique	Technical refernce	Articular level manipulated	Handling	Patient position	Therapist position	Directin of th ethrust	Indicator of success	Dosage	Score n/8	Media
Saayman 2011 [24]	(CMT) Specific short- lever, HVLA diversified techniques	-	+	-	-	-	-	-	+	2/8	-
De Camargo 2011 [18]	HVLA	-	+	+	+	+	+	+	+	7/8	P
Puentedura 2011 [21]	Thrust joint manipulation (TJM)	-	+	+	+	+	+	+	+	7/8	P
Martel 2011 [27]	(SMT) HVLA spinal manipulation	-	+	-	-	-	-	-	+	2/8	-
Murphy 2010 [26]	HVLA spinal manipulation	-	+	-	-	-	-	-	+	2/8	-
Gemmel 2010 [37]	Dynamic thrusts, HVLA force directed at one or more restricted upper thoracic or cervical spine segments. Diversified technique.	-	+	-	-	-	-	-	+	2/8	-
Boyles 2010 [41]	3 Cervical Manipulation Techniques: opening restrictions; closing restrictions; upslope	-	-	-	-	-	+	-	+	2/8	V/P
Haas 2010 [47]	HVLA SMT as describer by Peterson and Bergmann	+	-	-	-	-	-	-	+	2/8	-
Haas 2010 [47]	HVLA SMT as describer by Peterson and Bergmann	+	-	-	-	-	-	-	+	2/8	-
Borusiak 2009 [44]	SMT	-	-	-	+	-	+	-	+	3/8	
Vernon 2009 [23]	Hvla Chiropractic spinal manipulation (CSM)	-	-	-	-	-	-	-	+	1/8	-
Mansilla-Ferragut 2009 [20]	C0-C1 joint manipulation, HVLA thrust	-	+	+	+	+	+	+	+	7/8	P
Leaver 2007 [28]	HVLA movements, manipulation	-	-	-	-	-	-	-	+	1/8	-
Haavik-Taylor 2007 [46]	HVLAT (to the spine held in lateral flexion, with slight rotation and slight extension)	-	+	+	-	-	-	-	+	3/8	-
Hawk 2007 [32]	HVLA Spinal Manipulation C0 to C7	-	-	-	-	-	-	-	+	1/8	-
Palmgren 2006 [25]	HVLAT	-	-	-	-	-	-	-	+	1/8	-
Martınez-Segura 2006 [19]	HVLA manipulation	-	+	+	+	+	+	+	+	7/8	P
Hurwitz 2005 [29]	Controlled Dynamic Thrust, HVLA with minimal extension and rotation, directed at 1 or more restricted upper thoracic or cervical spine	-	-	-	-	-	-	-	+	1/8	-
Hurwitz 2004	Controlled Dynamic Thrust, HVLA with minimal extension and rotation, directed at 1 or more restricted upper thoracic or cervical spine	-	-	-	-	-	-	-	+	1/8	-
Haas 2004 [30]	HVLA spinal manipulation Peterson and Bergman	+	-	-	-	-	-	-	+	2/8	-
Evans 2003 [38]	Spinal manipulation CHIRO	-	+	-	-	-	-	-	-	1/8	-
Haas 2003 [47]	HVLAT as Bergmann et Peterson	+	+	-	+	-	-	-	+	4/8	-
Harrison 2003 [33]	Cervical manipulation_bilateral diversified rotary break, (a global lateral bending combined with a small amount of axial torsion of head and neck)	-	-	-	-	-	-	-	-	0/8	-
Hurwitz 2002 [31]	Controlled Dynamic Thrust, HVLA with minimal extension and rotation, directed at 1 or more restricted upper thoracic or cervical spine	-	-	-	-	-	-	-	+	1/8	-
Evans 2002 [38]	SMT	-	-	-	-	-	-	-	+	1/8	-
Moodley 2002 [48]	Spinal Manipulation, Adjustment, Diversified cervical rotatory and/or lateral break tecniques	-	-	+	-	-	+	-	+	3/8	-
Whittingham 2001 [49]	Toggle Recoil, short lever thrust, HVT	+	+	-	-	-	-	-	+	3/8	-
Wood 2001 [22]	Standard Diversified rotary/lateral break techniques.	+	+	+	+	-	+	+	+	7/8	-
Bronfort 2001 [40]	SMT short lever low amplitude high velocity	-	-	-	-	-	-	-	+	1/8	-
Heikkila 2000 [42]	HVLAT	-	+	-	-	-	-	-	+	2/8	-
van Schalkwyk 2000 [45]	Supine Cervical Rotatory Manipulation and Supine Lateral Break Manipulation by Szaraz	+	+	+	+	-	+	-	+	6/8	-
Tuchin 2000 [43]	Chiropractic diversified tecnique	-	+	-	-	-	-	-	+	2/8	-

-: negative score; +: positive score; P: presence of a photo; V: linked to a videoclip.

Discussion

In a field such as manual therapy, which engenders ever-growing interest in the rehabilitative process, vertebral manipulation represents a specific approach that cannot and must not be improvised. Clinicians who use this form of treatment should have certified training and manual skills that are continually practiced over time to achieve a high level of therapeutic success.

When reporting findings in the literature on the effects of this type of technique on their patients, authors need to describe the manipulative technique in great detail. This would facilitate the reproducibility of the treatment techniques in different conditions to those in the research, and minimize the non-controllable variables

Heterogeneity of nomenclature used in the scientific field to describe high velocity, small amplitude manipulative techniques is an issue, be it in the phase of consultation of databases, or in the interoperator communication. The diverse backgrounds of those who perform this work compounds it further. Early research findings suggest that the term 'manipulation' does not always identify high velocity, small amplitude techniques explicitly adding to the confusion. The acronym HVLAT (high velocity low amplitude technique) on the other hand appears to be more suitable when one refers to thrust techniques. Nevertheless a simple search on PubMed using the keyword "HVLAT" yielded only 3 results albeit all were very pertinent.

To apply a high velocity, low amplitude manipulation technique the therapist needs to select a vertebral level to be manipulated. Authors should specify the criteria used to determine which level to manipulate. In our analysis 16 studies [21, 22, 24, 26, 27, 37, 39, 42, 43, 45-47, 49] satisfactorily described the criteria used for their decision. Palpation seems to be the technique most frequently employed to identify levels of hypomobility and hyperreactivity in the cervico-occipital area

To perform a manipulative thrust, the therapist's hand position needs to be precise to effect a quick and localized movement. If the technique is to be reproducible it is of considerable importance, therefore, that the information provided regarding the point of contact and the grip for the hand that fixes or manipulates the segments be described. Few authors provided this type of information in their RCTs.

Positioning the patient in supine, prone or on the side, and the details regarding the patient set-up prior to manipulation are also necessary to allow or facilitate a favourable outcome.

Eight studies provide sufficient information.[18-22, 44, 45, 47] Notwithstanding the fact that the therapist's position is often important, only 4 authors described it.[18-21]

Another important element when accurately describing a manipulative technique is the direction of the thrust, be it lateral or rotary, in traction. Nine authors clearly expressed this information in their publication.[18-22, 41, 44, 45, 48] Techniques are not always chosen from the findings on the clinical assessment. In these situations authors must justify their choice to apply a standard technique.

Even the criterion used by the authors to determine the success or failure of the application of the thrust is a topic that is covered briefly. Only 5 authors [18-22] provided information about this element, regardless of whether or not they thought the sound often associated with joint cavitation was necessary.

Information that is easily obtained from the studies is the frequency with which the subjects are exposed to vertebral manipulation, though there is high variability of application from a single thrust [18-20, 29-31, 44, 46, 47] to a course of 20 or more treatments.[23, 40] While recognizing the importance of the subjective variables and the inability to establish dosage irrespective of the clinical findings, it is useful to understand the frequency with which the authors of the studies have decided to apply the described techniques in order to replicate the treatments.

Often authors cite references containing details of a technique.[22, 34-36, 45, 47, 49] In the opinion of the authors of this review, this strategy does not facilitate the dissemination of useful information. Rather, it forces the reader to refer to other publications and discourages the clinical application of a potentially effective technique.

One author [39] justify the lack of detail about treatment due to their pragmatic approach. This is a significant limitation when trying to identify not only the techniques that are more appropriate for a particular condition but also the vertebral levels on which they should be applied for a more effective outcome.

The recent advances in digitalization of the scientific literature allow the integration of material from multimedia articles, but there are only very few researchers in rehabilitation who are interested in making use of this great facility.

The premise that a few journals compel authors to provide a more detailed description of the techniques is confirmed by the fact that 4 [18-20, 22] of the 5 articles that receive a global score of at least 7 items satisfied are published in Journal of Manipulative and Physiological Therapeutics.

Conclusions

Notwithstanding the fact that in the past attempts have been made to encourage researchers to be more rigorous in the description of the manual techniques used in their studies,[12] the level of details provided by the authors seem to be, according to our evaluation matrix, not satisfactory.

Only five studies out of 32 reached a score of 7/8, and moreover 21 reported a scoreless of 3/8.

The use of cervical thrust techniques in clinical practice should be supported with greater commitment on the part of researchers by describing the techniques used in their studies and by using a recognized nomenclature.

Journals publishing articles in the field of manipulative therapy should impose higher standards on authors with regard to description of techniques.

The evaluation matrix used in this narrative review might suggest a list of elements to consider, in order to provide clinicians with a real chance to replicate the treatments.

The validity and the reliability of the evaluation matrix should be confirmed before any application.

References

1. Evans DW, Lucas N. What is 'manipulation'? A reappraisal. Man Ther 2010;15:286-91.
2. Cleland JA, Glynn P, Whitman JM, Eberhart SL, MacDonald C, Childs JD. Short-term effects of thrust versus nonthrust mobilization/manipulation directed at the thoracic spine in patients with neck pain: a randomized clinical trial. Phys Ther 2007;87:431-40.
3. Cleland JA, Fritz JM, Whitman JM, Childs JD, Palmer JA. The use of a lumbar spine manipulation technique by physical therapists in patients who satisfy a clinical prediction rule: a case series. J Orthop Sports Phys Ther 2006;36:209-14.
4. Cleland JA, Childs JD, McRae M, Palmer JA, Stowell T. Immediate effects of thoracic manipulation in patients with neck pain: a randomized clinical trial. Man Ther 2005;10:127-35.
5. Cleland JA, Childs JD, Fritz JM, Whitman JM, Eberhart SL. Development of a clinical prediction rule for guiding treatment of a subgroup of patients with neck pain: use of thoracic spine manipulation, exercise, and patient education. Phys Ther 2007;87:9-23.
6. Childs JD, Fritz JM, Flynn TW *et al*. A clinical prediction rule to identify patients with low back pain most likely to benefit from spinal manipulation: a validation study. Ann Intern Med 2004;141:920-8.
7. Bronfort G, Haas M, Evans RL, Bouter LM. Efficacy of spinal manipulation and mobilization for low back pain and neck pain: a systematic review and best evidence synthesis. Spine J 2004;4:335-56.
8. Dunning JR, Cleland JA, Waldrop MA *et al*. Upper cervical and upper thoracic thrust manipulation versus nonthrust mobilization in patients with mechanical neck pain: a multicenter randomized clinical trial. J Orthop Sports Phys Ther 2012;42:5-18.
9. Flynn T, Fritz J, Whitman J *et al*. A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. Spine (Phila Pa 1976) 2002;27:2835-43.
10. Jull G, Trott P, Potter H *et al*. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. Spine (Phila Pa 1976) 2002;27:1835-43; discussion 1843.
11. Fritz JM, Childs JD, Flynn TW. Pragmatic application of a clinical prediction rule in primary care to identify patients with low back pain with a good prognosis following a brief spinal manipulation intervention. BMC Fam Pract 2005;6:29.
12. Mintken PE, DeRosa C, Little T, Smith B, American Academy of Orthopaedic Manual Physical T. AAOMPT clinical guidelines: A model for standardizing manipulation terminology in physical therapy practice. J Orthop Sports Phys Ther 2008;38:A1-6.
13. Manns PJ, Darrah J. Linking research and clinical practice in physical therapy: strategies for integration. Physiotherapy 2006;92:88-94.
14. Oostendorp RA. Manual physical therapy in the Netherlands: reflecting on the past and planning for the future in an international perspective. J Man Manip Ther 2007;15:133-41.
15. Flynn TW. Manual physical therapy: moving beyond the theoretical. J Orthop Sports Phys Ther 2004;34:659-61.
16. Flynn TW, Childs JD, Bell S, Magel JS, Rowe RH, Plock H. Manual physical therapy: we speak gibberish. J Orthop Sports Phys Ther 2008;38:97-8.

17. Mintken PE, Derosa C, Little T, Smith B, American Academy of Orthopaedic Manual Physical T. A model for standardizing manipulation terminology in physical therapy practice. J Man Manip Ther 2008;16:50-6.
18. de Camargo VM, Alburquerque-Sendin F, Berzin F, Stefanelli VC, de Souza DP, Fernandez-de-las-Penas C. Immediate effects on electromyographic activity and pressure pain thresholds after a cervical manipulation in mechanical neck pain: a randomized controlled trial. J Manipulative Physiol Ther 2011;34:211-20.
19. Martinez-Segura R, Fernandez-de-las-Penas C, Ruiz-Saez M, Lopez-Jimenez C, Rodriguez-Blanco C. Immediate effects on neck pain and active range of motion after a single cervical high-velocity low-amplitude manipulation in subjects presenting with mechanical neck pain: a randomized controlled trial. J Manipulative Physiol Ther 2006;29:511-7.
20. Mansilla-Ferragut P, Fernandez-de-Las Penas C, Alburquerque-Sendin F, Cleland JA, Bosca-Gandia JJ. Immediate effects of atlanto-occipital joint manipulation on active mouth opening and pressure pain sensitivity in women with mechanical neck pain. J Manipulative Physiol Ther 2009;32:101-6.
21. Puentedura EJ, Landers MR, Cleland JA, Mintken PE, Huijbregts P, Fernandez-de-Las-Penas C. Thoracic spine thrust manipulation versus cervical spine thrust manipulation in patients with acute neck pain: a randomized clinical trial. J Orthop Sports Phys Ther 2011;41:208-20.
22. Wood TG, Colloca CJ, Matthews R. A pilot randomized clinical trial on the relative effect of instrumental (MFMA) versus manual (HVLA) manipulation in the treatment of cervical spine dysfunction. J Manipulative Physiol Ther 2001;24:260-71.
23. Vernon H, Jansz G, Goldsmith CH, McDermaid C. A randomized, placebo-controlled clinical trial of chiropractic and medical prophylactic treatment of adults with tension-type headache: results from a stopped trial. J Manipulative Physiol Ther 2009;32:344-51.
24. Saayman L, Hay C, Abrahamse H. Chiropractic manipulative therapy and low-level laser therapy in the management of cervical facet dysfunction: a randomized controlled study. J Manipulative Physiol Ther 2011;34:153-63.
25. Palmgren PJ, Sandstrom PJ, Lundqvist FJ, Heikkila H. Improvement after chiropractic care in cervicocephalic kinesthetic sensibility and subjective pain intensity in patients with nontraumatic chronic neck pain. J Manipulative Physiol Ther 2006;29:100-6.
26. Murphy B, Taylor HH, Marshall P. The effect of spinal manipulation on the efficacy of a rehabilitation protocol for patients with chronic neck pain: a pilot study. J Manipulative Physiol Ther 2010;33:168-77.
27. Martel J, Dugas C, Dubois JD, Descarreaux M. A randomised controlled trial of preventive spinal manipulation with and without a home exercise program for patients with chronic neck pain. BMC Musculoskelet Disord 2011;12:41.
28. Leaver AM, Refshauge KM, Maher CG *et al*. Efficacy of manipulation for non-specific neck pain of recent onset: design of a randomised controlled trial. BMC Musculoskelet Disord 2007;8:18.
29. Hurwitz EL, Morgenstern H, Vassilaki M, Chiang LM. Frequency and clinical predictors of adverse reactions to chiropractic care in the UCLA neck pain study. Spine (Phila Pa 1976) 2005;30:1477-84.
30. Hurwitz EL, Morgenstern H, Vassilaki M, Chiang LM. Adverse reactions to chiropractic treatment and their effects on satisfaction and clinical outcomes among patients enrolled in the UCLA Neck Pain Study. J Manipulative Physiol Ther 2004;27:16-25.
31. Hurwitz EL, Morgenstern H, Harber P, Kominski GF, Yu F, Adams AH. A randomized trial of chiropractic manipulation and mobilization for patients with neck pain: clinical outcomes from the UCLA neck-pain study. Am J Public Health 2002;92:1634-41.
32. Hawk C, Pfefer MT, Strunk R, Ramcharan M, Uhl N. Feasibility study of short-term effects of chiropractic manipulation on older adults with impaired balance. J Chiropr Med 2007;6:121-31.
33. Harrison DE, Harrison DD, Betz JJ *et al*. Increasing the cervical lordosis with chiropractic biophysics seated combined extension-compression and transverse load cervical traction with cervical manipulation: nonrandomized clinical control trial. J Manipulative Physiol Ther 2003;26:139-51.
34. Haas M, Spegman A, Peterson D, Aickin M, Vavrek D. Dose response and efficacy of spinal manipulation for chronic cervicogenic headache: a pilot randomized controlled trial. Spine J 2010;10:117-28.
35. Haas M, Groupp E, Aickin M *et al*. Dose response for chiropractic care of chronic cervicogenic headache and associated neck pain: a randomized pilot study. J Manipulative Physiol Ther 2004;27:547-53.
36. Haas M, Aickin M, Vavrek D. A preliminary path analysis of expectancy and patient-provider encounter in an open-label randomized controlled trial of spinal manipulation for cervicogenic headache. J Manipulative Physiol Ther 2010;33:5-13.
37. Gemmell H, Miller P. Relative effectiveness and adverse effects of cervical manipulation, mobilisation and the activator instrument in patients with sub-acute non-specific neck pain: results from a stopped randomised trial. Chiropr Osteopat 2010;18:20.
38. Evans R, Bronfort G, Nelson B, Goldsmith CH. Two-year follow-up of a randomized clinical trial of spinal manipulation and two types of exercise for patients with chronic neck pain. Spine (Phila Pa 1976) 2002;27:2383-9.
39. Evans R, Bronfort G, Bittell S, Anderson AV. A pilot study for a randomized clinical trial assessing chiropractic care, medical care, and self-care education for acute and subacute neck pain patients. J Manipulative Physiol Ther 2003;26:403-11.
40. Bronfort G, Evans R, Nelson B, Aker PD, Goldsmith CH, Vernon H. A randomized clinical trial of exercise and spinal manipulation for patients with chronic neck pain. Spine (Phila Pa 1976) 2001;26:788-97; discussion 798-789.
41. Boyles RE, Walker MJ, Young BA, Strunce J, Wainner RS. The addition of cervical thrust manipulations to a manual physical therapy approach in patients treated for mechanical neck pain: a secondary analysis. J Orthop Sports Phys Ther 2010;40:133-40.
42. Heikkila H, Johansson M, Wenngren BI. Effects of acupuncture, cervical manipulation and NSAID therapy on dizziness and impaired head repositioning of suspected cervical origin: a pilot study. Man Ther 2000;5:151-7.
43. Tuchin PJ, Pollard H, Bonello R. A randomized controlled trial of chiropractic spinal manipulative therapy for migraine. J Manipulative Physiol Ther 2000;23:91-5.
44. Borusiak P, Biedermann H, Bosserhoff S, Opp J. Lack of efficacy of manual therapy in children and adolescents with suspected cervicogenic headache: results of a prospective, randomized, placebo-controlled, and blinded trial. Headache 2010;50:224-30.
45. van Schalkwyk R, Parkin-Smith GF. A clinical trial investigating the possible effect of the supine cervical rotatory manipulation and the supine lateral break manipulation in the treatment of mechanical neck pain: a pilot study. J Manipulative Physiol Ther 2000;23:324-31.
46. Haavik-Taylor H, Murphy B. Cervical spine manipulation alters sensorimotor integration: a somatosensory evoked potential study. Clin Neurophysiol 2007;118:391-402.
47. Haas M, Groupp E, Panzer D, Partna L, Lumsden S, Aickin M. Efficacy of cervical endplay assessment as an indicator for spinal manipulation. Spine (Phila Pa 1976) 2003;28:1091-6; discussion 1096.

48. Moodley M, Brantingham JW. The relative effectiveness of spinal manipulation and ultrasound in mechanical pain: Pilot study. J Chiropr Med 2002;1:184-8.

49. Whittingham W, Nilsson N. Active range of motion in the cervical spine increases after spinal manipulation (toggle recoil). J Manipulative Physiol Ther 2001;24:552-5.

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 December 6, 2012 - Accepted for publication on March 19, 2013.

ORIGINAL ARTICLE

Selective activation of muscle sub-portions within the *vastus medialis*: effect of gender, knee angle and force level

A. GALLINA, M. GAZZONI

Laboratory for Engineering of the Neuromuscular System, Department of Electronics and Telecommunications, Politecnico di Torino, Turin, Italy

ABSTRACT

Aim. It is currently unknown whether preferential activation of the distal portion of the vastus medialis can be obtained by performing isometric knee extension exercises at selected knee angles and force levels. The aim of this study was to assess whether preferential activation of muscle sub-portions within the vastus medialis occurs at different knee angles or force levels, and if this depends on gender.

Methods. Nine male and nine female healthy subjects performed isometric knee extensions for all combinations of knee angles (15°, 45° and 90°, 0° meaning full extension) and force levels (20%, 60% and 100% of the maximal voluntary contraction). Electromyographic activity was collected from the Vastus Medialis by using a grid of 16x8 electrodes covering the whole muscle. The electromyographic activity of proximal and distal sub-portions was identified and the effect of gender, knee angle and force level on the amplitude of each cluster was tested with a repeated measures analysis of variance.

Results. The relative activity, calculated as the ratio between the amplitude values of distal and proximal clusters, was 1.2±0.18 (mean±SD) with no influence of force (P=0.74), angle (P=0.11) or gender (P=0.08).

Conclusion. No consistent trends for preferential recruitment of sub-portions within the vastus medialis muscle as a function of knee angle, force level or gender were observed. The results of this study suggest that no specific knee angles or force levels can be routinely recommended for the preferential recruitment of the distal portion of the vastus medialis during isometric exercises. *(it j physiotherapy 2013;3:20-9)*

Key words: Quadriceps muscle - Electromyography - Exercise therapy.

Anterior knee pain is a common musculoskeletal disorder [1] that is mainly characterized by knee pain during functional activities. Despite large efforts of the scientific community in investigating this multi-factorial syndrome, there is still limited convincing evidence on its aetiology. One of the main hypothesis is patellar maltracking, which is thought to play a major role in the development and maintenance of patellofemoral pain.[2] Among the others, one of the mechanisms that contributes to patellar stabilization and that is commonly targeted in physiotherapy practice is the dysfunction of the quadriceps muscle.[3]

Quadriceps muscle has four heads: *rectus femoris*, *vastus medialis*, *vastus lateralis*, *vastus intermedius*. Each head has its own fiber orientation [4] and line of action.[5] Along with producing knee extension, quadriceps heads act on the patellar motion, causing tilt, shift, and rotation.[6] Changes in fiber orientation can be also observed moving from distal to proximal position within each quadriceps head, especially in the case of vastus medialis (VM) muscle.[4, 7] Besides the changes in fiber orientation within the muscle, other factors suggest that the VM muscle should not be considered as a whole, but made of muscle sub-portions: proximal and distal muscle portion can be distinguished on the basis of different lines of force,[6] intramuscular pattern of innervation,[8] different motor points,[7, 9] different responses to fatiguing contraction,[10] and different fiber composition.[11] It was recently stated that no clear conclusions about the existence of VM muscle compartmentalization can be drawn on the basis of anatomical evidences;[12] however, differences in the activation of muscle sub-portions have not been yet analyzed.

Surface electromyographic (EMG) signals are commonly acquired to assess muscle activation. Recent advances in this technique allow to place more than a hundred electrodes on the skin, over a single muscle;[13, 14] the analysis of the amplitude distribution of the EMG signals collected with this technology can provide information about the position of active motor units.[15, 16] As muscles can exert force in different directions by means of a selective recruitment of motor units,[17] and motor units with similar biomechanical actions are spatially localized in discrete portions of the muscle,[15] it is possible to distinguish groups of motor units with similar biomechanical actions on the basis of the 2D representation of surface EMG signals.[18, 19]

It is currently unknown whether VM sub-portions can be preferentially activated when performing isometric knee extension exercises at different knee angles and force levels; this information might be useful for physiotherapists in the prescription of therapeutic exercises for patients with knee musculoskeletal pathologies. Therefore, the purpose of this study was to investigate the activation of each sub-portion of the VM in relation to force, angle and gender.

Materials and methods

Eighteen healthy subjects (nine men, nine women; age: mean 26 years old (SD 4), height: mean 175 (SD 8) cm, weight mean 67 (SD 9) kg) participated in the experiment. All the subjects were pain-free at the time of the experiment and reported no known knee pathologies or injuries. The subjects provided a written informed consent before beginning the experimental session and the study was approved by the local ethical committee.

Before beginning the experiment, the subjects performed a short warm up (up to five minutes, self-conducted). During the experimental protocol the subjects were comfortably sitting, with their dominant leg fixed in a torque brace; all the contractions were performed with the trunk in an erect position and the upper limbs crossed on the chest. The experimental protocol consisted of unilateral isometric contractions of the knee extensor muscles. Contractions were performed for all combinations of three knee angles (90°, 45°, 15° considering 0° as full extension) and three force levels (100%, 60% and 20% of the maximal voluntary contraction measured at each knee angle) in pseudo-random order. For each knee angle (selected in random order) two MVC contractions were performed and the one with the highest torque value was selected; then 20% and 60% MVC contractions were performed in random order. The two sub-maximal contractions were ten second long, whereas MVC lasted no more than five seconds. One minute rest was observed between consecutive contractions.

Both surface EMG and torque data were collected during the protocol. Torque data were collected using two torque-meters (full scale 200 Nm each) aligned with the knee joint rotation axis, one on each side, and a force amplifier (MISOII, LISiN, Turin). Force feedback was given to the subjects using a led bar. Surface EMG was collected using an adhesive matrix of 128 electrodes (8 columns by 16 rows, interelectrode distance 10 mm, circular electrodes 4 mm in diameter, LISiN). The skin of the subjects was shaved and cleaned with abrasive paste; then the electrode grid was positioned using anatomical landmarks as reference (Figure 1). The most lateral column of the electrode grid was positioned 10 mm medially to the line linking the center of the patella with the antero-superior iliac spine; the distal row was positioned 10 mm above the upper portion of the patella (manually identified at 90° of knee joint flexion). The surface EMG was acquired in monopolar mode and amplified with a 10-750 Hz bandwidth amplifier (EMG-

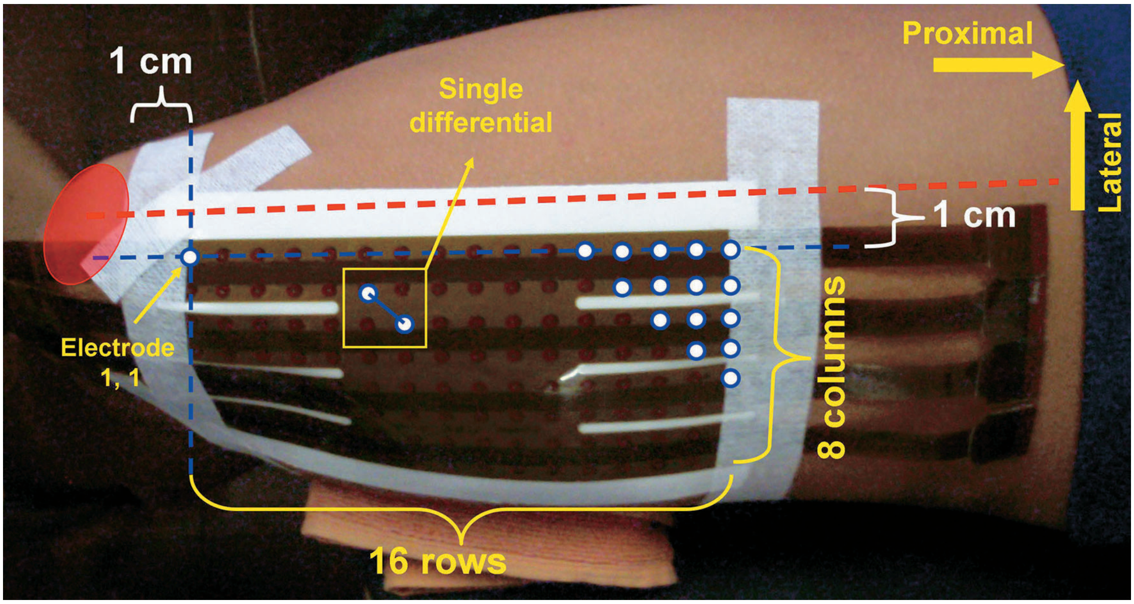

Figure 1.—Example of the positioning of the electrode grid to detect EMG signals from the VM muscle. The grid (16 rows by 8 columns of electrodes) was positioned with respect to anatomical references: the most lateral column of electrodes was placed 1 cm medially to the line linking the anterior superior iliac spine with the center of the patella (red dashed line) and the most distal row of electrodes was placed 1 cm proximally to the apex of the patella. The position of some electrodes is highlighted with blue circles in the proximal-lateral part of the grid. The EMG signals have been acquired in monopolar modality and the single differential signals have been computed along the matrix diagonal direction to approximate the fiber direction (an example of a couple of electrodes used for the computation of a single differential signal is shown).

USB amplifier, LISiN and OTBioelettronica, Turin). Both surface EMG and torque were digitized at 2048 samples/s using a 12-bit A/D converter (±2.5V dynamic range), and EMG signals were band-pass filtered (20-400 Hz). Eight channels (medial column, proximal channels) were devoted to collect the torque signals using two auxiliary inputs.

The acquired signals were visually inspected off-line to identify channels affected by electrode-skin contact problems; fewer than 5% of the channels were identified as bad channels. Single differential channels were calculated from monopolar recordings. As the main direction of muscle fibers was approximately 45° inclined with respect to the columns of the matrix, the single differential spatial filter was calculated along the diagonal (interelectode distance: 14 mm) as follows:

$$SD_{r,c}=M_{r,c} - M_{r+1,c+1}$$

where $SD_{r,c}$ is the diagonal single differential signal for row r ($r \in [1\ 7]$) and column c ($c \in [1\ 15]$), $M_{r,c}$ is the monopolar signal detected by the electrode in row r and column c (Figure 1). Examples of diagonal differential raw signals is shown in Figure 2. For each contraction, one epoch of the EMG signal was analyzed: in the case of MVC, the epoch corresponding to the two seconds centered on the torque peak was selected. In the sub-maximal contractions, the epoch corresponding to three seconds of signal (5-8th second) was selected. Root Mean Square value (RMS) of each SD channel was calculated on the epoch, resulting in one matrix of 15x7 RMS values for each of the nine conditions (i.e, three angle and three force levels). RMS values for bad channels identified by visual analysis were replaced with the mean of the four neighboring ones.

The EMG activity of the proximal and distal sub-portions of the VM was estimated as follows: first of all, two groups of channels representing the activity of distal (cluster one) and proximal (cluster two) sub-portions were identified (Figure 3A) on the basis of muscle architecture [7, 12] and electrode position described in literature.[10]

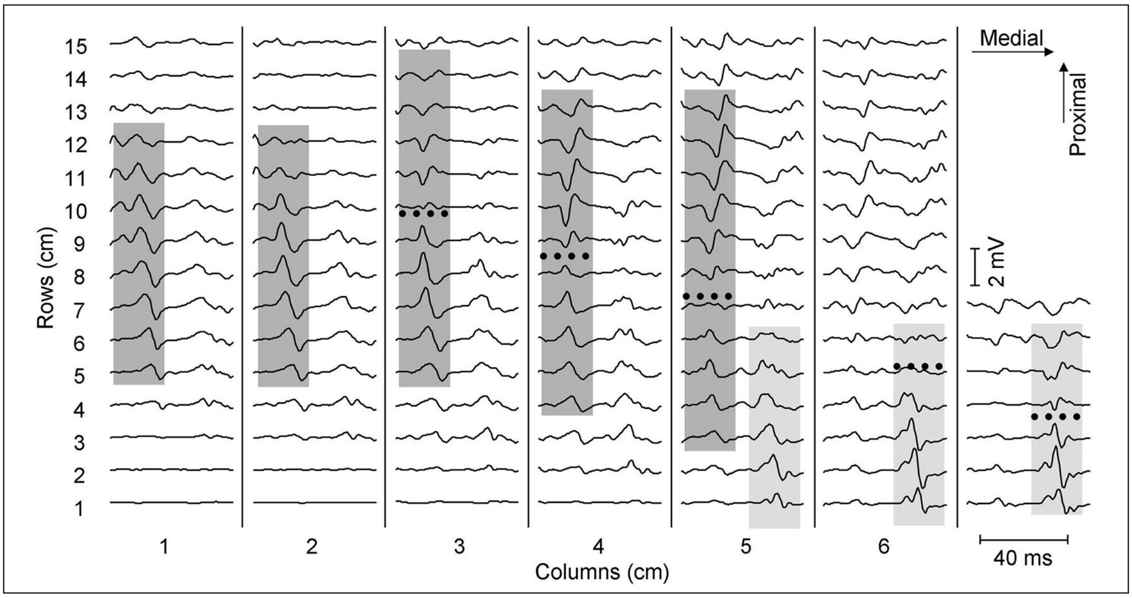

Figure 2.—Example of diagonal single differential EMG signals (Subject 9). The patella is positioned distally and laterally to the matrix. The innervation zones can be identified in most columns (dotted lines). Two motor unit action potentials are highlighted with different grey rectangles. The first action potential can be clearly seen in the columns 1, 2, 3, 4 and 5 in the time interval 0-20 ms; the second potential, instead, is better represented in the distal portion of the columns 7, 6 and 5.

The criteria according to which this process was done are described further in detail in the discussion session. Afterwards, within each cluster, the channels with amplitude higher than a threshold (70% of the maximum value in the cluster, validated in Vieira *et al.*)[20] were considered (fig. 3B). If channels localized proximally to the innervation zone (manually identified in each column as the channel showing phase inversion, Figure 2) were selected as relevant, these channels were removed from the analysis (Figure 3C). The activity level of each sub-portion was estimated by averaging the RMS values of the relevant channels. Finally, in order to analyze changes in the relative activity of the two muscle sub-portions, the ratio between the two amplitude values (cluster one divided by cluster two) was computed. Examples of the channel selection and of the ratio values of three representative subjects are shown in Figure 4.

Statistical analysis

Statistical analysis was performed using the software Statistica 6. The Shapiro-Wilk test was used to check the normality of the distribution; when the Shapiro-Wilk test resulted in a non-normal distribution, the statistical tests were performed on the rank transformed data. A repeated measures analysis of variance (ANOVA) was performed, testing the effects of gender, angle and force on the mean amplitude value of both clusters and on their ratio on separate tests. Tukey test was used for post-hoc comparisons. Statistical significance threshold was set at $P=0.05$.

Results

Results of the repeated measures ANOVA are summarized in Table I, whereas graphical representations of the data tested is provided in Figure 5.

A main effect of the force level on the amplitude of the EMG signal was present in both cluster one ($P<0.001$, $F=427.92$) and cluster two ($P<0.001$, $F=451.03$). Tukey post-hoc test revealed that EMG amplitude at each force level was significantly different from the others ($P<0.001$). A main effect of the angle of knee flexion on the amplitude of the EMG signal was present in both cluster one ($P<0.001$, $F=24.60$) and cluster two ($P<0.001$, $F=32.38$). Tukey

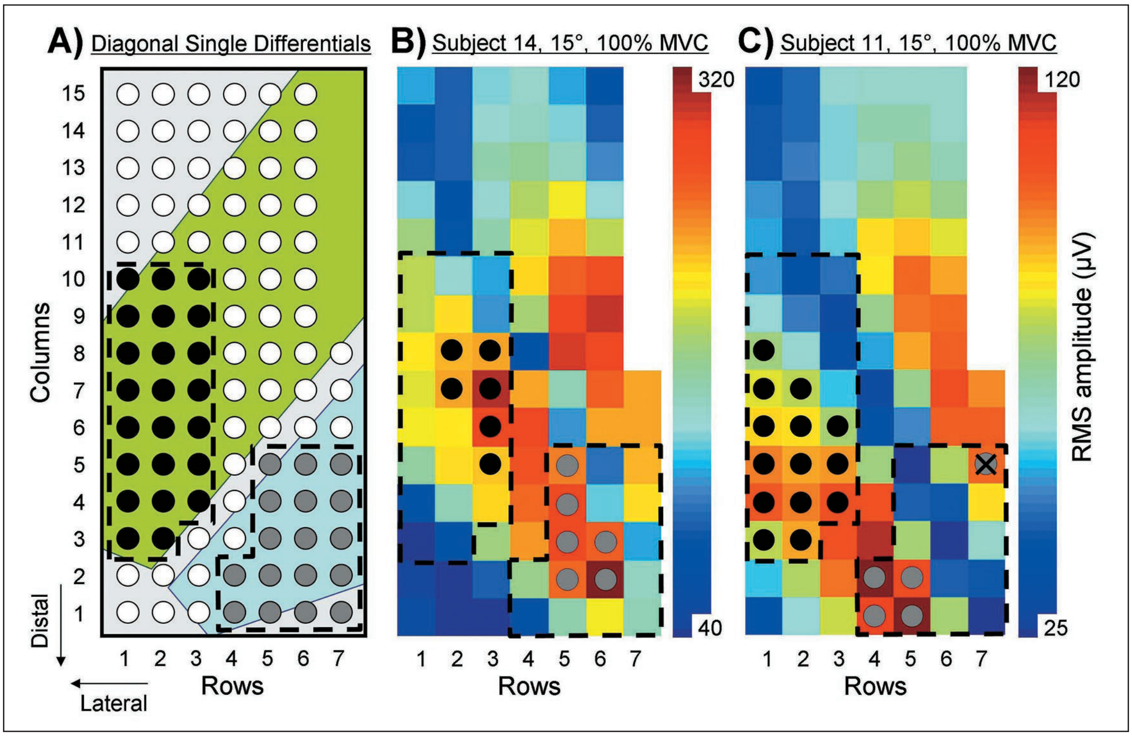

Figure 3.—Identification of VM muscle sub-portions. A) Position of the diagonal single differential channels on the grid; blue and green areas identify the indicative position and the orientation of the distal and proximal portions of the VM muscle respectively. Black dashed rectangles group the electrodes channels used to evaluate the activation level of the two muscle sub-portions (distal VM is cluster one, proximal VM is cluster two); these two areas were chosen in order to consider the channels positioned between the muscle innervation zone (see in B and C the low-amplitude channels that start from the distal, medial corner and run diagonally through the matrix) and the muscle insertion on the patellar tendon (low-amplitude electrodes in the distal-lateral corner of the matrix). Black circles are located above the proximal VM, grey ones on the distal VM. B) Example of a segmented amplitude RMS map. Within each area, the channels whose amplitude was higher than 70% of the maximal value were selected. C) Example of a segmented amplitude RMS map. When channels proximal to the innervation zone were selected (crossed circle), they were removed from the analysis.

post-hoc test revealed that EMG collected in the flexed position was significantly higher ($P<0.001$ in both clusters) than in the extended and mid-flexed positions; instead, no significant differences were observed between the extended and mid-flexed positions ($P=0.19$ in cluster one, $P=0.18$ in cluster two). A significant interaction of force and angle was present ($P<0.001$ in both clusters, $F=7.65$ in the first cluster and $F=9.92$ in the second one). Gender did not influence the amplitude of the EMG signals (cluster one: $P=0.09$, $F=3.20$; cluster two: $P=0.34$, $F=0.98$). No significant interactions of gender and angle ($P=0.51$ in cluster one, $P=0.43$ in cluster two), or gender and force ($P=0.52$ in cluster one, $P=0.52$ in cluster two) were detected.

The average value of the ratio was 1.20 ± 0.18 (mean±SD), with values higher than 1 meaning greater EMG amplitude in the distal cluster. The ratio of the amplitude value of the two clusters was not affected either by the knee angle ($P=0.11$, $F=2.39$) or the force level ($P=0.74$, $F=0.30$). The gender had no significant effect on the ratio ($P=0.08$, $F=3.54$). The interactions never reached statistical significance (angle and gender: $P=0.83$, $F=0.19$; force and gender: $P=0.94$, $F=0.06$; combination of the three factors: $P=0.35$, $F=1.12$).

Discussion

This study investigated whether, during isometric contractions at different angles and force levels, the VM muscle is homogeneously active

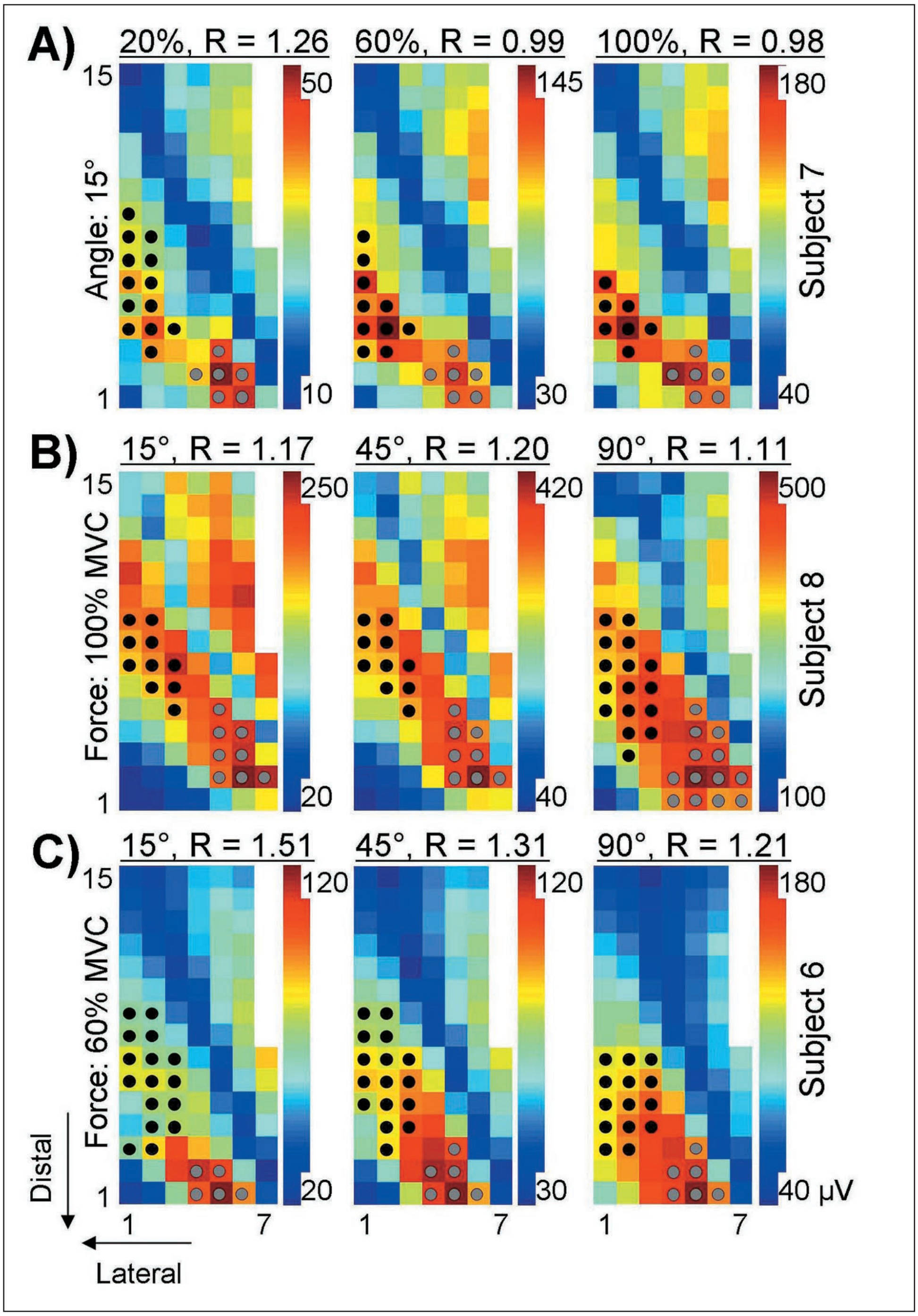

Figure 4.—Examples of changes of the distal/proximal VM EMG amplitude ratio in three representative subjects. A) Effects of force increase. Two peaks, positioned within the areas chosen as representative for the two muscle sub-portions, can be identified in each map. The ratio value (R, reported on top of each map) decreases as the force exerted increases, approaching the value 1 at the highest force levels; this means that at 20% MVC the amplitude value recorded from the distal portion of the muscle is higher than that of the proximal VM, whereas the two amplitude values are more similar at 60% and 100% MVC. B) Effect of knee angle. Few differences among the amplitude distributions can be observed. C) Effect of knee angle. In this subject, a preferential localization of EMG activity in the distal portion of the VM can be observed at 20% (R=1.51). At more flexed knee positions, the EMG amplitude collected by the channels on the proximal portion of the VM increases; this lowers the ratio to 1.31 and 1.21.

Table I.—*Results of the repeated measures ANOVA: effects of gender, angle and force on the EMG amplitude of both clusters and their ratio.*

	Cluster one		Cluster two		Ratio one/two	
	P	F	P	F	P	F
Angle	<0.01*	24.60	<0.01*	32.38	0.11	2.38
Force	<0.01*	427.92	<0.01*	451.03	0.74	0.30
Gender	0.09	3.20	0.34	0.98	0.08	3.54
Angle X Force	<0.01*	7.65	<0.01*	9.92	0.58	0.70
Angle X Gender	0.51	0.59	0.43	0.8	0.83	0.19
Force X Gender	0.52	0.63	0.52	0.7	0.94	0.06

*P<0.01
†P<0.05

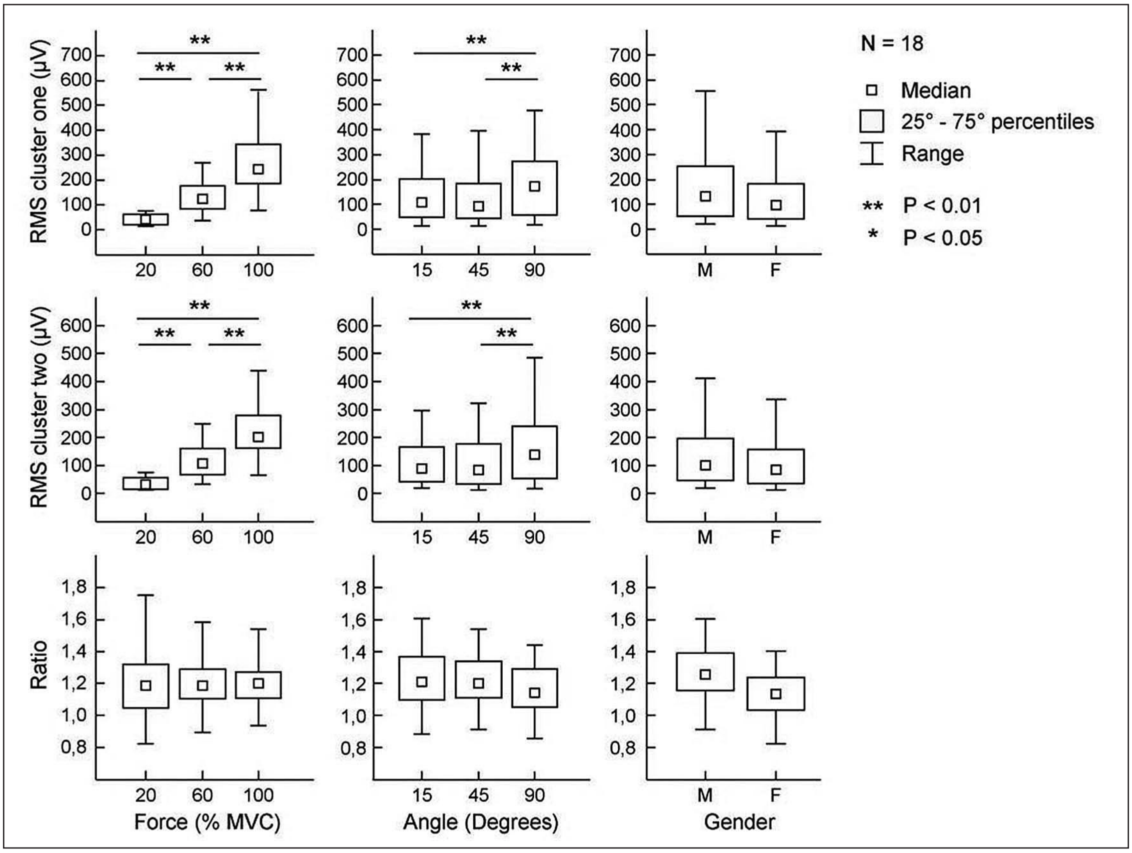

Figure 5.—Comparison of the EMG amplitude of the first and second cluster and their ratio (rows) as a function of force level, angle and gender (columns). Median values, percentiles and non-outlier intervals are represented for each condition. Statistical results of the ANOVA test (on ranks, repeated measures on 18 subjects) are shown.

or not. When different knee joint angles and force levels were tested, no common trends in terms of preferential activation of either sub-portion were evidenced. No effect of the gender on the relative activity of the two muscle sub-portions was present, even if the test approached the statistical significance. These issues are discussed further in detail hereafter.

The number and the position of the channels considered as representative of the activity of the two VM sub-portions were selected on the basis of the following factors: 1) the position of the electrode grid with respect to position and orientation of VM fibers;[7, 12] 2) the intramuscular pattern of innervation;[8] 3) the uniformity with the placement of the EMG detection system suggested by other studies.[10] In addition, in order to limit the effects of the anatomical factors on the EMG amplitude, only the area of the grid corresponding to the muscle fibers comprised between the innervation zone and the distal tendon was considered; indeed, the EMG amplitude along the muscle fiber direction is known to be mainly influenced by anatomical features of the muscle, whereas the EMG amplitude transversally to the fiber direction is affected by the spatial organization of the active motor units.[16] The portion of the muscle distal to the innervation zone was preferred, as it might be less affected by crosstalk from other muscles such as rectus femoris and sartorius, and it might present a lower thickness of the interposed tissues than the proximal area of the tight. The selection of subsets of high-amplitude channels within these areas defined on the basis of anatomical information might minimize differences in the position of high-activity areas due to inter-subject variability and shifts of the muscle as a function of knee angle. Our choice in the definition of these areas is further supported by the fact that other authors found within-muscle differences in EMG activity by placing electrodes in similar positions: Hedayatpour et al.[21] analyzed the surface EMG distribution of the whole quadriceps using a number of couples of electrodes, and reported site-specific differences in amplitude distribution after eccentric exercise until exhaustion; differences in myoelectric manifestations of fatigue and muscle activation were also pointed out by Rainoldi *et al.*,[10] comparing proximal and distal portions of the muscle.

In our experiment, both the amount of force produced and knee joint angle were shown to influence the EMG activity of both muscle sub-portions in a similar way. The relation between EMG amplitude and force is well known in the literature. Concerning the knee joint angle effect on the EMG amplitude, we found that VM EMG was higher at 90° flexion than at 45° and 15°, but no differences were found between the mid-flexed and the extended position. Our results are consistent with others reported in the literature: VM EMG activity was proven to be dependent on muscle length,[22] with increasing values approaching 90° flexion; these results also confirm findings of another group,[23] whereas others found no significant effects of the knee angle.[24] No relative changes in the EMG activity between the two muscle sub-portions due to force level or knee angle were disclosed. A possible, speculative interpretation might be the following: as the two portions of the VM have different biomechanical actions due to different orientation of the muscle fibers,[5, 6] the two muscle sub-portions work in synergy in healthy subjects, as one produces mainly extension force whereas the other contributes more significantly to patellar tracking.[5, 6] However, it is important to consider that a lack of statistical significance does not mean that the EMG spatial distribution did not vary among conditions, but rather that these variations were not consistent among subjects; in fact, clear differences among conditions can be observed if the subjects are considered individually (Figure 4).

No significant effects of gender on the EMG activity of either cluster could be identified. Previously, other groups observed no gender differences in the EMG activity of the whole VM during both isometric [25] and dynamic contractions.[26, 27] Furthermore, no significant effects of gender on the ratio between the amplitude of the two clusters were proven. However, a trend toward statistical significance ($P<0.1$) for the influence of gender is present in both the amplitude ratio and the amplitude of the distal cluster, with females showing a lower EMG activity in the distal portion. Absolute EMG amplitude could be affected by anatomical factors, such as the thickness of the subcutaneous tissue and the fiber orientation, rather than by different neuromuscular activations. No data about subcutaneous thickness were collected in this study; however, it is reasonable to assume a comparable subcutaneous thickness in the two clusters, and the estimation of amplitude ratio performs a sort of normalization reducing the effect of possible differences in the subcutaneous thickness among subjects. For what concerns fiber orientation, a recent review by Smith *et al.*[12] showed that no gender differences exist in fiber orientation in either compartment of the VM; furthermore, amplitude estimation was proven to be little affected by the misalignment of the electrode array with respect to muscle fiber orientation in another muscle with fibers parallel to the skin.[28] On the basis of this evidence, the trend toward an influence of gender on the EMG distribution in the VM muscle might be related to motor unit recruitment strategies rather than anatomical factors. The differences in EMG amplitude might suggest a less efficient patellar stabilization mechanism in females, possibly playing a role in their higher predisposition to knee disorders.[29] However, our tests did not reach statistical significance: experiments on a larger population should be done in the future to clarify this issue. Furthermore, as large inter-subject variability in patellar motion was observed in healthy subjects,[5, 6] it might be worthy testing whether specific distribution of EMG within the VM match with specific patellar kinematic patterns.

As quadriceps muscle dysfunction is common in patients with knee musculoskeletal disorders, exercises targeting knee extensors are widely used by physiotherapists in the treatment of these pathologies.[3] Several strategies such as preferring open or closed kinetic chain exercise,[30] changing the lower limb orientation and adding co-contractions of other muscles [31] are often used in clinical practice in attempt to modify the relative contribution of the quadriceps heads to the overall force production. Previous research showed that the relative activation of the heads of the quadriceps depends on both the knee angle[22] and the level of force exerted.[32, 33] Despite some subjects showing a muscle activity prevalently localized in the distal portion of the VM during low force contractions (20% MVC, fig. 4A) or at extended knee positions (15°, Figure 4C), our results suggest that these knee angle and force level did not consistently influence the relative activation of proximal/distal VM. For this reason, exercises targeted at restoring muscle imbalances within the VM do not necessarily have to comply to any indication regarding these factors.

Conclusions

To our knowledge, this is the first study investigating the effects of knee joint angle, force level and gender on the activation of VM muscle sub-portions by using surface electromyography. The EMG amplitude of the VM was dependent on both force level and knee angle, with no changes in the relative activation between the sub-portions. A trend toward an influence of the gender on the relative activity of the two clusters was highlighted, possibly due to a lower activity of the VM muscle in females; however, these results did not reach statistical significance and further research is necessary. It is concluded that, during isometric knee extensions, changes of knee angle or force level do not result in variations of the EMG spatial distribution consistent among subjects.

References

1. Wood L, Muller S, Peat G. The epidemiology of patellofemoral disorders in adulthood: a review of routine general practice morbidity recording. Prim Health Care Res Dev 2011;12:157-64.
2. Powers C, Bolgla L, Callaghan M, Collins N, Sheehan FT. Patellofemoral Pain: Proximal, Distal, and local Factors. J Orthop Sports Phys Ther 2012;42:A1-A20.
3. Fagan V, Delahunt E. Patellofemoral pain syndrome: a review on the associated neuromuscular deficits and current treatment options. Br J Sports Med 2008;42:789-95.
4. Blazevich AJ, Gill ND, Zhou S. Intra- and intermuscular variation in human quadriceps femoris architecture assessed in vivo. J Anat 2006:209:298-310.
5. Wilson NA, Sheehan FT. Dynamic in vivo quadriceps lines-of-action. J Biomech 2012;43:2106-13.
6. Lin F, Wang G, Koh JL, Hendrix RW, Zhang L. In vivo and noninvasive three-dimensional patellar tracking induced by individual heads of quadriceps. Med Sci Sports Exerc 2004;36:93-101.
7. Lefebvre R, Leroux A, Pouramat G, Galtier B, Guillot M, Vanneuville G *et al.* Vastus medialis: anatomical and functional considerations and implications based upon human and cadaveric studies. J Manipulative Physiol Ther 2006;29:139-44.
8. Thiranagama R. Nerve supply of the human vastus medialis muscle. J Anat 1990;170:193-8.
9. Botter A, Oprandi G, Lanfranco F, Allasia S, Maffiuletti NA, Minetto MA. Atlas of the muscle motor points for the lower limb: recommendations for optimal placement of electrical stimulation electrodes. Eur J Appl Physiol 2011;111:2461-71.
10. Rainoldi A, Falla D, Mellor R, Bennel K, Hodges P. Myoelectric manifestations of muscle fatigue in vastus lateralis, medialis obliquus and medialis longus muscles. J Electromyogr Kinesiol 2008;18:1032-37.
11. Travnik L, Pernus F, Erzen I. Histochemical and morphometric characteristics of the normal human vastus medialis longus and vastus medialis obliquus muscles. J Anat 1995;187:403-11.

12. Smith TO, Nichols R, Harle D, Donell ST. Do the vastus medialis obliquus and vastus medialis longus really exist? A systematic review. Clin Anat 2009;22:183-99.
13. Merletti R, Aventaggiato M, Botter A, Holobar A, Marateb HR, Vieira TMM. Advances in surface EMG: recent progress in detection and processing techniques. Crit Rev Biomed Eng 2010;38:305-45.
14. Merletti R, Botter A, Cescon C, Minetto MA, Vieira TMM. Advances in surface EMG: recent progress in clinical research applications. Crit Rev Biomed Eng 2010;38:347-79.
15. Zhou P, Suresh NL, Rymer WZ. Surface electromyogram analysis of the direction of isometric torque generation by the first dorsal interosseous muscle. J Neural Eng 2011;8:036028.
16. Gallina A, Merletti R, Gazzoni M. Uneven spatial distribution of surface EMG: what does it mean? Eur J Appl Physiol 2012 [Epub ahead of print].
17. Desmedt JE, Godaux E. Spinal Motoneuron Recruitment in man: rank deordering with direction but not with speed of voluntary movement. Science 1981;214:933-5.
18. Staudenmann D, Kingma I, Daffertshofer A, Stegeman DF, van Dieen JH. Heterogeneity of muscle activation in relation to force direction: a multichannel surface electromyography study on the triceps surae muscle. J Electromyogr Kinesiol 2009;19:882-95.
19. Watanabe K, Kouzaki M, Moritani T. Task-dependent spatial distribution of neural activation pattern in human rectus femoris muscle. J Electromyogr Kinesiol 2012;22:251-8.
20. Vieira TMM, Merletti R, Mesin L. Automatic segmentation of surface EMG images: Improving the estimation of neuromuscular activity. J Biomech 2010;43:2149-58.
21. Hedayatpour N, Falla D, Arendt-Nielsen L, Farina D. Sensory and Electromyographic mapping during delayed-onset muscle soreness. Med Sci Sports Exerc 2008;40:326-34.
22. Pincivero D, Salfetnikov Y, Campy RM, Coelho AJ. Angle- and gender- specific quadriceps femoris muscle recruitment and knee extension torque. J Biomech 2004;37:1689-97.
23. Brownstein BA, Lamb RL, Mangine RE. Quadriceps torque and integrated electromyography. J Orthop Sports Phys Ther 1985;6:309-14.
24. Zabik RM, Dawson ML. Comparison of force and peak EMG during a maximal voluntary isometric contraction at selected angles in the range of motion for knee extension. Perceptual Motor Skills 1996;83:976-8.
25. Pincivero DM, Green RC, Mark JD, Campy RM. Gender and muscle differences in EMG amplitude and median frequency, and variability during maximal voluntary contractions of the quadriceps femoris. J Electromyogr Kinesiol 2000;10:189-96.
26. Cramer JT, Housh TJ, Weir JP, Johnson GO, Berning JM, Perry SR *et al.* Mechanomyographic and electromyographic amplitude and frequency responses from the superficial quadriceps femoris muscles during maximal, eccentric isokinetic muscle actions. Electromyogr Clin Neurophysiol 2002;42:337-46.
27. Carneiro JG, Gonçalves EM, Camata TV, Altimari JM, Machado MV, Batista AR *et al.* Influence of gender on the EMG signal of the quadriceps femoris muscles and performance in high-intensity short-term exercise. Electromyogr Clin Neurophysiol 2010;50:326-32.
28. Cescon C, Rebecchi P, Merletti R. Effect of electrode array position and subcutaneous tissue thickness on conduction velocity estimation in upper trapezius muscle. J Electromyogr Kinesiol 2008;18:628-36.
29. Boling M, Padua D, Marshall S, Guskiewiccz K, Pyne S, Beutler A. Gender differences in the incidence and prevalence of patellofemoral pain syndrome. Scand J Med Sci Sports 2010;20:725-30.
30. Spairani L, Barbero M, Cescon C, Combi F, Gemelli T, Giovanetti G *et al.* An electromyographic study of the vastii muscles during open and closed kinetic chain submaximal isometric exercises. Int J Sport Phys Ther 2012;7:617-26.
31. Smith TO, Bowyer D, Dixon J, Stephenson R, Chester R, Donell ST. Can vastus medialis be preferentially activated? A systematic review of electromyographic studies. Physiother Theory Pract 2009;25:69-98.
32. Pincivero DM and Coelho AJ. Activation linearity and parallelism of the superficial quadriceps across the isometric intensity spectrum. Muscle Nerve 2000;23:393-8.
33. Herrington L, Pearson S. Does the level of load affect relative activation levels of vastus medials obliquus and lateralis? J Electromyogr Kinesiol 16:379-83.

Acknowledgements.—The authors are sincerely grateful to prof. Roberto Merletti for the useful discussion on data processing and for the revision of the draft, and to Gratiela Deak for her help in the experimental measures. This work was funded by Fondazione Cassa di Risparmio di Torino and Compagnia di San Paolo.

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 February 15, 2013. Accepted for publication on March 20, 2013.

Corresponding auhtor: A. Gallina, Via Cavalli 22/H, Turin, Italy. E-mail: alessio.gallina@delen.polito.it

ORIGINAL ARTICLE

Activation of fixation muscles in keeping the raised lower limb position in subjects of different ages

A. TETTAMANTI, T. NIZZOLA, M. LOCATELLI, F. ZEGNA, R. GATTI

Laboratory of Analysis and Rehabilitation of Motor Function, Vita-Salute San Raffaele University, Milan, Italy

ABSTRACT

Aim. The elevation of the lower limb in the supine position entails the simultaneous activation of hip flexor muscles as the agonist, and the controlateral hamstrings and abdominals as the fixation muscles to avoid anterior rotation of the pelvis. This study compares the activation pattern of the muscles with a role of body segment fixation in older and young subjects.

Methods. Forty-two healthy subjects were divided into three groups depending on age: 18-35 years; 36-64 years; over 65 years. Subjects were asked to keep their right lower limb elevated at 45° in supine position. The test position was reached: 1) by raising the right lower limb and 2) by putting the left lower limb down on the bed after both legs had been raised.

Results. Surface electromyographic activations (sEMG) of right rectus femoris (RF), left biceps femoris (BF) and two rectus abdominis (RA) were recorded. International Physical Activity Questionnaire (IPAQ) scores were also collected. A similar sEMG pattern of fixation muscles (BF, rightRA, leftRA, $P<0.0001$) and level of physical activity (IPAQ $P=0.288$) were detected among the groups.

Conclusion. Older adults with levels of physical activity similar to young subjects do not seem to have differences in fixation patterns, compared to younger adults. *(it j physiotherapy 2013;3:30-6)*

Key words: Aging - Electromyography - Posture - Muscles.

The execution of voluntary movements activates muscles with both agonist and postural roles and all skeletal muscles can be involved in these two tasks.[1] Activation of postural muscles is necessary to contrast the body mechanical perturbations produced by movement. Postural muscles have two functions: to fix the position of the segments that serve as a reference frame for actions and to manage the body center of mass by anticipatory postural adjustments (APAs) during self-induced displacements.[2]

The fixation of body segments is achieved by isometric contractions to avoid moving one of the two bones on which the agonist muscles are inserted. For example, the elevation of the lower limb in the supine position entails the simultaneous activation of the hip flexor muscles as agonist and the hamstrings of the opposite side and abdominal muscles to avoid anterior rotation of the pelvis.[3]

It is worth noting that the patterns involved in activating the fixation muscles that maintain the elevation of the extended right lower limb are different in healthy young people, depending on how this position is obtained. If the position is reached by raising the right lower limb from the supine position, there is high activation of the left biceps femoris and low activation of the abdominal muscles. When the same position is reached by putting the left lower limb down on the bed after both legs have been raised, there is increased activation of the abdominal muscles and a decreased activation of the left biceps femoris. By contrast, the muscular activation pattern does not change in people affected by multiple sclerosis, no matter how they reach the position.[4]

The clinical relevance of alterations of fixation muscles activation has been scarcely investigated in the literature. Some of the reported data has been related to postural activation of the trunk muscles during the perturbations induced by voluntary arm movements. For example, people affected by low back pain in comparison to healthy people show slower activation of the transversus abdominis when performing single rapid arm movements.[5] Mehta *et al.*[6] studied the activation of abdominal and trunk extensor muscles during a self-initiated perturbation that consisted of a rapid shoulder flexion in people with and without low back pain. People with low back pain showed a delayed onset of the trunk muscles activation and a shorter cocontraction, compared to healthy people.

Alterations of fixation mechanisms have been demonstrated in people affected by multiple sclerosis and back pain. It is difficult to speculate about the physiopathology of these alterations since the two cited clinical conditions are very different. The common component between people with multiple sclerosis and people with back pain could be a reduction of their motor skills. Therefore, it is reasonable to wonder whether a reduction of motor skills could provoke an alteration in the activation of fixation muscle. To answer to this question and considering that people show decreased motor ability with aging,[7-9] the aim of this study is to compare the activation pattern of fixation muscles in subjects of different ages.

Materials and methods

Study design and aim of the study

A quantitative research report design was used for this study. Its purpose was to compare in subjects with different ages the activation of fixation muscles in maintaining the raised lower limb position, which was accomplished by two different modalities.[4]

The study was performed in the Laboratory of analysis and rehabilitation of motor function of the Vita-Salute San Raffaele University (Milan, Italy). All study participants signed an informed consent form and the study was approved by the internal ethics committee of the San Raffaele Scientific Institute.

Subjects

Healthy subjects of different ages were enrolled in the study. The inclusion criteria were the ability to walk with or without a cane, the autonomy in daily living activities and the ability to dwell in a community. The exclusion criteria were orthopedic, neurological, respiratory, cardiovascular, or cognitive pathologies that could affect the execution of the test. The inclusion criteria were checked by two physiotherapists involved in the study and the exclusion criteria were certified by a physician. The study participants were enrolled among university students and their relatives.

The study participants were 42 healthy individuals ranging in age from 18 to 84 years; they were divided into three groups, depending on age and in accordance with described age classes.[10-14] Group 1 was composed of subjects with 18-35 years; group 2 of subjects with 36-64 years and group 3 of subjects with 65 years or older. In group 1 there were 15 participants (11 male and 4 female, mean age 22.2±3.3 years); 14 participants in group 2 (9 male and 5 female, mean age 47.8±8.4 years) and 13 participants in group 3 (8 male and 5 female, mean age 73.7±5.4 years).

Experimental design

The experimental procedure was composed of two consecutive parts: 1) the acquisition of the surface electromyographic activity (sEMG) during the test positions [15] and 2) the administration of the International Physical Activity Questionnaire (IPAQ).[16, 17] To be better informed about the participants' functional status, they were asked to report about episodes of falling in the previous year.

Before executing the tests, the maximal sEMG activity for the following muscles in each individual was recorded: right rectus femoris, longhead of left biceps femoris, bilateral rectus

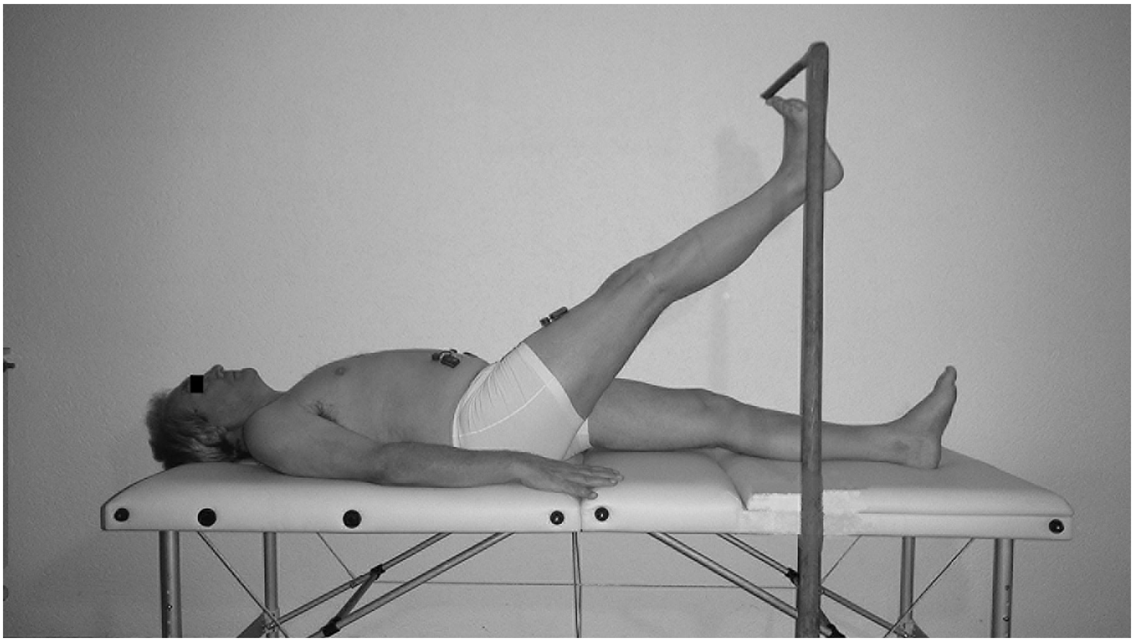

Figure 1.—Test position: the subject is lying in supine position, the right lower limb is raised of 45° over the horizontal plane with the knee extended.

abdominis. To assess fixation muscle activation a test already described in the scientific literature was used.[4] Subjects were asked to keep their right lower limb elevated at 45° in supine position for 5 seconds (Figure 1). A target height was set for each subject to make sure that the angle between the elevated limb and the horizontal plane was 45°. The angle was measured by a goniometer before the acquisition. The test position was reached in two different ways: 1) by raising the right lower limb from the supine position up to a fixed target (*i.e.*, exercise A) and 2) by returning the left lower limb down on the bed after both legs had been raised to the set target (*i.e.*, exercise B). Both movements were performed at spontaneous speed and one of the authors demonstrated the movement to the study participants before the acquisition. Each subject performed one trial for each exercise after a pause of 60 seconds. The order of execution of the exercises was randomized by using a computer-generated list created and managed by an author. Even numbers were assigned to exercise A and odd numbers to exercise B. The self-administered IPAQ questionnaire was administrated to the subjects to assess their level of physical activity at the end of the sEMG acquisition.

Data acquisition and management

The electromyographic signal was recorded by using 15-mm diameter bipolar surface electrodes and a 30-mm inter-electrode distance. The subjects' skin was treated with abrasive paste before applying the electrodes. The signal was preamplified 1000 times and sent by telemetry (telemg; BTS) to a device for further amplification (gain=5) and for storage on a personal computer. The sample frequency was 1000 Hz. The sEMG of the following muscles was acquired: the right rectus femoris, the longhead of the left biceps femoris and the bilateral rectus abdominis. The muscles chosen for analysis were based on a study by Gatti *et al.*[4] The electrodes were positioned according to the following criteria:[18]

— rectus femoris. The electrodes were placed in the middle of the line connecting the anterior superior iliac spine to the superior edge of the patella;

— long head of the biceps femoris. The electrodes were placed in the middle of the line connecting the ischiatic tuberosity and the lateral epicondyle of tibia;

— rectus abdominis. The electrodes were placed about 3 cm beside the umbilicus, along the course of the muscular fibers.

In order to normalize the sEMG activity, each subject was asked to perform 5 seconds of maximal isometric voluntary contraction of the acquired muscles in the following positions:

— rectus femoris. The subjects were asked to perform a hip flexion with the knee extended in supine position; the operator blocked the movement by applying resistance to the distal part of the thigh;

— biceps femoris. The subjects performed a knee flexion in the prone position with a 30° knee flexion; the operator blocked the movement by applying resistance to the ankle;

— rectus abdominis. The subjects were asked to flex the trunk in the supine position while the operator blocked the movement by applying resistance to the subjects' shoulders.

The sEMG signal was filtered by a 10-500 Hz filter, rectified and integrated with a time constant of 30 milliseconds. The sEMG intensity during the tests was computed as the mean amplitude value of the interval between the first and the fourth second of the elevated lower limb position. sEMG signal was analyzed using the Myolab software.

In the self-reported IPAQ questionnaire, subjects reported the weekly frequency and duration of: moderate and/or vigorous activities, walking, and hours spent in a sitting position. The level of physical activity was converted into a score, indicating the metabolic equivalent of task energy expenditure estimated by using the specific algorithms.[16, 17]

Statistical analysis

The Kolmogorov-Smirnov test has been used for verifying data distribution. sEMG data were expressed as a percentage of the maximal isometric voluntary contraction. Activation of the same muscles in the two exercises were compared within the same group and compared between groups by an analysis of variance (ANOVA) for repeated measure. A post-hoc Bonferroni analysis was conducted when necessary. A one-way ANOVA was used to compare IPAQ scores between groups. Significance was fixed at $P<0.05$. Statistical analyses were conducted by using SPSS 13.0 software.

Results

None of the subjects used a cane or reported any episodes of falling in the previous year. Most data showed a normal distribution. All participants correctly performed the test. Table I shows the percentage of the maximal sEMG

Table I.—*The mean (standard deviation) of the surface electromyographic activation, expressed as a percentage of the maximal surface electromyographic activity during the exercises A and B in subjects of the three groups. The activation of the rectus femoris is similar, whereas the activation of the postural muscles changes in the two exercises.*

	Rectus femoris		Biceps femoris		Right rectus abdominis		Left rectus abdominis	
	ex A	ex B	ex A	Ex B	ex A	ex B	ex A	ex B
Group 1 18-35 years	20.40 (10.59)	20.15 (10.09)	17.30 (8.48)	10.65 (9.32)	6.86 (3.64)	14.24 (5.47)	5.91 (5.80)	16.76 (15.32)
Group 2 36-64 years	28.24 (22.02)	29.19 (23.63)	17.84 (7.17)	9.09 (7.86)	8.32 (4.92)	17.45 (8.72)	6.94 (3.26)	16.24 (8.01)
Group 3 ≥ 65 years	34.83 (14.65)	38.27 (17.81)	26.31 (12.10)	16.73 (12.06)	7.46 (3.28)	17.72 (7.06)	7.23 (2.43)	15.44 (5.16)
Within group	F1.39=3.53 P=0.068		F1.39=66.12 P<0.0001*		F1.39=86.40 P<0.0001*		F1.39=55.16 P<0.0001*	
Between groups	F2.39=3.21 P=0.051		F2.39=3.36 P=0.045*		F2.39 = 0.97 P=0.388		F2.39=0.006 P=0.994	
Interaction tests x groups	F2.39=2.15 P=0.130		F2.39=0.74 P=0.485		F2.39 = 0.77 P=0.472		F2.39=0.37 P=0.696	

Abbreviations: ex A, exercise A; ex B, exercise B; *P<0.05.

TABLE II.—*Mean (standard deviation) of IPAQ scores in the study participants in the three groups.*

	IPAQ score
Group 1 18-35 years	4403.6 (2761.74)
Group 2 36-64 years	3172.0 (2908.6)
Group 3 ≥65 years	2938.4 (2100.9)
P	0.288

activation of each muscle in the two positions in the three groups. The within-group ANOVA analysis showed a different sEMG activation of fixation muscles between exercises A and B in all three groups, whereas activation of the rectus femoris (RF) did not change between the two exercises. In particular, exercise B in comparison to exercise A had a pattern of decreased activation of the biceps femoris (BF) and increased activation of the two rectus abdominis (RA) (BF, $P<0.0001$; rightRA, $P<0.0001$; leftRA, $P<0.0001$; RF, $P=0.068$). The ANOVA between groups showed a significant difference only in BF activation ($P=0.045$). Nevertheless the post-hoc analysis did not demonstrate any significant difference between the groups. The interaction test per group never reached statistical significance. As Table II shows, no significant difference was found when comparing the IPAQ score among the three groups ($P=0.288$).

Discussion

The elevation movement of one lower limb from the supine position requires the postural activation of the biceps femoris and the abdominal muscles (which determines pelvic retroversion), whereas the hip flexor muscles of the raised limb induce pelvic anteversion.[3] When the elevation of the right lower limb at 45° is reached by raising the right lower limb (exercise A), an important activation of the biceps femoris and mild activation of the abdominal muscles have been previously described. By contrast, increased activation of the abdominal muscles (which are already active because of the elevation of both lower limbs) and reduced activity of the biceps femoris are recorded when the position is reached by putting the left lower limb down on the bed after both legs have been raised (exercise B).

Our data showed similar postural behavior in all studied subjects, regardless of their age. The comparison between groups showed a significant difference in BF activation. This data could be explained by the difficulty of older subjects to lie in prone position and, consequently, to exert the BF MVC or by the fact that the lower limb muscles of older adults have reduced mass [19] so they need greater muscle activity to counteract the anterior rotation of the pelvis. However, aim of the study was to compare muscular activation in the two exercises to see if older adults have the same activation patterns of fixation muscles as young adults more than to compare the muscular activations between groups.

Older adults recruited in this study had physical activity levels similar to young adults, as documented by the fact that there is no difference between groups in the IPAQ score. This condition has probably been determined by the characteristics of the study participants' enrollment. Selection bias could be determined by the requirement that study participants must be able get to the laboratory. This influenced the selection to subjects who were able to walk, to drive, or, at least, to take taxi, bus or subway to reach the laboratory, which is situated in the town suburbs. For this reason it is not possible to ensure that similar results would be recorded in sedentary older adults.

Activation of fixation muscles in older adults has never been studied; however, it could be speculated that the presented data could seem to contrast with data in the literature about alterations in the anticipatory postural adjustments (APAs) in older subjects.[10, 20] Even though APAs and activation of fixation muscles have different mechanical objectives, they are both postural mechanisms.[2] A possible explanation of the difference between the unimpaired fixation mechanism and the impaired APAs could be caused by the poor engagement of the locomotors system in the studied position. In fact, to maintain the right lower limb raised from the supine position the balance control is unnecessary, the joints are not stressed because an inertial moment is not applied to the body segments and great body masses are not moved. Since older adults are often affected by osteoporosis [21] and osteoarthritis, it is reasonable to speculate that a sort of muscular inhibition could affect the motor tasks most engaged.[22]

Limitations of the study

A limitation of the study method could be the cross-talk phenomena affecting the surface EMG signals. Even if it is not possible to exclude this bias, the study tried to reduce crosstalk by using small (15-mm diameter) electrodes placed close to each other (30 mm apart). Moreover, the large size of the studied stabilizing muscles decreases the possibility of the crosstalk phenomena. By contrast, considering the record of the rectus femoris sEMG, it is much more difficult to exclude crosstalk with the other bellies of the quadriceps or with the lateral wall of the abdominal muscles. However this possibility may not affect the results concerning the stabilization muscle patterns.

In this study, older adults fixation mechanism ability has been proved only by achieving a position in two different ways. To generalize the results, it may be interesting to study different situations in which more fixation mechanisms could be tested.

Conclusions

The experimental question of this work was whether a reduction of motor skills provokes an alteration in the activation of muscle fixation. To answer this question, subjects of different ages have been studied. It could be speculated from our results that old age is not connected with impaired fixation muscles activation. In a group of older adults without disease and who lead an active life, the activation patterns of muscles involved with a fixation role resulted in data comparable to those obtained from younger subjects.

Assuming that motor abilities decrease with the passing of time,[23-25] impaired activation of muscles when they have a fixation role does not seem to be related to a decrease in motor skills.

References

1. Baldissera F, Rota V, Esposti R. Postural adjustments in arm and leg muscles associated with isodirectional and antidirectional coupling of upper limb movement in the horizontal plane. Exp Brain Res 2008;190:289-305.
2. Massion J. Postural control system. Curr Opin Neurobiol 1994;4:877-87.
3. Gatti R, Corti M, Cervi P, Pulici L, Boccardi S. Biomechanics of lower limb raising from the supine position. Eura Medicophys 2006;42:185-93.
4. Gatti R, Corti M, Govetto S, Bonzani K, Boccardi S. Electromyographic activity to keep a lower limb in a raised position in healthy subjects and subjects with multiple sclerosis. Mult Scler 2008;14:691-3.
5. Tsao H, Galea MP, Hodges PW. Reorganization of the motor cortex is associated with postural control deficits in recurrent low back pain. Brain 2008;131:2161-71.
6. Mehta R, Cannella M, Smith SS, Silfies SP. Altered trunk motor planning in patients with nonspecific low back pain. J Mot Behav 2010;42:135-44.
7. Schimpl M, Moore C, Lederer C, Neuhaus A, Sambrook J, Danesh J *et al.* Association between walking speed and age in healthy, free-living individuals using mobile accelerometry—a cross-sectional study. PLoS One 2011;6:e23299.
8. Najdi A, El Achhab Y, Nejjari C, Norat T, Zidouh A, El Rhazi K. Correlates of physical activity in Morocco. Prev Med 2011;52:355-7.
9. Legh-Jones H, Moore S. Network social capital, social participation, and physical inactivity in an urban adult population. Soc Sci Med 2012;74:1362-7.
10. Uemura K, Yamada M, Nagai K, Ichihashi N. Older adults at high risk of falling need more time for anticipatory postural adjustment in the precrossing phase of obstacle negotiation. J Gerontol A Biol Sci Med Sci 2011;66:904-9.
11. Stehr MD, von Lengerke T. Preventing weight gain through exercise and physical activity in the elderly: A systematic review. Maturitas 2012;72:13-22.
12. Kappagoda T, Amsterdam EA. Exercise and heart failure in the elderly. Heart Fail Rev 2012;17:635-62.
13. Gokee-LaRose J, Gorin AA, Raynor HA, Laska MN, Jeffery RW, Levy RL *et al.* Are standard behavioral weight loss programs effective for young adults? Int J Obes (Lond) 2009;33:1374-80.
14. Loras H, Sigmundsson H. Interrelations between three fine motor skills in young adults. Percept Mot Skills 2012;115:171-8.
15. Soderberg GL, Knutson LM. A guide for use and interpretation of kinesiologic data. Phys Ther 2000;80:485-98.
16. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE *et al.* International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35:1381-95.
17. Tomioka K, Iwamoto J, Saeki K, Okamoto N. Reliability and Validity of the International Physical Activity Questionnaire (IPAQ) in Elderly Adults: The Fujiwara-kyo Study. J Epidemiol 2011;21:459-65.
18. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol 2000;10:361-74.
19. Masanes F, Culla A, Navarro-Gonzalez M, Navarro-Lopez M, Sacanella E, Torres B *et al.* Prevalence of sarcopenia in healthy community-dwelling elderly in an urban area of Barcelona (Spain). J Nutr Health Aging. 2012;16:184-7.
20. Bleuse S, Cassim F, Blatt JL, Labyt E, Derambure P, Guieu JD *et al.* Effect of age on anticipatory postural adjustments in unilateral arm movement. Gait Posture 2006;24:203-10.
21. Garriguet D. Bone health: osteoporosis, calcium and vitamin D. Health Rep 2011;22:7-14.

22. Siéssere S, Sousa LG, Lima Nde A, Semprini M, Vasconcelos PB, Watanabe PC *et al.* Electromyographic activity of masticatory muscles in women with osteoporosis. Braz Dent J 2009;20:237-342.
23. Gorniak SL, Zatsiorsky VM, Latash ML. Manipulation of a fragile object by elderly individuals. Exp Brain Res 2011;212:505-16.
24. Pereira C, Baptista F. Variation of the different attributes that support the physical function in community-dwelling older adults. J Sports Med Phys Fitness 2012;52:190-7.
25. Raw RK, Kountouriotis GK, Mon-Williams M, Wilkie RM. Movement control in older adults: does old age mean middle of the road? J Exp Psychol Hum Percept Perform 2012;38:735-45.

Corresponding author: M. Locatelli, Laboratory of Analysis and Rehabilitation of Motor Function, Vita-Salute San Raffaele University, via Olgettina 58, 20132 Milan, Italy. E-mail: matteolocatelli@email.it