APPENDIX A

The demographic and general information questionnaires, informed consent and standard incremental treadmill test data collection forms

ISSD·ISWO
Institute for Sport Science and Development
Instituut vir Sportwetenskap en -ontwikkeling

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

General information, informed consent and heart rate and graded maximal test values protocol to determine rugby game intensities.

GENERAL INFORMATION

Please write clearly!

1. GEOGRAPHICAL INFORMATION

1.1 Surname: **Initials** **First Name**

1.2 Age:

Years:	Months:

1.3 Birth date:

Year:	Month:	Day:

1.4 Job description (cross out the one that is applicable):

Student	Part-time employment	*Full-time employment	*Major sponsorship

** Please specify if you marked any of these two options:*

1.5 Permanent residential address in South Africa:

____
____
____
____
____
____

1.6 Permanent postal address in South Africa:

____
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____
____
____

1.7 Phone numbers:

Home:	Work:
Fax:	Cell:
E-mail:	

1.8 Ethnic group

White	Coloured	Black	Indian

In the next few question cross out the answers that are applicable to you!!

2. INFORMATION REGARDING TRAINING HABITS

2.1 Years you've been playing rugby - since you started to specialise in rugby.

1-2 years	3-4 years	5-6 years	7-8 years	8-9 years	10-11 years	12 or more

2.2 Frequency of training - how many days per week do you normally train?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.3 Frequency of training - how many days per week do you normally do weight training?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.4 Frequency of training - how many days per week do you normally have field sessions?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.5 How many hours per day do you normally train?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.6 How many hours per day do you normally spend on weight training?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.7 How many hours per day do you normally spend on training on the field?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.8 Do you spend any time on psychological preparation for rugby and competitions?

Never	*Sometimes	*Often	*Always

*** Please specify the type of psychological preparation you do if you marked any of these three options:**

____
____
____
____
____
____
____
____

3. MEDICAL INFORMATION

3.1 Please describe any past or current musculoskeletal conditions you have incurred (i.e., muscle pulls, sprains, fractures, surgery, back pain, or any general discomfort):

Head/Neck:

____
____
____
____
____

Shoulder/Clavicle:

____
____
____
____
____
____

Arm/Elbow/Wrist/Hand:

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____
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____
____

Back:

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____
____
____
____

Hip/Pelvis:

____
____
____
____
____

Thigh/Knee:

____
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____
____
____

Lower leg/Ankle/Foot:

____
____
____
____

3.2 Please list any medication being taken currently and/or taken during the last year:

3.3 List any other illness or disorder that a physician has told you of:

4. COMPETITION DATA

4.1 At what level are you competing this year?

4.2 What is the highest level that you competed at last year?

Club	Provincial	National	International

4.3 How many matches, approximately, have you played?

Club =	Provincial/National =

4.4 What were the highest achievements you attained the past two years?

Achievement	Competition	Date

4.5 What are your most important competitions this year and when will it take place?

No. of importance	Competition	Date
1		
2		

3		
4		

4.6 What position/s do you usually play during matches?

1.
2.
3.

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CONFIDENTIAL

Informed consent form

PART 1

1. **School/Institute:**

   School for Biokinetics, Recreation and Sport Science and The Institute for Sport Science and Development.

2. **Title of project/trial:**

   The use of heart rate and graded maximal test values to determine rugby game intensities.

3. **Full names, surname and qualifications of project leader:**

   Ben Coetzee, B.Sc., B.Sc. (Hons), M.Sc. and Ph.D

4. **Rank/position of supervisor:**

   (Professor, Lecturer, research scientist etc.)

   Senior Lecturer

5. **Full names, surname and qualifications of supervisor of the project:**

   (Complete only if not the same person named in 4.)

   Same as above.

6. **Name and address of supervising medical officer *(if applicable)*:**

   Not applicable

7. Aim of this project

The aim of this study is:

- To determine the intensities of tertiary institution rugby games when making use of heart rates and graded maximal test values.
- To determine the positional differences in tertiary institution rugby game intensities when making use of heart rates and graded maximal test values.

8. Explanation of the nature of all procedures, including identification of new procedures:

a) ***Collection procedures and selection of rugby players.***

The test subjects will consist of players from the first and second rugby teams of the North-West University. In order for the players to be included in the study, they must spend at least 80% of the game on the field. Any players that do not adhere to this criteria, will be excluded in the study. Thus 22 players will be monitored for the duration of the game.

b) ***Procedures***

I. Demographic and general information questionnaire

A demographic and general information questionnaire will be used to collect the players' demographic and personal information (age & ethnicity). The players' exercise habits, injury occurrence and competing levels will also be obtained by means of this questionnaire. The VO_2 data will be collected through a test battery.

II. Standard incremental maximal oxygen uptake test (SIMOUT):

A standard incremental maximal oxygen uptake (VO_{2max}) test (SIMOUT) will be conducted by means of open-circuit spirometry. Each of the players will perform the SIMOUT to the point of exhaustion on a Woodway Pro XL treadmill (WOODAY, W229 N591, Foster Ct, Waukesha, WI). At commencement of the SIMOUT the first 2 minutes will be performed at 8 km/h after which the treadmill speed will be increased to 10 km/h and by 1 km/h every minute after the first two minutes. Expired air will continuously be sampled by an Oxycon Pro static ergospirometry system (Jaeger Oxycon Pro, Viasys, 22745, Savi ranch parkway, Yorba Linda, CA, USA) and the rate of oxygen consumption (VO_2), carbon dioxide production (VCO_2), minute ventilation (Ve) and the respiratory exchange ratio (R) will be calculated every 5 seconds by an on-line computer system. The Oxycon Pro will be calibrated according to the manufacturer's specifications at the beginning of each test day. The test will be stopped if the rugby player indicates that it must be stopped or if the criteria for reaching the VO_{2max} value is achieved (McArdle *et al.*, 2001:33).

Ventilatory threshold point (VTP) and respiratory compensation point (RCP)

Two physiological gas exchange points will be identified. The VTP will be determined using the criteria of and increase in Ve/VO_2 with no increase in Ve/VCO_2 and departure from the linearity of Ve (Chicharro *et al.,* 2000:452). The RCP will be taken as the point which corresponds to an increase in both Ve/VO_2 and Ve/VCO_2 (Chicharro *et al.,* 2000:452). VTP and RCP will be visually detected by two independent experienced observers. Throughout the test, heart rate will be recorded for each 5 sec period by means of a Fix Polar T61 Heart Rate Transmitter Belt (Polar electro OY, Kempele, Finland).

The different gas exchange phases will be used to determine the heart rates that correspond to the three exercise intensities (Chicharro *et al.,* 2000:451). Heart rates that correspond to the exercise intensities below VT will be classified as low intensity heart rates; heart rates that correspond to the exercise intensities between VT and RCP will be classified as moderate intensity heart rates and heart rates that correspond to the exercise intensities above RCP will be classified as high intensity heart rates.

III. <u>Rugby game heart rates:</u>

The heart rate of each player will be recorded at 5 second intervals during three matches using the Hosand TM Pro telemetry heart rate monitoring system (HOSAND technologies Srl, Verbania, Italy). Recordings will be made for the matches of the first and second team of the North-West University respectively. An electrode belt will be strapped around the chest at the lower sternum of each player before the start of each match. The heart rate signal will be downloaded to a PC during each of the matches.

IV. <u>Test protocol</u>

The players will undergo two days of testing. A SIMOUT will be performed on day one which will fall in the week between match 1 and 2. The 3rd match will take place approximately a month later. Another SIMOUT will be performed three days before match 3 takes place.

9. Description of the nature of discomfort or hazards of probable permanent consequences for the subjects which may be associated with the project:

(Including possible side-effects of and interactions between drugs or radio-active isotopes which may be used.)

The subjects may sustain slight muscle injuries, experience a bit of muscle discomfort and nausea.

10. Precautions taken to protect the subjects:

The players will perform a proper warm-up before the SIMOUT commences and the testing procedures and methods will be thoroughly explained to each of the players.

11. Description of the benefits which may be expected from this project:

The results might point to possible rugby game intensities, as well as game intensity differences between playing positions. This will also help coaches to plan their season correctly in order to optimize performance for their players.

12. Alternative procedures which may be beneficial to the subjects:

(Complete only if applicable.)

The physiological measurements will give the players and researcher an indication of the importance of different energy systems contributing to rugby games.

Signature:.. **Date:** 18/05/2009

Project leader

PART 2

To the subject signing the consent as in part 3 of this document:

You are invited to participate in a research project as described in paragraph 2 of Part 1 of this document. It is important that you read/listen to and understand the following general principles, which apply to all participants in our research project:

1. Participation in this project is voluntary.
2. It is possible that you personally will not derive any benefit from participation in this project, although the knowledge obtained from the results may be beneficial to other people.
3. You will be free to withdraw from the project at any stage without having to explain the reasons for your withdrawal. However, we would like to request that you would rather not withdraw without a thorough consideration of your decision, since it may have an effect on the statistical reliability of the results of the project.
4. The nature of the project, possible risk factors, factors which may cause discomfort, the expected benefits to the subjects and the known and the most probable, permanent consequences which may follow from your participation in this project, are discussed in Part 1 of this document.
5. We encourage you to ask questions at any stage about the project and procedures to the project leader or the personnel, who will readily give more information. They will discuss all procedures with you.
6. If you are a minor, we need the written approval of your parent or guardian before you may participate.
7. We require that you indemnify the University from any liability due to detrimental effects of treatment by University staff or students or other subjects to yourself or anybody else. We also require indemnity from liability of the University regarding any treatment to yourself or another person due to participation in this project, as explained in Part 1. Lastly it is required to abandon any claim against the University regarding treatment of yourself or another person due to participation in this project as described in Part 1.

PART 3

Consent

Title of the project: The use of heart rate and graded maximal test values to determine rugby game intensities.

I, the undersigned ……………………………………………………………… (Full names) read/listened to the information on the project in PART 1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project with the project leader and I declare that I participate in the project as a volunteer. I hereby give my consent to be a subject in this project.

I indemnify the University, also any employee or student of the University, of any liability against myself, which may arise during the course of the project.

I will not submit any claims against the University regarding personal detrimental effects due to the project, due to negligence by the University, its employees or students, or any other subjects.

(Signature of the subject)

Signed at .... on ………………………………………..

Witnesses

1. ....

2. ....

Signed at .... on ……………………………………

For non-therapeutic experimenting with subjects under the age of 18 years the written approval of a parent or guardian is required.

I, ………………………………………………………………………………………………… (Full names)
Parent or guardian of the subject named above, hereby give my permission that he/she may participate in this project and I also indemnify the University and any employee or student of the University, against any liability which may arise during the course of the project.

Signature: .... Date: ……………………………

Relationship: ………………….

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NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

VO_{2max} PROTOCOL

		M	F
NAME AND SURNAME			
AGE			
DATE BIRTH			

	TRIAL 1	**TRIAL 2**	**AVERAGE**
STATURE (cm)			
BODY MASS (kg)			

VO_{2max}

LEVEL	SPEED (KM/H)	HEART RATE
1	8-10	
2	10-11	
3	11-12	
4	12-13	
5	13-14	
6	14-15	
7	15-16	
8	16-17	
9	17-18	
10	18-19	
11	19-20	
12	20-21	
13	21-22	
14	22-23	
15	23-24	

APPENDIX B

Submission guidelines for authors and an example of a article: Journal of Strength and Conditioning Research

Manuscript Submission Guidelines

Authors should submit the original file in one of the following formats: Microsoft® Word® (.doc, .rtf, .txt), Corel® WordPerfect® (.wpd, .rtf, .txt), or Adobe® Acrobat® (.pdf).

You must submit the cover letter, copyright release, and manuscript separately to separate identifying information from the manuscript.

Manuscript must match JSCR formatting, including terminology use and units.

Please attempt to keep all figures and tables in a single file (instead of submitted as separate attachments). We prefer that each diagram be pasted into a PowerPoint presentation. Ensure all figures are labeled and referenced in the manuscript.

IRB approval must be mentioned.

If you use Microsoft Word, save in the .doc format.

Cover Letter: A cover letter must accompany the manuscript and state the following: "This manuscript is original and not previously published, nor is it being considered elsewhere until a decision is made as to its acceptability by the *JSCR* Editorial Review Board." Please include the corresponding author's full contact information, including address, email, and phone number.

Compliance with NIH and Other Research Funding Agency Accessibility Requirements: A number of research funding agencies now require or request authors to submit the post-print (the article after peer review and acceptance but not the final published article) to a repository that is accessible online by all without charge. As a service to our authors, LWW will identify to the National Library of Medicine (NLM) articles that require deposit and will transmit the post-print of an article based on research funded in whole or in part by the National Institutes of Health, Wellcome Trust, Howard Hughes Medical Institute, or other funding agencies to PubMed Central. The revised Copyright Transfer Agreement provides the mechanism.

Copyright Form: The National Strength and Conditioning Association must receive in writing the exclusive assignment of copyright from all authors at the time of manuscript submission. This form can be found at **http://journals.lww.com/nsca-jscr/Documents/copyrightTransfer.pdf**. If only one author signs the copyright assignment form, such author warrants that he/she is the duly authorized agent of all other co-authors. Your manuscript will not be published if a signed copyright release form is not returned. Please return your original signed copyright assignment form to the editorial office at the time you submit your manuscript. Please keep a copy for your records. Manuscripts are considered for publication on the condition that they are contributed solely to the *JSCR* and, therefore, have not been and will not be published elsewhere, in part or in whole. Manuscripts containing data that have been posted to the Internet for public access will not be considered for publication. Copyright forms can be faxed to 860-486-6898 or 860-486-1123.

IRB: The NSCA and the Editorial Board of the *JSCR* have endorsed the American College of Sports Medicine's policies with regards to animal and human experimentation. Their guidelines can be found online at **http://www.editorialmanager.com/msse/**. Please read these policies carefully. Each manuscript must show that they have had Institutional Board approval for their research and appropriate consent has been obtained pursuant to law. All manuscripts must have this clearly stated in the methods section of the paper or the manuscript will not be considered for publication.

Authorship: All authors should be aware of the publication and be able to defend the paper and its findings and should have signed off on the final version that is submitted. For additional details related to authorship, see "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" at **http://www.icmje.org/**.

Formatting and Units: All manuscripts must be double-spaced with an additional space between paragraphs on 8½ x11-inch paper. The paper should include a minimum of 1-inch margins and page numbers in the upper right corner next to the running head. Please use a font of at least 12. Authors must use terminology based upon the International System of Units (SI). A full list of SI units can be accessed online at **http://physics.nist.gov/**. Manuscript identification numbers (e.g., R-12034) will be assigned to each manuscript, and should be placed on all revised manuscripts and used along with the manuscript title for all communications with the Editorial Office. Any revision should have the revision number placed after the manuscript number, (e.g., R-12034, Revision 1).

Language Use: Again the *JSCR* endorses the same policies as the American College of Sports Medicine in that the language is English for the publication. "Authors who speak English as a second language are encouraged to seek the assistance of a colleague experienced in writing for English language journals. Authors are encouraged to use nonsexist language as defined in the American Psychologist 30:682-684, 1975, and to be sensitive to the semantic description of persons with chronic diseases and disabilities, as outlined in an editorial in *Medicine & Science in Sports & Exercise*®, 23(11), 1991. As a general rule, only standardized abbreviations and symbols should be used. If unfamiliar abbreviations are employed, they should be defined when they first appear in the text. Authors should follow Webster's Tenth Collegiate Dictionary for spelling, compounding, and division of words. Trademark names should be capitalized and the spelling verified. Chemical or generic names should precede the trade name or abbreviation of a drug the first time it is used in the text."

Manuscript Format Guidelines

1. Title Page

The title page should include the manuscript title, brief running head, laboratory(s) where the research was conducted, authors' full name(s) spelled out with middle initials, department(s), institution(s), full mailing address of corresponding author including telephone and fax numbers, and email address, and disclosure of funding received for this work from any of the following organizations: National Institutes of Health (NIH); Welcome Trust; Howard Hughes Medical Institute (HHMI); and other(s).

2. Blind Title Page

A second title page should be included that contains only the manuscript title. This will be used for reviewer copies.

3. ABSTRACT and Key Words

On a separate sheet of paper, the manuscript must have an abstract with a limit of 275 words followed by 3 – 6 key words not used in the title. The abstract should have sentences (no headings) related to the purpose of the study, brief methods, results, conclusions and practical applications. Do not end with statements such as "will be discussed."

4. Text

The text must contain the following sections with titles in ALL CAPS in this exact order:

A. INTRODUCTION

This section is a careful development of the hypotheses of the study leading to the purpose of the investigation. Limit information that is "chapter like" in nature as this is not an exhaustive review of the topic. Focus the studies lending support to your hypothesis(es) and giving the proper context to the problem being studied. In most cases use no subheadings in this section and try to limit it to 4 – 6 concisely written paragraphs.

B. METHODS

Within the METHODS section, the following subheadings are required in the following order: "Experimental Approach to the Problem," where the author(s) show how their study design will be able to test the hypotheses developed in the introduction and give some basic rationales for the choices made for the independent and dependent variables used in the study; "Subjects," where the authors include the Institutional Review Board or Ethics Committee approval of their project and appropriate informed consent has been gained. All subject characteristics that are not dependent variables of the study should be included in this section and not in the RESULTS; "Procedures," in this section the methods used are presented with the concept of "replication of the study" kept in mind. After reading this section another investigator should be able to replicate your study. Under this subheading you can add others but please limit their use to that which makes the methods clear and in order of the investigation (e.g., Biochemical Assays or EMG Analyses); "Statistical Analyses," here is where you clearly state your statistical approach to the analysis of the data set(s). It is important that you include your alpha level for significance (e.g., $P < 0.05$). Please place your statistical power in the manuscript for the n size used and reliability of the dependent measures with intra-class correlations (ICC Rs). Additional subheadings can be used but should be limited

C. RESULTS

Present the results of your study in this section. Put the most important findings in Figure or Table format and less important findings in the text. Do not include data that is not part of the experimental design or that has been published before. Place descriptive data about subjects in the METHODS section under the subheading of Subjects. Make sure that you cite each Figure and Table, and in space between paragraphs indicate roughly where you want each Figure or Table to appear (e.g., Table 1 about here)

D. DISCUSSION

Discuss the meaning of the results of your study in this section. Relate them to the literature that currently exists and make sure that you bring the paper to completion with each of your hypotheses. Limit obvious statements like, "more research is needed."

E. PRACTICAL APPLICATIONS

In this section, tell the "coach" or practitioner how your data can be applied and used. It is the distinctive characteristic of the *JSCR* and supports the mission of "Bridging the Gap" for the NSCA between the laboratory and the field practitioner. This section of the paper should speak directly to this audience and not to the exercise or sport scientist.

5. References

All references must be alphabetized by surname of first author and numbered. References are cited in the text by numbers [e.g., (4,9)]. All references listed must be cited in the manuscript and referred to by number therein. For original investigations, please limit the number of references to fewer than 40 or explain why more are necessary. The Editorial Office reserves the right to ask authors to reduce the number of references in the manuscript. Please check references carefully for accuracy.

Changes to references at the proof stage, especially changes affecting the numerical order in which they appear, will result in author revision fees. Below are several examples of references:

Journal Article
Hartung, GH, Blanco, RJ, Lally, DA, and Krock, LP. Estimation of aerobic capacity from submaximal cycle ergometry in women. *Med Sci Sports Exerc* 27: 452-457, 1995.

Book
Lohman, TG. Advances in Body Composition Assessment. Champaign, IL: Human Kinetics, 1992.

Chapter in an edited book
Yahara, ML. The shoulder. In: Clinical Orthopedic Physical Therapy. Richardson, JK and Iglarsh, ZA, eds. Philadelphia: Saunders, 1994. pp. 159-199. ***Software***
Howard, A. Moments [software]. University of Queensland, 1992.

Proceedings
Viru, A, Viru, M, Harris, R, Oopik, V, Nurmekivi, A, Medijainen, L, and Timpmann, S. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences. Tenenbaum, G and Raz-Liebermann, T, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22 - 30.

Dissertation/Thesis
Bartholmew, SA. Plyometric and vertical jump training. Master's thesis, University of North Carolina, Chapel Hill, 1985.

6. Acknowledgements

In this section you can place the information related to Identification of funding sources; Current contact information of corresponding author; and gratitude to other people involved with the conduct of the experiment. In this part of the paper the conflict of interest information must be included. Authors are required to state in the acknowledgments all funding sources, and the names of companies, manufacturers, or outside organizations providing technical or equipment support. In particular, authors should: 1) Disclose professional relationships with companies or manufacturers who will benefit from the results of the present study, and 2) State that the results of the present study do not constitute endorsement of the product by the authors or the NSCA. Failure to disclose such information could result in the rejection of the submitted manuscript.

7. Figures

First, create a page entitled "Figure Legends" in which each of the figure legends are listed. Include this page in your manuscript document. Next, place each of the figures in a PowerPoint presentation if possible. All figures should be labeled and each figure must be referenced in the manuscript. All figures should be professional in appearance. They should also be viable for size reductions to fit manuscript space allocations. One set of figures should accompany each manuscript. Use only clearly delineated symbols and bars.

Electronic photographs copied and pasted into Word and PowerPoint will not be accepted. Images should be scanned at a minimum of 300 pixels per inch (ppi). Line art should be scanned at 1200 ppi. Please indicate the file format of the graphics. We accept TIFF or EPS format for both Macintosh and PC platforms. We also accept image files in the following Native Application File Formats:

Adobe Photoshop (.psd)

Adobe Acrobat (.pdf) (use Press setting under Job Option)

Illustrator (.ai)

Macromedia FreeHand (.fh)

Corel Draw (.cdr)

Canvas (.cvs)

PowerPoint (.ppt)

Word (.doc)

Excel (.xls)

InDesign (.id)

PageMaker (.pmd)

QuarkXPress (.qxd)

If you will be using a digital camera to capture images for print production, you must use the highest resolution setting option with the least amount of compression. Digital camera manufacturers use many different terms and file formats when capturing high-resolution images, so please refer to your camera's manual for more information.

Please also attempt to format tables into the PowerPoint presentation and include a title. If necessary, tables can be added to the end of the manuscript, but must be double-spaced and include a brief title. Provide generous spacing within tables and use as few line rules as possible. When tables are necessary, the information should not duplicate data in the text. All figures and tables must include standard deviations or standard errors.

Color figures. The author may elect to cover the costs of color at the rate of $500 for the first figure within the article, $100 for each additional single-image figure within the same article, or $200 for each additional figure with more than one part (labeled "a," "b," etc.). If the author decides not to pay for color reproduction, they can request that the figures be converted to black and white at no charge.

Manuscript Format Checklist

Approval by Institutional Review Board

Manuscript contains the following sections (in order)

Title Page

Blind Title Page

Abstract and Key Words

Introduction

Methods

Results

Discussion

Practical Applications

References

Acknowledgements

Figure Legends

Figures

Tables

Manuscript Submission Checklist

Cover Letter

Completed **Copyright Assignment Form**

Original Manuscript, including IRB reference and references to all figures.

Figures, in a single powerpoint presentation if possible.

Terminology and Units of Measurement

Per the *JSCR* Editorial Board and to promote consistency and clarity of communication among all scientific journals authors should use standard terms generally acceptable to the field of exercise science and sports science. Along with the American College of Sports Medicine's Medicine and Science ins Sport and Exercise, the *JSCR* Editorial Board endorses the use of the following terms and units.

The units of measurement shall be Système International d'Unités (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. Authors should refer to the *British Medical Journal* (1:1334 – 1336, 1978) and the *Annals of Internal Medicine* (106:114 – 129, 1987) for the proper method to express other units or abbreviations. When expressing units, please locate the multiplication symbol midway between lines to avoid confusion with periods; e.g., $mL{\cdot}min^{-1{\cdot}kg-1.}$

The basic and derived units most commonly used in reporting research in this Journal include the following:

mass—gram (g) or kilogram (kg); force—newton (N); distance—meter (m), kilometer (km); temperature—degree Celsius (℃); energy, heat, work —joule (J) or kilojoule (kJ); power—watt (W); torque—newton-meter (N·m); frequency —hertz (Hz); pressure—pascal (Pa); time—second (s), minute (min), hour (h); volume—liter (L), milliliter (mL); and amount of a particular substance—mole (mol), millimole (mmol).

Selected conversion factors:

1 N = 0.102 kg (force);

1 J = 1 N·m = 0.000239 kcal = 0.102 kg·m;

1 kJ = 1000 N·m = 0.239 kcal = 102 kg·m;

1 W = 1 J·s-1 = 6.118 kg·m·min-1.

When using nomenclature for muscle fiber types please use the following terms. Muscle fiber types can identified using histochemical or gel electrophoresis methods of classification. Histochemical staining of the ATPases is used to separate fibers into type I (slow twitch), type IIa (fast twitch) and type IIb (fast twitch) forms. The work of Smerdu et. al (AJP 267: C1723, 1994) indicates that type IIb fibers contain type IIx myosin heavy chain (gel electrophoresis fiber typing). For the sake of continuity and to decrease confusion on this point it is recommended that authors use IIx to designate IIb fibers in theie manuscripts.

Effects of a Short-Term Aquatic Resistance Program on Strength and Body Composition in Fit Young Men

Juan C. Colado,[1] Victor Tella,[1] N. Travis Triplett,[2,3] and Luis M. González[1]

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Abstract

Colado, JC, Tella, V, Triplett, NT, and González, LM. Effects of a short-term aquatic resistance program on strength and body composition in fit young men. *J Strength Cond Res* 23(2): 549–559, 2009—This study was designed to analyze the effects of a short-term periodized aquatic resistance program (PARP) on upper-limb maximum strength, leg muscular power, and body composition (BC) in fit young men. Twenty subjects (21.2 ± 1.17 years) were randomly assigned to an exercise or control group; 12 subjects completed the study. The aquatic exercise group (AEG; $n = 7$) participated in an 8-week supervised program of 3 $d \cdot wk^{-1}$, and the control group (CG; $n = 5$) maintained their regular activities. The PARP consisted of a total-body resistance exercise workout using aquatic devices that increased drag force, with a cadence of movement controlled and adjusted individually for each exercise and subject. The volume and intensity of the program were increased progressively. Submaximal tests were carried out to determine the change in upper-limb maximum strength, as well as a squat-jump test to determine the change in leg muscular power. Four skinfold sites, 6 circumference sites, body weight, and stature were used to determine changes in BC. A significant increase in upper-limb maximum strength and leg muscular power was observed for the AEG. A significant increase also was noted in the circumference and muscular area of the arm, and there were significant decreases in pectoral and abdominal skinfolds. Nevertheless, the circumference, muscular area, and local fat of the lower limbs did not change. There were no significant changes in any variables in the CG. These results indicate that the PARP produces significant improvements in muscular strength, power, and fat-free mass and, thus, seems to be a very effective form of resistance exercise.

Key Words drag force, monitored cadence of movement, periodized

Introduction

Both the number of physical conditioning activities carried out in water and the number of those exercising have significantly increased in the United States and Europe in recent decades. The physiological and articular benefits offered by the specific properties of this medium (7,38) may have promoted this increase. These activities have traditionally been aimed at and prescribed for those populations with some kind of disability. However, they are currently used both to improve the physical condition of healthy individuals who regularly take part in recreational training (9) and as a complement to improve the performance of athletes (5,16,25,27,33). Although the physiological responses, effects, and benefits offered by performing aerobic exercises in water are well known (8,15), studies are lacking on the potential effects of a program of resistance exercises in water (32). The absence of methodological criteria with which to control resistance objectively and progressively while performing these exercises (30,31) may be one of the reasons for this, and as a result this type of training has not been recommended by academic professionals or used by practitioners.

In general terms, the same program design recommendations should be followed for the specific application of strength training programs in water (31,36). Therefore, to design a strength training program in the aquatic medium, studies (6,7,9,10,12,17,23,28,30–32,36,38) have recommended that it is essential to achieve the combined control of i) the pace of the movement, ii) the size of the aquatic devices that increase the drag force, iii) the length of the lever of the limb being exercised, iv) the hydrodynamic position of the segment mobilized and the aquatic devices used, and v) the

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performance of a targeted number of repetitions based on the desired goal. In addition, it should be pointed out that in all cases the individuals exercising carry out the movements with the aquatic devices at a pace determined by a cadence of beats per minute that has been previously identified on the basis of the predicted targeted number of repetitions. It has been shown that the workload in water is always similar as long as the movement is performed at the same pace and under the same exercise conditions (7,12). Thus, to increase the resistance offered by the water, either the pace per minute must be increased or the area of the aquatic device must be increased (7). Therefore, objective criteria exist with which to quantify the progressive increase in the "load" or resistance, marked by the proposed pace per minute and the aquatic device used (7). The moment when neither the pace nor correct performance can be maintained defines when muscular actions are inadequate for the stimulus (29).

No scientific studies have examined the basic aspects of the design of resistance programs in combination with the use of adequate aquatic devices and the performance of movements according to a previously evaluated pace. Although several studies have confirmed the positive adaptations caused by aquatic resistance exercises (3,37,39), many of them display methodological shortcomings when it comes to controlling the resistance generated by the exercises both immediately and in the long term, as well as usually being applied to untrained middle-aged or older subjects with whom it is easier to cause certain adaptations in the early stages of strength training programs. Therefore, to analyze the effects that an aquatic resistance program can have on fit young men regarding maximum strength, muscular power, and body composition (BC), a randomized and supervised study was carried out for which a method was designed to adapt and control exercise intensity objectively. The hypothesis of the current study was that aquatic resistance training can generate positive neuromuscular adaptations in fit men if the resistance applied to the training movements is controlled by a specific cadence of movement for each exercise and subject according to the targeted number of repetitions initially prescribed.

Methods

Experimental Approach to the Problem

In accordance with the methodology proposed by Kraemer et al. (23) for using elastic devices for strength training, in this study a specific cadence of movement using the same aquatic device to increase drag force was used to complete an 8- to 12-repetition maximum (RM) range with a 10-repetition target. To this end, a cadence of movement was identified for each subject in the aquatic exercise group (AEG) that allowed the subject to achieve the amount of resistance needed to maintain the targeted number of repetitions (RM zone ± 2 rep) while using good technique. The subjects trained using an acoustic metronome throughout the training program, with each individually following the initially identified cadence of movement for each exercise. Whenever necessary, greater resistance was provided by using a faster cadence of movement to maintain the targeted number of repetitions. At least 1 trained monitor was always present to corroborate the correct application of this methodology. Muscle function and BC were tested before and after the resistance training program to determine its effects. All measurements and practical procedures were always carried out by the same researchers, all of whom had experience with this kind of trial. All subjects were continually encouraged, and the laboratory conditions were always the same. Pre- and posttests were filmed, and the film was then checked to ensure the validity of the procedures followed. The study was approved by a research commission and by the Department of Physical Education and Sports from the University of Valencia (Spain).

Subjects

Twenty men volunteers from third-year students at the Faculty of the Sciences of Physical Activity and Sports at the University of Valencia (Spain) were randomly assigned into a control group (CG; 8 subjects) and an AEG (12 subjects), with no significant differences ($p > 0.05$) in any intergroup baseline measurement. All subjects were physically active as they performed $5.08 \pm 1.5\ d\cdot wk^{-1}$ of varied physical training at moderate intensity for at least 20 minutes, and all had done so for at least 6 months before the study. They did not normally perform resistance exercises on dry land, and they never had performed aquatic resistance exercises. All subjects signed an agreement by which they committed themselves, for the duration of the study, not to carry out any specific physical activity for strength training in their free time, to maintain their habitual lifestyle and eating habits, and not to take performance-enhancing substances (after prior corroboration that they never had taken these substances). The subjects did not suffer any cardiovascular, neuromuscular, orthopedic, or psychological disorders. All subjects were informed of the nature of the study before volunteering to take part in it. To evaluate any possible interference with the training program followed in the study, and to better understand certain results obtained, each subject was supplied with a diary in which he listed the type of physical activity he had carried out during the day, his diet, his rest periods, and his feelings during the aquatic resistance training sessions. Finally, after the usual withdrawals and eliminations associated with any unremunerated experimental study, the final make-up of the groups was as follows: a) AEG: $n = 7$, 21 ± 1 years, 173.96 ± 4.97 cm, 73.43 ± 7.97 kg; b) CG: $n = 5$, 21.4 ± 1.34 years, 178.12 ± 4.08 cm, 76.38 ± 5.03 kg.

Body Composition

All measurements were carried out by the same fully trained individual under identical environmental conditions using exactly the same instruments. A Harpenden skinfold caliper was used to measure skinfolds, and the average of 2 trials was used except in the case in which the measurements differed by more than 2.0 mm. In this case, a third measurement was obtained, and the mean value was used. The skinfolds measured were those of the right-hand side of the chest, abdomen, and thigh, following the usual protocol (18). In addition, a skinfold was taken from the brachial triceps region of the right arm for later analysis. Body density was calculated (21), and the value was used to determine body fat percentage by applying the Siri formula (35) for Caucasian men; subsequently, fat-free mass was determined. In addition, the circumferences of the relaxed right arm, the internal and thoracic region at shoulder height at maximum inspiration, the relaxed hip, and the upper thigh were measured. We also measured fasting body weight and height using the spinal column extension method and normal procedures for these measurements (18). Finally, the muscle area of the arm and thigh were determined by using the above measurements and applying the formulas used by Huygens et al. (20).

Procedures

It was scrupulously ensured that the correct range and technique were used for each exercise during the tests. All subjects were required to perform a standardized warm-up. Two measurement sessions with 48 hours of separation between them were carried out for both the initial and final tests, and there were 72 hours separating the final training session from the first posttest evaluation. The best result for each variable measured was taken for analysis. The intraclass correlation coefficient was calculated from the measurements of the pre- and posttests of the control group. For the anthropometric and strength variables, the intraclass correlation coefficient values for our protocols ranged between 0.87 and 0.98 and between 0.82 and 0.87, respectively.

Maximum Strength. The exercises chosen for the dry-land evaluation involved the same muscle groups and working angles exercised during the periodized aquatic resistance program (PARP) in as similar a fashion as possible. The exercises used and the order of evaluation were always the same, which prevented any possible interference with performance that could be a result of the order in which the exercises were carried out. The order was as follows: a) vertical row, b) horizontal bench press, c) horizontal bench row, d) arm lateral raise, and e) squat-jump. Previously calibrated standard materials were used, consisting of bars with diameters of 2.5 cm and weights of 11 kg, dumbbells with diameters of 2.5 cm and weights of 2.5 kg, weight plates with standard features, collars, and standard supports. Subjects were familiarized with each exercise, and their technique was checked before the performance of each test. A submaximal test only allowing a maximum of 6 repetitions until muscular failure with correct technique was used (14). A submaximal test was used because a large number of muscle groups were evaluated by means of different tests, and it was necessary to the quality and validity of the tests to minimize fatigue of the subjects. If a subject exceeded the number of repetitions, he rested and then tried again with a higher load. The Brzycki formula (4) was used to calculate maximal strength from the submaximal repetitions.

Power. To identify the evolution of lower-limb muscle power, the static vertical jump or squat-jump test was used because it also exclusively assesses the concentric muscle action that characterized the PARP used in this study. It was performed using the recommendations of Lehmkuhl et al. (24). The muscular power of each vertical jump was estimated by applying the prediction equation of Sayers et al. (34).

Periodized Aquatic Resistance Training Program

Exercises. Because the subjects were not used to aquatic resistance exercises, they were taught the correct technique for performing them before starting the training program. The researchers explained the exercises to the group, and each subject then carried them out under supervision. The criteria for correct technical performance were those described by Colado (9), and the exercises are described in Table 1. The temperature of the water in the swimming pool where the training program took place was 28 ± 1° C, and the depth of immersion was always such as to allow the exercises to be carried out in a technically correct fashion. Standard materials were used during the training program. For example, the gloves had a projected area of 293 cm^2, the fins had a projected area of 430 cm^2, and the boards had a projected area of 874 cm^2. Noodles were used to maintain the horizontal flotation position in the exercises training the abdominal musculature.

Resistance Identification. A Wittner metronome and a digital audio editing program were used to record a compact disc with 12 tracks corresponding to different paces and ranging from 46 beats per minute to 102 beats per minute. Each of the tracks was thoroughly checked to guarantee that they did not contain alterations to the preset pace. The subjects initially used the aquatic devices to carry out the basic exercises prescribed at a pace determined by a cadence of beats per minute chosen on the basis of pilot tests and the prior experience of the researchers. This meant that the subjects had to match their movements to the individual beats of the tracks recorded on the compact disc. Those subjects who were not able to generate enough resistance from the water to reach muscle failure with the preset number of repetitions at the pace initially planned and without varying their technique took a rest period and then increased the pace by choosing the next track. Similarly, the subjects for whom the pace was too difficult to reach the prescribed number of repetitions chose the previous track after the rest period. This allowed them to obtain the initial "load" after identifying the track offering the optimal pace to be used by each subject for each of the exercises. From then on, the "load" was adjusted to the aquatic movement by changing the track. The subjects repeated the process after resting for 2 hours to ensure that the track chosen for each exercise was correct. This test was carried out 48 hours after having carried out the dry-land pretests to determine maximum strength and muscular power. Table 1 also shows the beats per minute (pace) most commonly used for each of the basic training program exercises.

TABLE 1. Exercises used in the different cycles of the periodized aquatic resistance program (PARP).

Device name	Exercise name		Pace*	Description of the joint movements
Gloves	Horizontal shoulder ab-adduction	H.Sh Ab/d	69	Horizontal abduction and adduction of the shoulders
	Oblique shoulder ab-adduction	O.Sh Ab/d	69	Oblique abduction and adduction of the shoulders
	Vertical shoulder ab-adduction	V.Sh Ab/d	72	Abduction and adduction of the shoulders
	Elbow flexion-extension	Elb F/E	72	Flexion and extension of the elbows
Boards	Horizontal press-pull	H P/P		On a horizontal plane: flexion and extension of the shoulders and elbows
	Oblique press-pull	O P/P		In an oblique direction: flexion and extension of the shoulders and elbows
	Vertical press-pull	V P/P		On a frontal plane: abduction and adduction of the shoulders and flexion and extension of the elbows
	Arms press-pull	A P/P		Flexion and extension of the elbows
Fins	Frontal kick	FK	60	Flexion and extension of the knee with a small supported flexion of the hip
	Great frontal kick	GFK	46	Flexion and extension of the knee and hip
Fins and boards	Dorsal resisted batter	DRB		Dorsal resisted batter with the boards in every hand and below the body
	Lateral resisted batter	LRB		Lateral resisted batter with the board held with the hands over the head
Noodles	Frontal top crunch	FTC		Frontal top crunch in horizontal position and with a noodle in lengthwise direction
	Frontal low crunch	FLC		Frontal low crunch in horizontal position and with a noodle in longitudinal direction

*Cadence of movement (bpm) most typically applied to each of the basic exercises of the training program.

Training Program. One member of the research group was always present during the training sessions to ensure that the program was performed correctly. Training compliance for the subjects was 95%. The exercises performed during warm-up and cool-down were standardized to avoid any possible interference with the aims of the study. Despite the fact that a short-term program was used to maximize training effects, and given that the subjects were physically active, a periodized model for strength training was used, with a total duration of 8 weeks, divided into 2 consecutive 3-week cycles and a final 2-week cycle, with a frequency of 3 sessions a week. To vary the training stimulus, the volume was modified in each cycle by an overall increase in the sets and the exercises. Table 2 shows the methodological criteria followed to perform the different cycles and the exercises according to the specific association with the technique of preexhaustion overloading of agonist muscle groups. The exercises for dynamic training of the abdominal musculature were performed following a repetition speed of 1 second for the outward stage and 2 seconds for the return stage to the initial position.

As mentioned previously, a very high volume was applied in this PARP. With the use of aquatic resistance devices, all movements are concentric only, such that the opposing muscles around a joint are primarily trained in the concentric manner in each direction of joint movement, which serves to increase the overall training volume compared with that of dry-land training. The recovery time between sets was always 90 seconds, which is typical of the 8- to 12-repetition range. These rest periods, combined with the significant length of the sessions, meant that the subjects carried out slow jogging movements and/or slow active range-of-motion exercises of different joints during the recovery periods to avoid the risk of suffering from hypothermia, with some subjects even training while wearing thin thermal garments.

Statistical Analyses

The data gathered were analyzed using the SPSS program. The homogeneity of the dependent variables was checked using the Levene test ($p > 0.05$), and their normality was evaluated using Kolgomorov-Smirnov statistics ($p > 0.05$). Descriptive statistics were then calculated. *t*-Tests were used for within-group differences, and ANOVA was used to analyze independent (between-group) samples. All differences were accepted as statistically significant at $p \leq 0.05$ and as very significant at $p \leq 0.01$.

Table 2. Periodized aquatic resistance program (PARP) followed in the study.

Cycle number		Exercises and workout order	Sets per exercise	Repetitions per set 1	2	3
1	1°	Horizontal shoulder ab-adduction	3	8–12		
	2°	Oblique shoulder ab-adduction	3	8–12		
	3°	Vertical shoulder ab-adduction	3	8–12		
	4°	Elbow flexion-extension	5	8–12		
	5°	Frontal kick	5	8–12		
	6°	Great frontal kick	5	8–12		
	7°	Frontal top crunch	4	15		
2	1°	(1) Oblique shoulder ab-adduction + (2) oblique press-pull	3	8–12	15	
	2°	(1) Vertical shoulder ab-adduction + (2) vertical press-pull	3	8–12	15	
	3°	(1) Horizontal shoulder ab-adduction + (2) horizontal press-pull	3	8–12	15	
	4°	(1) Elbow flexion-extension + (2) arms press-pull	5	8–12	15	
	5°	(1) Great frontal kick + (2) lateral resisted batter	5	8–12	15	
	6°	(1) Frontal kick + (2) dorsal resisted batter	5	8–12	15	
	7°	(1) Frontal low crunch + (2) frontal top crunch	4	15	15	
3	1°	(1) Vertical shoulder ab-adduction + (2) vertical press-pull + (3) vertical shoulder ab-adduction	4	8–12	15	8–12
	2°	(1) Horizontal shoulder ab-adduction + (2) horizontal press-pull + (3) horizontal shoulder ab-adduction	4	8–12	15	8–12
	3°	(1) Elbow flexion-extension + (2) arms press-pull + (3) elbow flexion-extension	5	8–12	15	8–12
	4°	(1) Frontal kick + (2) dorsal resisted batter + (3) frontal kick	5	8–12	15	8–12
	5°	(1) Great frontal kick + (2) lateral resisted batter + (3) great frontal kick	5	8–12	15	8–12
	6°	(1) Frontal top crunch + (2) frontal low crunch + (3) frontal top crunch	5	15	15	15

Rest interval between sets: 90 seconds.

Results

Tables 3 and 4 show the effects caused by the PARP on muscular fitness and global BC, stating the baseline value and final absolute change after comparing the initial value with that obtained after the 8 weeks of training. Additionally, Figures 1 and 2 show the individual values of the AEG for the variables indicated.

The PARP led to significant improvements in both the maximum strength of the upper limbs and in the power of the lower limbs (Table 3). The PARP also led to significant increases in fat-free mass (Table 4) and arm/hip circumference (Table 5). In addition, the PARP significantly reduced local fat in the abdominal and pectoral region (Table 5) together with overall fat mass (Table 4), there being a significantly positive correlation in the AEG between weight increase and reduction of body fat mass ($p \le 0.01$). However, the PARP did not lead to any modification of lower-limb BC.

Discussion

Except for the study carried out by Pöyhönen et al. (32) analyzing the effects caused by a PARP with movements performed with aquatic devices on the strength and BC of young, physically active women, there are no other scientific studies focusing on the effects that a total-body workout PARP using aquatic devices could have on other populations, especially where intensity is controlled objectively. Therefore, in the current investigation it was necessary to create a methodology that had been lacking up to now. The method used here to control intensity in aquatic strength training through joint control of the pace of movement and target number of repetitions is in agreement with current recommendations for controlling training against resistance (29). The results highlight the fact that the PARP developed was effective in increasing both strength and fat-free mass with only 8 weeks of training, despite the fact that there are aquatic devices available that are more appropriate because they are larger and more ergonomically designed than those used in the current investigation, and even though the subject attrition reduced the final statistical power, which is accounted for when making generalizations about the results obtained in this investigation.

The results provided by this study show a clear increase in the maximum strength of upper-limb muscle groups in young, healthy, physically fit men with an intermediate level of muscular fitness. Faced with the lack of equivalent studies in

Table 3. Change in maximum strength.

Variable	Group	Previous value and change		SD(±)	(p)[1]	(p)[2]
Horizontal bench press (kg)	CG	Pre	64.31	6.77	0.209	0.004†
		Change	−2.12	3.17		
	AEG	Pre	62.28	9.50	0.003†	
		Change	+3.19	1.76		
Arm lateral raise (kg)	CG	Pre	25.77	2.99	0.686	0.465
		Change	−0.01	2.55		
	AEG	Pre	23.74	3.37	0.044*	
		Change	+2.30	2.40		
Horizontal bench row (kg)	CG	Pre	69.67	5.02	0.541	0.154
		Change	+0.95	3.18		
	AEG	Pre	72.38	13.32	0.033*	
		Change	+4.46	4.29		
Vertical row (kg)	CG	Pre	44.82	2.42	0.235	0.028*
		Change	+1.44	2.1		
	AEG	Pre	44.70	10.91	0.018*	
		Change	+4.88	2.35		
Squat-jump (W)	CG	Pre	4694.95	437.54	0.658	0.210
		Change	−89.51	419.07		
	AEG	Pre	4471.07	581.37	0.045*	
		Change	+135.62	141.84		

(p)[1] = Statistical intragroup significance; (p)[2] = posttest statistical intergroup significance with regard to the change.
CG = control group; AEG = aquatic exercise group.
*Significant statistical difference ($p \leq 0.05$); †very significant statistical difference ($p \leq 0.01$).

the aquatic medium with which to compare the results, in this analysis the results can only be compared with those from other programs carried out on dry land, in which the testing and training were done with the same exercise. The results obtained with the PARP are similar to those obtained in other studies using resistance devices on dry land, although they were applied using methods and subjects with slightly different characteristics to the AEG. For example, the first 8 weeks of the study of Hostler et al. (19) used traditional training methods for improving maximum strength in the horizontal bench press exercise (2–3 $d \cdot wk^{-1}$, 3 sets of 7 RM). The young men chosen were physically active and had not carried out any specific strength training in the previous 6 months. The relative strength of the 2 groups of men analyzed was significantly higher than that of the subjects of the AEG (1.22 and 1, respectively, vs. 0.85 for the AEG). The subjects of the Hostler et al. study improved their 1RM by 4.1 and 5.1 kg in 8 weeks (increases of 4.89 and 6.47%, respectively), and the AEG subjects improved by 3.19 kg (an increase of 5.12%), with the dry-land groups showing respective relative strength improvements of 3.28 and 5.82% compared with an improvement of 4.70% for the AEG. Thus, the studies analyzed show how the improvement in the maximum strength of the AEG in the bench press exercise is similar to that obtained by those participating in dry-land programs, even though the subjects in the current investigation performed the horizontal press-pull during part of the aquatic training program, which is only moderately equated to the bench press. This may have limited the strength gains in the bench press test of the subjects in the current investigation.

However, as was previously mentioned, it is very important to point out that concentric muscle actions were prioritized in the PARP, whereas tests were carried out that required combined concentric and eccentric muscle actions to evaluate the change in maximum strength in the AEG. It is generally accepted that gains in strength shown in a test are greater when the test exercise, training exercise, type of muscle action required, and type of resistance to be overcome are similar. Therefore, the most appropriate evaluation test for assessing the current program adaptations should focus exclusively on the concentric phase of maximum dynamic strength (32,37). However, the effects on maximum strength caused by participation in this study were evaluated using exercises of a combined concentric and eccentric nature, using weight equipment that is typically used in dry-land programs. Although this is a possible limitation to the current investigation in defining the real improvements of the program followed, it was necessary because improvements in muscular fitness achieved with aquatic exercise programs will usually be transferred and applied to performance on dry land.

Regarding the training effects on muscular power of the lower limbs, the AEG showed a significant improvement of 3.03% over its initial value of 4471.07 W. Although existing studies have shown that the power of the lower limbs is improved by following aquatic training programs (25,27,33), these studies are solely based on carrying out multijump exercises, unlike the PARP followed in our study where only traditional open-kinetic-chain resistance exercises were performed. The dry-land studies of Coutts et al. (13) and Lehmkuhl et al. (24) can be used to compare the results of our PARP with their programs because they also used the squat-jump as the evaluation test, trained the strength of the lower limbs by using common open- and closed-kinetic-chain strength exercises, and at no time used multijump training

Table 4. Change in overall body composition.

Variable	Group	Previous value and change		SD(±)	(p)[1]	(p)[2]
Fat-free mass (kg)	CG	Pre	69.58	3.03	0.043*	0.000†
		Change	−1.42	0.48		
	AEG	Pre	66.01	7.53	0.000†	
		Change	+1.28	0.47		
Percentage of body fat (%)	CG	Pre	8.78	3.24	0.875	0.092
		Change	+0.12	1.59		
	AEG	Pre	10.13	2.25	0.019*	
		Change	−1.32	1.10		
Fat mass (kg)	CG	Pre	6.80	2.90	0.893	0.194
		Change	−0.02	1.44		
	AEG	Pre	7.42	1.71	0.023*	
		Change	−0.91	0.79		
Body weight(kg)	CG	Pre	76.38	5.03	0.112	0.029*
		Change	−1.44	1.59		
	AEG	Pre	73.43	7.98	0.374	
		Change	+0.37	0.88		

(p)[1] = Statistical intragroup significance; (p)[2] = posttest statistical intergroup significance with regard to the change.
CG = control group; AEG = aquatic exercise group.
*Significant statistical difference ($p \le 0.05$); †very significant statistical difference ($p \le 0.01$).

too light. Applying the Sayers et al. (34) formula to the results of the study shows that 1 group improved its initial value of 4382.12 W by 2.8%, and the other group improved its initial value of 4575.64 W by 4.96%. The Lehmkuhl et al. (24) study used a combined sample of men and women athletes who were given performance-enhancing supplements. Their training program lasted 8 weeks and consisted of a total-body workout prioritizing maximum strength training for 3 d·wk^{-1} and using multiple sets. As before, if the Sayers et al. (34) formula is applied, it can be shown that the placebo group improved its initial jump value of 4642.22 W by 1.5%. As previously stated, the 3.0% improvement in lower-limb power by the AEG in the current study was significant,

resources. The 2 groups of subjects in the Coutts et al. (13) study trained for the first 6 weeks at 3 d·wk^{-1}, with a total-body workout of 7 exercises including one for the lower limbs (back squat), carrying out multiple sets of 10–16 repetitions at an intensity of 55–73.5% 1RM, with a 1-minute rest interval. The load was modified when it was perceived as too heavy or

although there were no significant differences in power when compared with the CG. This can be explained by the use of nonspecific aquatic devices such as the fins. This material modified the movement pattern of the basic frontal kick and great frontal kick exercises, meaning that the subjects struck the bottom of the swimming pool as a result of the increased length of the limb caused by using this device. This made it difficult to carry out the exercise in technically correct fashion while stabilizing the body. One additional problem of this material used for the lower extremities was that it could have caused some ankle joint pain, and this fact could have limited the intensity, and maintained performance of the movements as the joint was subjected to significant stress. Another factor that could have had a negative effect was the type of test used, despite following the suggestions of previous studies (37) and the fact that the squat-jump really provided evaluation appropriate to the muscle action trained. However, the movement

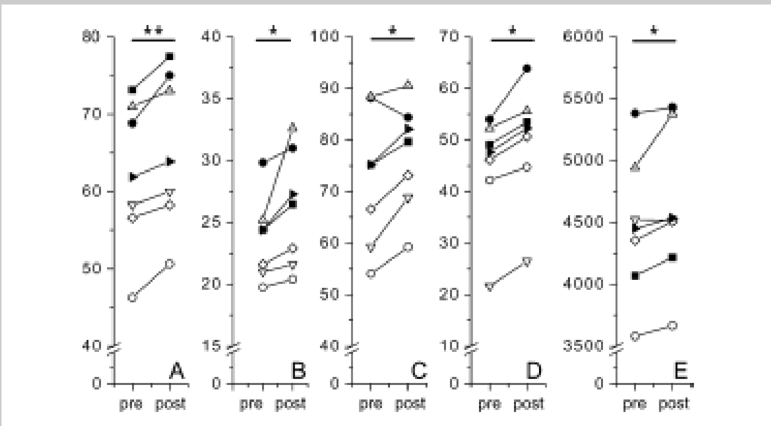

Figure 1. Individual values of the aquatic exercise group for maximum strength before and after 8 weeks of aquatic resistance training. From left to right, the panels represent A) horizontal bench press (kg), B) arm lateral raise (kg), C) horizontal bench row (kg), D) vertical row (kg), and E) squat-jump (W). The significant differences between the pre- and posttests are indicated by *($p \le 0.05$) and **($p \le 0.01$).

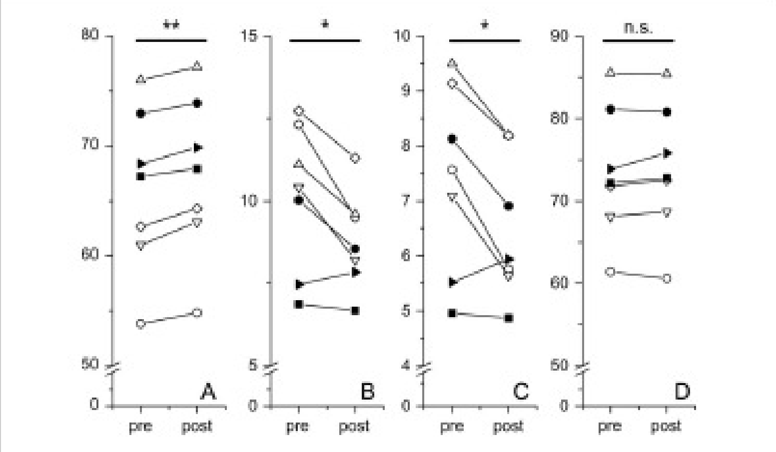

Figure 2. Individual values of the aquatic exercise group for overall body composition before and after 8 weeks of aquatic resistance training. From left to right, the panels represent A) fat-free mass (kg), B) percentage of body fat (%), C) fat mass (kg), and D) body weight (kg). The significant differences between the pre- and posttests are indicated by *($p \le 0.05$) and **($p \le 0.01$). n.s. = no significant difference.

pattern and the type of strength trained showed significant differences. These limiting factors were not present in the Pöyhönen et al. (32) study because Hydro-tone boots were used. These devices do not prevent correct execution of the exercise and do not overload the ankle joint. They also have a greater surface area that allows them to generate greater drag force. The leg extension test used by Pöyhönen et al. (32) was also better suited to the movement pattern trained. It is therefore likely that the limitations of the present investigation contributed to the lack of intergroup differences and the absence of change in the BC of the thigh segment. Thus, there is a need to carry out further studies in which these factors are taken into account, allowing future PARPs to be designed and evaluated more precisely.

One other important factor that should be highlighted is the fact that no relevant eccentric muscle actions have appeared in PARPs carried out using aquatic devices (31,32), which has created questions as to whether aquatic resistance programs can result in increases in strength and muscle mass of young, healthy, physically active subjects. However, physiological adaptations should result whenever the magnitude of muscular stress generated by the muscle action is greater than the normal level of stress to which the muscle group is subjected. The results of the current study support the statement that those PARPs using aquatic devices that prioritize concentric muscle action are effective in increasing both strength and fat-free mass. The fact that this kind of program was based on single-joint movements has possibly favored the very early gains in fat-free mass (32). Despite the fact that dietary modification as a basic factor for increasing fat-free mass was not manipulated while the PARP was being carried out, it should be noted that this kind of PARP did include typical program variables aimed at favoring muscle hypertrophy, such as the rest interval and the number of repetitions performed, the large number of sets per muscle group, the use of preexhaustion methods, the weekly training frequency, and the anabolic environment usually created by programs combining these aspects that also involve many large muscle groups.

Although the diet was not manipulated, the subjects agreed not to change their dietary practices and filled in daily questionnaires during the duration of the study to reduce any confounding effects with the PARP, as was the case with previous studies (37). These were checked every week to ensure that their habits before starting the study had not changed. Thus, the PARP applied led to a significant improvement of 1.285 kg of fat-free mass in only 8 weeks. This increase is even more significant considering that there was a significant reduction in physical activity (outside of the PARP in the AEG) during the course of the semester, which would normally lead to a reduction in fat-free mass, as was seen in the CG. In general terms, the improvements of the AEG are in line with those obtained in other dry-land programs following a similar methodology, obviously excepting the specific aquatic applications. It has been reported that fat-free mass increases by about 2.0 kg after 10–16 weeks of total-body resistance training (2). In another study, Mazzetti et al. (26) submitted young trained men to a classical linear periodized resistance training program emphasizing strength and hypertrophy phases for 12 weeks. In this study, the initial 68.22 kg of fat-free mass in the supervised group increased by 1.38 kg–an improvement of 2.02% that is very similar to the 1.95% increase in the AEG studied here.

Despite the small reduction in the body fat percentage of the AEG, which is within the error range associated with the determination of body fat via skinfold methods (26), the results also suggest that the PARP applied was significantly effective in the reduction of body fat, despite not being designed for this purpose. The PARP involved extra expenditure of calories that, because it was not compensated for by an increase in the calories provided by the daily diet, caused a negative balance that led to a slight reduction in the fat mass of subjects with very low percentages of body fat. These results are therefore very positive because the PARP created a stimulus that both increased muscle mass and favored an overall reduction in fat–more specifically, that

Table 5. Change in body composition by segments.

Variable	Group	Previous value and change		SD(±)	(p)[1]	(p)[2]
Arm circumference (cm)	CG	Pre	30.48	1.81	0.142	0.000†
		Change	−0.10	0.12		
	AEG	Pre	30.03	2.18	0.000†	
		Change	+1.33	0.22		
Arm skinfold (mm)	CG	Pre	7.92	2.23	0.288	0.589
		Change	−0.56	1.02		
	AEG	Pre	10.63	4.56	0.095	
		Change	−0.94	1.26		
Arm muscular area (cm2)	CG	Pre	52.48	6.27	0.524	0.000†
		Change	+0.37	1.19		
	AEG	Pre	47.11	6.97	0.000†	
		Change	+5.49	1.99		
Thigh circumference (cm)	CG	Pre	60.48	2.66	0.181	0.71
		Change	−1.12	1.55		
	AEG	Pre	59.57	4.39	0.286	
		Change	+0.64	1.45		
Thigh skinfold (mm)	CG	Pre	11.88	2.85	0.542	0.294
		Change	+1.00	3.36		
	AEG	Pre	12.06	4.53	0.356	
		Change	−0.57	1.51		
Thigh muscular area (cm2)	CG	Pre	291.53	25.28	0.185	0.71
		Change	−10.65	14.89		
	AEG	Pre	283.72	41.92	0.278	
		Change	+6.24	13.84		
Thoracic internal circumference (cm)	CG	Pre	102.88	3.59	0.269	0.948
		Change	−0.90	1.57		
	AEG	Pre	100.84	5.37	0.121	
		Change	−0.96	1.40		
Thoracic external circumference (cm)	CG	Pre	119.20	3.66	0.533	0.880
		Change	−1.12	3.68		
	AEG	Pre	117.64	6.74	0.413	
		Change	−0.84	2.54		
Pectoral skinfold (mm)	CG	Pre	7.04	2.38	0.102	0.113
		Change	−0.52	0.50		
	AEG	Pre	8.77	3.44	0.039*	
		Change	−1.51	1.14		
Waist circumference (cm)	CG	Pre	83.88	3.89	0.004†	0.013†
		Change	−2.56	0.99		
	AEG	Pre	82.60	3.07	0.398	
		Change	−0.54	1.24		
Abdominal skinfold (mm)	CG	Pre	13.32	6.72	0.964	0.052*
		Change	−0.04	1.86		
	AEG	Pre	15.97	4.42	0.009†	
		Change	−2.17	1.50		
Hip circumference (cm)	CG	Pre	100.06	5.25	0.345	0.040*
		Change	−1.78	3.21		
	AEG	Pre	96.49	4.20	0.049*	
		Change	+1.51	1.63		

(p)[1] = Statistical intragroup significance; (p)[2] = posttest statistical intergroup significance with regard to the change.
*Significant statistical difference ($p \leq 0.05$); †very significant statistical difference ($p \leq 0.01$).
CG = control group; AEG = aquatic exercise group.

located in the pectoral and abdominal region (13.59%)–in fit subjects with excellent BC who only trained at a frequency of 3 d·wk^{-1}. Colado et al. (11) observed that aquatic resistance exercises using aquatic devices showed a certain tendency towards creating greater cardiovascular and metabolic response than dry-land resistance exercises with elastic bands, something possibly caused by the continuous participation of concentric muscle actions and, possibly, by the greater muscular demands made on stabilizing muscles in the aquatic medium. The PARP also used a progressive overload method based on increasing volume by grouping exercises that not only increased the total involvement of the number of muscle groups but also increased the duration of the effort and the number of muscle actions per session. In typical dry-land training, the load is constant for both the eccentric and concentric phases of movement. Conversely, with PARP and aquatic devices, the muscle actions are predominantly concentric for all movements, which may actually result in a higher growth hormone response (22). Therefore, this hormonal response could have a positive effect on improving BC, given the role played by growth hormone in the mobilization of fatty acids for use as an energy substrate, and it could be one of the causes underlying the results regarding the improvements in BC among the AEG. However, specific studies should be carried out to confirm this.

Body composition did not change equally in the upper and lower body, with no significant changes in BC seen in the lower body among the AEG. It is possible that the local training volume applied was too low when compared with that applied to the upper limbs. It is also possible that more time than that used in this program is needed to achieve muscle adaptations in the lower limbs, this not being the case for the upper limbs (1).

Nevertheless, despite the positive effects that can be provided by training programs that prioritize concentric muscle actions, we should be cautious with regard to the fact that eccentric actions do not play a major role in PARPs using aquatic devices, which are typical of sport and of daily life and are usually combined with concentric actions in many motor situations. Thus, it should be recommended that any overall neuromuscular conditioning program should include dry-land exercises that demand such actions for those taking part in a PARP. However, Colado (9) suggests that the fact that eccentric actions are minimized and training is carried out using muscle pairs (agonist/antagonist) could favor a reduction in delayed muscle pain, less risk of injury, greater calorie consumption, and reduced training time. These factors would increase adherence to the programs, routines for functional pairs that are easier to balance, and, as has been shown in this study, fat-free mass and strength.

An important contribution of the current investigation is that it offers a practical solution to one of the main drawbacks of strength training in the aquatic medium, which is control over the intensity of work (7,31) and, consequently, the possibility of objectively quantifying the resistance used. Prior methods were dependent on the subjective criteria of those exercising, who had to perform the exercises to a high speed depending on their effort perception (32,37); such methods therefore offered little control. Through quantification of the pace of movement per minute, with adjustments to a specific targeted number of repetitions according to the specific needs of each exercise and each subject, control of the intensity applied to each set, exercise, and training session could be maintained at all times. This method has provided tangible, objective, and practical criteria with which to monitor aquatic resistance exercises. Finally, it is very important to point out that quantification of the "load" for strength training in water using the methodology proposed here could allow the individual to target any particular program goal (hypertrophy, strength, muscle endurance, power). In conclusion, the present results indicate that a PARP with a cadence of movement monitored and adjusted individually for each exercise and subject using a metronome produces significant improvements in muscular strength, power, and fat-free mass and, thus, seems to be a very effective form of resistance exercise.

Practical Applications

As well as being an effective training method for increasing maximum strength and fat-free mass, the aquatic resistance program has a positive effect on reducing body fat. As with dry-land exercises, these effects appear when the correct, progressive program design is established, meaning that the resistance offered by the water in each of the sets and exercises must be controlled. In the aquatic medium, progressive and well-adapted increases of the "load" or resistance can be applied as long as the subjects use aquatic devices with which they already have been evaluated to find a pace of movement per minute for each exercise that allows them to perform a certain number of repetitions at the initially prescribed perceived intensity. However, for this resource to be valid, we also must ensure that the subjects always maintain the same arm and lever length and the same position of the segments and the aquatic devices that increase the drag force. Therefore, if similar findings are made, we are witnessing a new future for strength training in such different fields as rehabilitation, sports performance, health, and aesthetics.

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APPENDIX C

Submission guidelines for authors and an example of an article: Journal of Sports Sciences

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2. Submission
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On submission, authors should select the relevant Section Editor (see journal homepage) or, in case of any doubt, submit to the Editor-in-Chief. Authors should keep a copy of all materials sent for later reference. Papers submitted to the Journal will be refereed **anonymously** by acknowledged experts in the subject; at least two such referees will be involved in this process. In the event of conflicting reviews, the Section Editor will normally seek a further independent review. As the Journal operates an anonymous peer-review policy, please ensure that your manuscript submission has all information identifying the author(s) removed. If you are submitting a revised manuscript and have used track changes, please make sure that any comments are anonymous in order to ensure your anonymity. Alternatively, please highlight your text changes through the use of red font.

The Section Editor will forward papers recommended for publication to the Editor-in-Chief, who has the final decision on publication. Manuscripts should not exceed 4,000 words, without the specific consent of the Editor-in-Chief or a Section Editor. Discursive treatments of the subject matter are discouraged. Section Editors will not accept manuscripts in two or more parts unless this has been agreed in advance by the Editor-in-Chief. As well as normal length communications of original research, shorter communications are also considered subject to the same refereeing process. Review papers will normally be by invitation of a Section Editor; authors wishing to submit a review paper are advised to consult the appropriate Section Editor before doing so. Book reviews are by invitation only. **When preparing manuscripts, please use a standard word-processing package, such as WordPerfect or Microsoft Word.**

On submission, authors are required to nominate up to four expert referees for their paper; these potential referees must not have been informed that they have been nominated or be members of the authors' institutions. The nominated referees may or may not be used, at the Section Editor's discretion, and at least one of the referees involved in the review of the paper will be independent of the nominated list.

3. Originality

We require authors to confirm the originality of material by ticking the appropriate checkbox on submission of the manuscript. Material submitted will not enter the refereeing process until such an undertaking has been received.

We discourage the practice of publishing parts of one study in different journals. Authors who submit a manuscript to the ***Journal of Sports Sciences*** from a study, some of these data from which has been or will be published elsewhere, must provide a strong justification in the accompanying letter to the Section Editor. The justification for not publishing all of the data together in one manuscript or as multiple papers in a single issue of the ***Journal of Sports Sciences*** must also be included in the covering letter.

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Papers should be written and arranged in a style that is succinct and easy to follow. An informative title, a concise abstract and a well written introduction will help to achieve this. Authors should avoid some of the more common pitfalls, such as excessive use of the passive voice and past tense and **unnecessary use of fabricated abbreviations** within the text. The Journal would prefer authors to describe human volunteers as **participants rather than subjects** in the methods section. Figures and tables should be used to add to the clarity of the paper, not to pad it out. At all times, please try to think about your readers, who will not all be specialists in your discipline.

5. Manuscript

(a) *General*

The manuscript must be in English; UK English spellings and words should be used in preference to other versions of English. It must be word-processed, double-spaced throughout, with a 4 cm margin on the left side, with no 'headers and footers' (other than page numbers), and without footnotes unless these are absolutely necessary. Arrange the manuscript under headings (such as Introduction, Methods, Results, Discussion, Conclusions) and subheadings. Ideally, the main body of the text should not exceed 4,000 words, excluding references. Longer manuscripts may be accepted at the discretion of the respective Section Editor. Authors must make every effort to ensure that manuscripts are presented as concisely as possible. The Editors cannot consider for publication papers that are seriously deficient in presentation or that depart substantially from these 'Notes and Guidelines'.

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The Journal will accept only papers that conform to the highest standards of ethics and participant protection. All experimental work in which humans are participants must conform to the laws of the country in which the work took place. The manuscript should contain a statement to the effect that the work reported has been approved by a recognised ethics committee or review board. There are two exceptions: 1. Where information is in the public domain such as on a website that contains statistical or other archive-type data, formal ethics approval is not necessarily a requirement but a statement about the source of the data must be made. 2. Retrospective analysis of data, such as those produced as a result of long-term monitoring of athletes that provides information worthy of broadcast to a wider audience: reporting of these data is seen as exceptional. The Journal's clear preference is for prior approval of experimental work, but it is recognised that information can arise from local applied sport science work that has not had prior ethics approval. In such instances, it must be made clear that data were collected as part of an athlete monitoring program and that none of the measurements was made for research purposes: authors must provide a detailed explanation of the absence of formal ethics approval. Normally, statements about ethics approval or sources of data should be made at the beginning of the methods section.

(c) *Anonymous refereeing*

Because of the adoption of anonymous refereeing by the Journal with effect from 1 January 1998, the title page and manuscript should include no information that clearly identifies the authors or their affiliations. Authors should submit a separate cover letter, which is not part of the manuscript, that can include the following information: the full title; the names of the authors without qualifications or titles; the affiliations and full addresses of the authors; the name, address, telephone and fax numbers, and e-mail address of the author responsible for all correspondence and correction of proofs. Any acknowledgements should also appear on this page, not in the manuscript. These acknowledgements will appear in the printed version if the manuscript is accepted.

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Include the following information on the first page of the manuscript: the full title; a running title of no more than 75 characters and spaces; and up to five keywords for indexing purposes.

(e) *The abstract*

The abstract must not exceed 200 words and it must summarize the paper, giving a clear indication of the conclusions it contains.

(f) *Tables and illustrations*

Illustrations and tables must accompany the manuscript but not be included in the text. Authors may wish to express a preference for the location of tables and figures by including comments such as ****Table 1 near here**** or ****Figure 2 near here**** separated by at least one line space from the main text. Tables, referred to as 'Table 1', 'Table 2', and so on, must be numbered in the order in which they occur in the text. Tables must be clearly and simply laid out with clear row and column legends, units where appropriate, no vertical lines and horizontal lines only between the table title and column headings, between the column headings and the main body of the table, and after the main body of the table.

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Routledge

Changes in running economy at different intensities following downhill running

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Abstract

In this study, we tested the hypothesis that running economy assessed at a high intensity [e.g. 90% maximal oxygen capacity ($\dot{V}O_{2max}$)] would be affected more than at a lower intensity (e.g. 70% $\dot{V}O_{2max}$) after downhill running. Fifteen untrained young men performed level running at 70, 80, and 90% $\dot{V}O_{2max}$ (5 min for each intensity) before and 2 and 5 days after a 30-min downhill run (gradient of −16%) at the intensity of their pre-determined 70% $\dot{V}O_{2max}$. Oxygen consumption, minute ventilation, respiratory exchange ratio, heart rate, rating of perceived exertion, and blood lactate concentration were measured during the level runs together with kinematic measures (e.g. stride length and frequency) using high-speed video analysis. Downhill running resulted in significant ($P < 0.05$) decreases in maximal isometric strength of the knee extensors, the development of muscle soreness, and increases in plasma creatine kinase activity and myoglobin concentration, which lasted for 5 days after downhill running. Significant ($P < 0.05$) changes in all running economy and kinematic measures from baseline were evident at 2 and 5 days after downhill running at 80% and 90% $\dot{V}O_{2max}$, but not at 70% $\dot{V}O_{2max}$. These results suggest that running economy assessed at high intensity is affected more than at low intensity (lower than the lactate threshold).

Keywords: *Muscle damage, muscle strength, running performance, oxygen consumption, blood lactate concentration*

Introduction

Exercise-induced muscle damage is characterized by a prolonged decrease in muscle strength, delayed-onset muscle soreness, and increases in muscle proteins such as creatine kinase (Clarkson, Nosaka & Braun, 1992). Muscle damage also appears to affect running economy, which is generally defined as oxygen consumption ($\dot{V}O_2$) at a constant sub-maximal running velocity (Braun & Dutto, 2003; Chen, Nosaka, & Tu, 2007b). However, in the literature controversy exists about the effect of muscle damage on running economy (Braun & Dutto, 2003; Chen et al., 2007b; Hamill, Freedson, Clarkson, & Braun, 1991; Paschalis et al., 2005, 2008; Scott, Rozenek, Russo, Crussemeyer, & Lacourse, 2003).

Some studies reported no significant effect of muscle damage on running economy during sub-maximal (55–75% $\dot{V}O_{2max}$) treadmill running after free-weight lower body resistance exercises (Scott et al., 2003) or maximal eccentric exercise of the knee extensors on an isokinetic dynamometer (Paschalis et al., 2005, 2008) using untrained participants. Hamill et al. (1991) showed that downhill running did not affect $\dot{V}O_2$ during a run at 80% $\dot{V}O_{2max}$ in healthy female recreational runners, although it resulted in small alterations in lower body kinematics and minor muscle damage. In contrast, Braun and Dutto (2003) and Chen et al. (2007b) showed that running economy during sub-maximal treadmill running (65, 75, and 85% $\dot{V}O_{2peak}$) was significantly reduced for 3 days after downhill running in trained individuals who had signs of muscle damage.

It would appear that the intensity of the running economy test and magnitude of muscle damage are important. The intensities (55–75% $\dot{V}O_{2max}$) of running economy tests in studies that did not find a significant effect of muscle damage on running economy (Paschalis et al., 2005, 2008; Scott et al., 2003) were likely to be under the lactate threshold. It

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may be that the effect of muscle damage on running economy is intensity dependent, and the higher the intensity, the greater the effect. However, this has not previously been investigated systematically. Regarding the magnitude of muscle damage, it could be that the damage to the muscles used in a running economy test was not severe enough to observe changes in running economy in some studies (Hamill et al., 1991; Scott et al., 2003). It is likely that larger decreases in running economy will be seen when greater muscle damage is induced by downhill running that is performed by individuals who are more susceptible to muscle damage.

In the present study, therefore, we compared three different intensities (below the lactate threshold: 70% $\dot{V}O_{2max}$; at the lactate threshold: 80% $\dot{V}O_{2max}$; and above the lactate threshold: 90% $\dot{V}O_{2max}$) for changes in running economy after downhill running in untrained individuals. It was hypothesized that running economy would be reduced by downhill running, but that running economy assessed at a high intensity (e.g. 90% $\dot{V}O_{2max}$) would affected to a greater extent than that at a lower intensity (e.g. 70% $\dot{V}O_{2max}$).

Methods

Participants and general procedures

Fifteen adult males who had not participated in resistance and endurance training or recreational sport activities (e.g. hiking, soccer, volleyball) in the previous year were recruited to the study, which had the approval of the institutional ethics committee. They provided written informed consent by completing a university-approved document before their participation, in conformity with the Declaration of Helsinki. Their mean ($\pm s$) age, stature, body mass, and maximal aerobic capacity ($\dot{V}O_{2max}$) were 21.5 ± 1.6 years, 1.72 ± 0.06 m, 64.8 ± 8.4 kg, and 49.8 ± 5.4 ml · kg^{-1} · min^{-1}, respectively. Maximal aerobic capacity was determined by a graded maximal treadmill test on a motor-driven treadmill (Valiant, Lode BV, Groningen, Netherlands) and an automated gas analysis system (Vmax29c, SensorMedics Corp., Yorba Linda, CA, USA) using the same protocol as described previously (Chen et al., 2007b; Chen, Nosaka, & Wu, 2008). All participants were requested not to perform any unaccustomed exercise or vigorous physical activity, and not to take any anti-inflammatory agents or nutritional supplements, during the experimental period.

All participants were familiarized with treadmill running for the determination of $\dot{V}O_{2max}$ and running economy 1 and 2 days before the $\dot{V}O_{2max}$ test, which was performed a week before the downhill running. Baseline running economy and kinematic parameters described below were assessed 5 and 2 days before downhill running, and at 2 and 5 days after downhill running. Maximum voluntary isometric contraction strength (MVC) of the knee extensors and muscle soreness were measured 3 and 1 days before downhill running, and the baseline blood sample for the measurement of plasma creatine kinase activity and myoglobin concentration was also taken 3 and 1 days before downhill running. These measures were repeated immediately after and for five consecutive days after downhill running at approximately the same time of day. During the recovery days (0–5 days after downhill running), the order of the measurements was standardized as follows: blood sampling, muscle soreness, MVC, and running economy and kinematic variables described below. The average of the values from the two testing days was used as the pre-exercise value for muscle soreness, MVC, parameters of running economy, and kinematic variables.

Downhill running

All participants performed a 30-min downhill run on the motor-driven treadmill. The downhill running protocol was the same as that reported previously (Chen et al., 2007b, 2008). After general stretching for 10 min, the participants performed level running on the treadmill for 5 min at a velocity equivalent to 70% of their pre-determined $\dot{V}O_{2max}$ (143.3 ± 20.2 m · min^{-1}) as a warm-up exercise followed immediately by downhill running. The gradient of the treadmill for the downhill run was −16% (−9°). Each participant ran at 70% of his pre-determined $\dot{V}O_{2max}$ for 2 min and the velocity was adjusted in the next 1–2 min (within 5 min of the beginning of downhill running) to obtain each participant's pre-determined 70% $\dot{V}O_{2max}$ target. The velocity thereafter remained unchanged until the completion of downhill running. The average velocity during downhill running (5–30 min) was 194.5 ± 32.4 m · min^{-1}, while the average $\dot{V}O_2$ during downhill running was 35.6 ± 3.9 ml · kg^{-1} · min^{-1}, which was $70.1 \pm 3.9\%$ of $\dot{V}O_{2max}$.

Indicators of muscle damage

Muscle damage markers consisted of MVC of the knee extensors, perceived muscle soreness, plasma creatine kinase activity, and myoglobin concentration.

Maximum voluntary isometric contraction strength. Maximum voluntary isometric contraction strength of the left knee extensors was assessed at 90° (1.57 rad; full knee extension = 0°) on a calibrated isokinetic dynamometer (Biodex System 3 Pro; Biodex Medical Systems, Inc., Shirley, NY, USA). The participants were seated in an upright position with the trunk at approximately 90° of flexion, and with restraining straps crossed over the upper trunk (chest), hip, and thigh. The gravity corrections for limb mass were performed before each isometric assessment in accordance with the manufacturer's instructions (Biodex Pro Manual, Applications/Operations, Biodex Medical Systems, Inc., Shirley, NY, USA). The knee joint was aligned with the axis of rotation of the dynamometer, and the leg was secured to the dynamometer arm at the ankle. For all tests, the participants were asked to perform three maximal isometric contractions for 3 s each, with 1 min between contractions. Peak torque was identified for each contraction by the dynamometer software (Biodex System 3 Advantage Software, Biodex Medical Systems, Inc., Shirley, NY, USA), and the average of the three contractions was recorded for further analysis.

Muscle soreness. Muscle soreness was assessed using a visual analogue scale consisting of a 100-mm continuous line anchored by "no pain" (0 mm) and "very, very painful" (100 mm) (Chen, Nosaka, & Sacco, 2007a). Since previous studies (Chen et al., 2007b, 2008) did not report any differences between legs in the muscle soreness assessment after downhill running, the measurements were taken from the left leg only in the present study. Participants were asked to record the severity of muscle soreness of the anterior thigh and shank, posterior thigh and shank, and hip regions of their left leg immediately after they performed stepping on a 40-cm box five times on each occasion (Chen et al., 2007b, 2008). The sum of the values from the five regions, where 500 was the maximum value, was used for further analysis.

Blood analysis. Approximately 10 ml of blood were drawn from the antecubital vein by a standard venepuncture, and centrifuged for 10 min to obtain plasma. Plasma samples were stored for 2–4 weeks at −20°C until analysis for creatine kinase activity and myoglobin concentration. Plasma creatine kinase activity was determined spectrophotometrically by an automated clinical chemistry analyser (Model 7080, Hitachi, Co. Ltd., Tokyo, Japan) using a test kit (Sigma Diagnostics, St. Louis, MO, USA). Plasma myoglobin concentration was assessed by a biochemical analyser (Model ADVIA-Centaur, Bayer Co. Ltd., Leverkusen, Germany) using a test kit (Denka-Seiken Co. Ltd., Tokyo, Japan). Samples were analysed in duplicate, and the mean of the two measures was used for statistical analysis. The normal reference ranges for creatine kinase and myoglobin are 38–174 $IU \cdot l^{-1}$ and <110 $\mu g \cdot l^{-1}$, respectively, according to the information provided in the kit.

Parameters of running economy

Running economy parameters consisted of $\dot{V}O_2$, minute ventilation, respiratory exchange ratio, heart rate, and rating of perceived exertion. After the same warm-up exercise as that performed before downhill running, participants performed level running at 70%, 80%, and 90% of pre-determined $\dot{V}O_{2max}$ (5 min for each intensity separated by a 10-min recovery between different intensities) in a randomized order, 5 and 2 days before, and 2 and 5 days after, downhill running. A pilot study showed that heart rate and $\dot{V}O_2$ returned to similar values within 10 min of level running regardless of the intensities, and the effect of one level run on the next intensity appeared to be minimal. Based on previous research (Paschalis et al., 2005, 2008; Scott et al., 2003) and our pilot study, the present study adopted three intensities: 70%, 80%, and 90% $\dot{V}O_{2max}$ based on the assumption that 70% $\dot{V}O_{2max}$ would be below the lactate threshold, 80% $\dot{V}O_{2max}$ would be close to the lactate threshold, and 90% $\dot{V}O_{2max}$ would be above the lactate threshold. This was confirmed by the blood lactate concentrations measured after each level run. The treadmill velocities for the three intensities were determined for each participant, and the same velocities were used for the three level runs during the experimental period. The average treadmill velocity for 70%, 80%, and 90% $\dot{V}O_{2max}$ was $143.3 \pm 20.2\ m \cdot min^{-1}$, $172.6 \pm 23.4\ m \cdot min^{-1}$, and $204.4 \pm 25.5\ m \cdot min^{-1}$, respectively.

During running, expired gases were collected continuously using an automated gas analysis system (Vmax29c, SensorMedics Corp., Yorba Linda, CA, USA). It was confirmed that a steady state in the $\dot{V}O_2$ response was obtained within the first 3 min for all intensities, and thus the average of the last 60 s was used to represent running economy. Heart rate was recorded by short-wave radio telemetry (Polar S610 monitor, Kempele, Finland) during level running, and the mean value of the last 60 s of each intensity was used for further analysis. Ratings of perceived exertion were assessed during the last 20 s of each intensity using a Borg scale (Borg, 1970).

Blood lactate concentration was measured by a portable Lactate-Pro analyser (Lactate Pro™, Tester Meter, Arkray Inc., Kyoto, Japan) before level running, and 3 min after running at each intensity (70, 80, and 90% $\dot{V}O_{2max}$), using fingertip blood samples.

Kinematics measures

Sagittal plane images of level running were recorded for 10 s between 3 and 4 min at each intensity by a video camera (GR-DVL9800U, JVC Co., Kanagawa, Japan) at 120 Hz. Stride length, stride frequency, and range of motion of the ankle, knee, and hip joints were determined using the Ariel Performance Analysis System (Ariel Dynamics Inc., NJ, USA), following the method described by Chen et al. (2007b).

Reliability

The values of the criterion measures (MVC, muscle soreness, running economy parameters) obtained from the 15 participants taken on two different days before downhill running were compared by a paired *t*-test, and the test–retest reliability of these variables was assessed by coefficients of variation. The paired *t*-test showed no significant differences between days for any measures, with the coefficients of variation for MVC, muscle soreness, creatine kinase, and myoglobin being 9.8%, 0.0%, 9.3%, and 10.4%, respectively. The coefficients of variation for $\dot{V}O_2$, minute ventilation, respiratory exchange ratio, heart rate, rating of perceived exertion, lactate concentration, stride length, stride frequency, hip range of motion, knee range of motion, and ankle range of motion at different intensities (70%, 80%, 90% $\dot{V}O_{2max}$) were 3.3–3.8%, 6.2–8.2%, 1.1–3.1%, 3.1–4.7%, 4.4–5.4%, 6.5–7.4%, 5.5–6.4%, 3.0–3.4%, 4.7–7.4%, 3.7–6.1%, and 4.9–6.4%, respectively.

Statistical analysis

Changes in MVC, muscle soreness, plasma creatine kinase activity, and myoglobin concentration over time (before, immediately after, and 1–5 days after downhill running) were analysed by repeated-measures one-way analysis of variance (ANOVA). Changes in $\dot{V}O_2$ during a 5-min level run at each intensity before, and 2 and 5 days after, downhill running were analysed by one-way repeated-measures ANOVA to determine when a steady state in $\dot{V}O_2$ was achieved. Changes in running economy parameters and kinematic measures during level running were also analysed by a one-way ANOVA with repeated measures for each intensity separately. When a significant time effect was found, a Scheffé *post-hoc* test was conducted to determine where it was significantly from baseline. Changes in $\dot{V}O_2$, minute ventilation, respiratory exchange ratio, heart rate, and rating of perceived exertion (the average value of the final minute of the 5 min of level running) before, and 2 and 5 days after, downhill running were compared among the three intensities (70%, 80%, and 90% $\dot{V}O_{2max}$) by two-way repeated-measures ANOVA. Changes in the kinematic measures (stride length, stride frequency, and ankle, knee, and hip range of motion) before, and 2 and 5 days after, downhill running were also compared among the intensities by two-way repeated-measures ANOVA. If the ANOVA revealed a significant interaction effect (intensity × time), a Scheffé *post-hoc* test was performed to check the difference at each time point. Statistical significance was set at $P < 0.05$. Data are presented as means ± standard deviations unless otherwise stated.

Results

Indicators of muscle damage

Table I shows changes in the muscle damage indicators over time after downhill running. Downhill running resulted in significant ($P < 0.05$) development of muscle soreness, decreases in peak MVC, and increases in plasma creatine kinase activity and myoglobin concentration that lasted for 5 days after downhill running.

Changes in running economy after downhill running

Figure 1 shows changes in $\dot{V}O_2$ during the 5-min running economy test before, and 2 and 5 days after, downhill running for the different intensities (70%, 80%, and 90% $\dot{V}O_{2max}$). Steady-state $\dot{V}O_2$ was achieved within 3 min of the start for all intensities

Table I. Changes in maximal voluntary contraction strength of the knee extensors (MVC), muscle soreness (sum of the scores of five regions), and plasma creatine kinase activity and myoglobin concentration (mean ± *s*, *n* = 15) before (baseline), immediately after (0), and 1–5 days after downhill running.

	Time (day)						
	Baseline	0	1	2	3	4	5
MVC (N · m)	209.5 ± 20.5	151.8 ± 41.0*	154.6 ± 44.9*	162.5 ± 53.3*	163.2 ± 49.7*	168.9 ± 47.3*	173.6 ± 45.3*
Soreness (mm)	0.0 ± 0.0	29.2 ± 34.3*	113.9 ± 78.6*	119.3 ± 74.3*	89.3 ± 63.0*	41.6 ± 49.0*	17.9 ± 28.1*
Creatine kinase (IU · l⁻¹)	115.9 ± 10.8	230.8 ± 136.9*	762.8 ± 550.6*	818.4 ± 598.4*	666.5 ± 475.8*	621.3 ± 555.9*	501.7 ± 434.8*
Myoglobin (μg · l⁻¹)	33.5 ± 3.5	155.7 ± 100.4*	273.7 ± 214.6*	242.3 ± 176.4*	209.1 ± 136.3*	177.4 ± 109.8*	147.4 ± 87.6*

*Significant ($P < 0.05$) difference from baseline values.

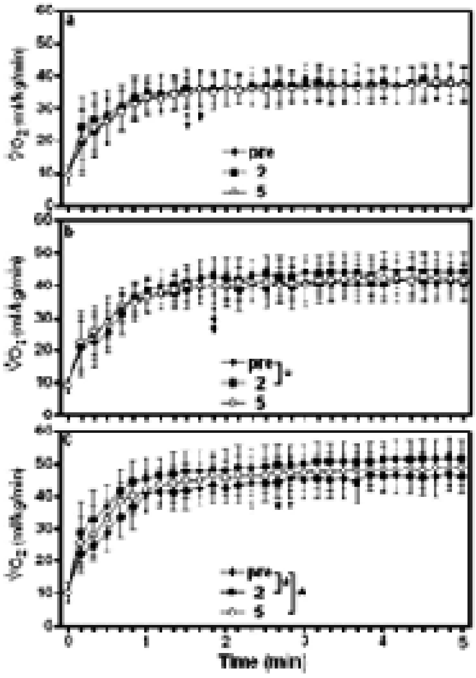

Figure 1. Changes in $\dot{V}O_2$ (mean ± s) during 5 min of level running at intensities of (a) 70%, (b) 80%, and (c) 90% $\dot{V}O_{2max}$ before (pre), and 2 and 5 days after, downhill running. *Significant ($P < 0.05$) interaction (day × time) effect. The arrows (†: before; †: 2 days after; †: 5 days after) indicate the points at which a steady state was achieved.

regardless of the test occasion, although the time taken to reach the steady state increased with increasing intensity. When comparing between days, no significant difference was evident for the 70% intensity; however, a significant difference was evident between baseline and 2 days after downhill running for the 80% intensity, and between baseline and both 2 and 5 days after downhill running for the 90% intensity.

Figure 2 shows changes in all running economy parameters before, and 2 and 5 days after, downhill running. Minute ventilation, $\dot{V}O_2$, respiratory exchange ratio, heart rate, rating of perceived exertion, and blood lactate concentration increased significantly ($P < 0.05$) both 2 and 5 days after downhill running for the 80% and 90% running intensities, but this was not the case for the 70% intensity. For example, $\dot{V}O_2$ increased by 12% (2 days after downhill running) and 5% (5 days after downhill running) from baseline for 90% $\dot{V}O_{2max}$, and by 7% (2 days after downhill running) and 2% (5 days after downhill running) for 80% $\dot{V}O_{2max}$, with the magnitude of increase being significantly greater for the 90% than the 80% intensity (Figure 2a). The changes in other running economy parameters except for minute ventilation were also significantly greater for the 90% $\dot{V}O_{2max}$ than 80% $\dot{V}O_{2max}$.

Changes in kinematic measures after downhill running

Table II shows normalized changes in the kinematic variables from baseline values in the 5-min running economy test 2 and 5 days after downhill running for all three intensities (70%, 80%, and 90% $\dot{V}O_{2max}$). No significant changes in the variables were evident for 70% $\dot{V}O_{2max}$. In contrast, stride frequency and the other variables (stride length, and ankle, knee and hip range of motion) showed significant ($P < 0.05$) increases and decreases, respectively, from baseline 2 and 5 days after downhill running for the 80% and 90% intensities. For example, stride length decreased by 8% (2 days after downhill running) and 4% (5 days after downhill running) for 90% $\dot{V}O_{2max}$, and by 4% (2 days after downhill running) and 2% (5 days after downhill running) for 80% $\dot{V}O_{2max}$, with the magnitude of decrease being significantly greater for the 90% than the 80% intensity. The changes in the parameters following downhill running were significantly greater for 90% $\dot{V}O_{2max}$ than 80% $\dot{V}O_{2max}$ for the other variables also.

Discussion

The main purpose of the present study was to compare changes in running economy among level runs at three different intensities (70%, 80%, and 90% $\dot{V}O_{2max}$) after downhill running performed by untrained individuals. The development of muscle soreness, loss of muscle strength, and increases in plasma creatine kinase activity and myoglobin concentration after downhill running (Table I) indicate muscle damage (Braun & Dutto, 2003; Byrne, Twist, & Eston, 2004; Chen et al., 2007b, 2008). Based on the indirect markers of muscle damage (MVC, muscle soreness, creatine kinase, and myoglobin), the magnitude of muscle damage induced by the downhill running in the present study appeared to be greater than that in a previous study in which the same downhill running was performed (Chen et al., 2007b). The difference in the magnitude of muscle damage was likely due to the different samples used, such that the present study used untrained individuals whereas Chen et al. (2007b) used trained soccer players. The effect of downhill running on changes in running economy and kinematic measures (Figure 2, Table II) also appeared to be greater in the present study than that of Chen et al. (2007b). It is likely that the greater

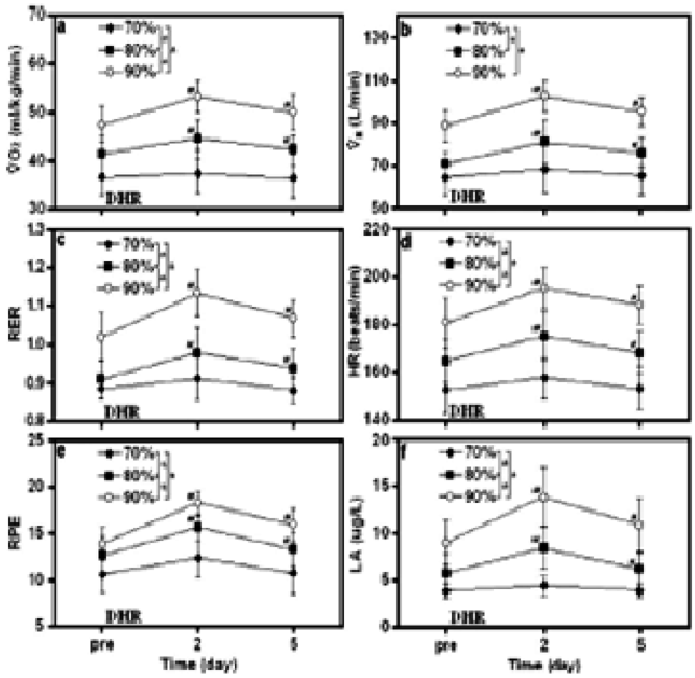

Figure 2. Changes (mean ± *s*) in (a) $\dot{V}O_2$, (b) minute ventilation ($\dot{V}_E$), (c) respiratory exchange ratio (RER), (d) heart rate (HR), and (e) rating of perceived exertion (RPE) during 5 min of level running, and (f) blood lactate concentration (LA) 3 min after 5 min of level running at 70%, 80%, and 90% $\dot{V}O_{2max}$ before (pre), and 2 and 5 days after, downhill running (DHR). *Significant ($P < 0.05$) interaction (intensity × time) effect. #Significant ($P < 0.05$) difference from baseline (pre) values.

muscle damage induced in the present study contributed to the larger decreases in running economy compared with previous studies (Braun & Dutto, 2003; Chen et al., 2007b).

Before discussing the results further, it is important to confirm if steady-state $\dot{V}O_2$ was achieved during the 5-min level run in the running economy test for all intensities, and whether the average of the last one minute of data for the running economy parameters represented changes in running economy after downhill running. As shown in Figure 1, $\dot{V}O_2$ reached a steady state in the first 3 min for all intensities, and no drift in $\dot{V}O_2$ was evident even for the high-intensity running. Thus, it would appear that the last minute of each intensity represents the steady state. It is also important to note that muscle damage did not affect the time taken to reach a steady state in $\dot{V}O_2$, although one might assume that muscle damage would delay the achievement of a steady state.

As shown in Figure 2 and Table II, significant changes in running economy and kinematic measures 2 and 5 days after downhill running were observed for the 80% and 90% intensities but not for the 70% intensity. Previous studies (Paschalis et al., 2005, 2008; Scott et al., 2003) that did not report a significant effect of muscle damage on running economy used a relatively low intensity of running to assess running economy (e.g. 55–75% $\dot{V}O_{2max}$). It would appear that the effect of muscle damage on running economy depends on the intensity of the running economy test. It is possible that no significant effect of muscle damage on running economy found in previous studies (Hamill et al., 1991; Paschalis et al., 2005, 2008; Scott et al., 2003) was due either to the low intensity of running used to assess running economy or minor muscle damage induced by exercise, which did not affect the muscles used in the running economy test.

It may be that the significant effect of muscle damage on running economy at high intensities (80% and 90%) was related to a difference in muscle fibre recruitment between the 70% and higher intensities. It should be noted that the blood lactate concentration after the level run at 70% $\dot{V}O_{2max}$ was close to 4 mmol · l^{-1}, but it was above 4 mmol · l^{-1}

Table II. Changes in stride length, stride frequency, range of motion of the ankle, knee, and hip joints during level running at 70%, 80%, and 90% $\dot{V}O_{2max}$ intensities before (baseline), and 2 and 5 days after, downhill running.

	Time (day)		
Measures	Before	2	5
Stride length (m · stride^{-1})			
70%	100 (*1.73 ± 0.11*)	98.4 ± 4.0	99.5 ± 3.5
80%[*]	100 (*2.00 ± 0.11*)	95.9 ± 1.9[#]	97.8 ± 1.5[#]
90%[*]	100 (*2.33 ± 0.14*)	92.4 ± 2.2[#]	96.3 ± 2.6[#]
Stride frequency (steps · s^{-1})			
70%	100 (*2.68 ± 0.08*)	101.7 ± 4.2	100.6 ± 3.5
80%[*]	100 (*2.77 ± 0.09*)	104.4 ± 2.0[#]	102.4 ± 1.8[#]
90%[*]	100 (*2.84 ± 0.10*)	107.5 ± 2.3[#]	103.9 ± 1.6[#]
Hip range of motion (°)			
70%	100 (*19.85 ± 1.47*)	96.8 ± 2.8	98.3 ± 2.9
80%[*]	100 (*21.59 ± 1.26*)	93.2 ± 3.8[#]	96.2 ± 3.9[#]
90%[*]	100 (*24.51 ± 1.16*)	91.0 ± 3.7[#]	94.4 ± 2.8[#]
Knee range of motion (°)			
70%	100 (*66.98 ± 2.25*)	97.9 ± 3.7	98.5 ± 3.1
80%[*]	100 (*67.99 ± 3.79*)	94.7 ± 2.0[#]	96.9 ± 3.1[#]
90%[*^]	100 (*74.05 ± 4.49*)	90.7 ± 2.1[#]	94.8 ± 2.1[#]
Ankle range of motion (°)			
70%	100 (*40.37 ± 2.28*)	97.9 ± 4.9	98.7 ± 3.3
80%[*]	100 (*41.08 ± 2.02*)	92.5 ± 2.6[#]	94.8 ± 2.2[#]
90%[*]	100 (*43.35 ± 2.79*)	90.4 ± 3.3[#]	93.9 ± 3.1[#]

Note: For before downhill running, absolute values (mean ± *s*, *n* = 15) are shown, and normalized changes from the baseline value (percentage of baseline value) are shown for the days after downhill running.
[*]Significant difference ($P < 0.05$) from 70% $\dot{V}O_{2max}$. [^]Significant difference ($P < 0.05$) from 80% $\dot{V}O_{2max}$. [#]Significant difference ($P < 0.05$) from baseline.

for the other two intensities (Figure 2f). This indicates that the level run at 80% and 90% $\dot{V}O_{2max}$ were performed above the lactate threshold. It has been documented that type I fibres are recruited predominantly at intensities below the lactate threshold, but that type II fibres are recruited at intensities above the lactate threshold (Abernethy, Thayer, & Taylor, 1990; Gollnick, Karlsson, Piehl, & Saltin, 1974). As shown in Table I, MVC was lower than at baseline by 22% and 17% two and five days after downhill running, which indicates muscle damage. Increases in plasma creatine kinase activity and myoglobin concentration (Table I) also indicate that the muscle fibres were damaged (Chen et al., 2007b; Marqueste, Giannesini, Fur, Cozzone, & Bendahan, 2008). It has been shown that type II fibres are more susceptible to eccentric exercise-induced muscle damage than type I fibres (Fridén, Sjöstrom, & Ekblom, 1983). It could be that more type II fibres were recruited during the high-intensity runs (i.e. 80%, 90%) compared with that before downhill running. The greater increases in lactate after downhill running found for the 80% and 90% intensities (Figure 2f) may reflect a greater contribution of anaerobic metabolism (Braun & Dutto, 2003; Gleeson, Blannin, Zhu, Brooks, & Cave, 1995). In contrast, at the lower intensity (i.e. 70%), it is possible that the recruitment of type II muscle fibres was limited and it was not necessary to increase their recruitment. This might be the reason why no effect of muscle damage on running economy at 70% $\dot{V}O_{2max}$ was evident.

The decreases in running economy at 80% and 90% $\dot{V}O_{2max}$ can also be associated with the changes in kinematic parameters (Table II). Avela and Komi (1998) found that the decreased muscle performance after marathon running was due to impairment of the ability to utilize elastic energy. Byrne and Eston (2002) have also reported that the ability to utilize elastic energy decreases following a high-intensity squat exercise (10 sets of 10 repetitions with a 70% body mass load). The significant decreases in stride length together with the significant decreases in range of motion of the ankle, knee, and hip joints when running at high intensities (Table II) suggests that the amount of elastic energy stored was attenuated. In fact, stride frequency was increased significantly after downhill running at 90% $\dot{V}O_{2max}$ (Table II). This suggests that more energy is required to keep running at the same high intensity.

The results of the present study suggest that muscle damage could have a greater effect on endurance performance at high than at low intensity. It is possible that muscle damage induced by training impairs high-intensity endurance running performance. It could be that the performance of team sports athletes is affected by muscle damage because of not only a decrease in muscle strength and power but also a decrease in endurance performance. This should be considered by coaches and exercise practitioners when they design training schedules before competitions or games.

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