320. Electrovibrostimulation During the Training of Sportsmen, an Experimental Set-up

Koos Jaap Van Zwieten[1], Iris Verhaegen[1], Bert Op 'T Eijnde [2], Anatoly Zinkovsky [3], Irina Zubova[3], Klaus Schmidt[1] and Peter Lippens[1]

[1]University of Hasselt, Department of Basic Medical Sciences, Human Movement Studies, BioMed Institute, B-3590 Diepenbeek, Agoralaan, phone: + 32 (0)11 26 85 05, fax: + 32 (0)11 26 85 99, **e-mail:** *koosjaap.vanzwieten@uhasselt.be*

[2]Provinciale Hogeschool Limburg, Department of Health Care Sciences, REVAL Research Institute, B-3500 Hasselt, Guffenslaan 39, phone: + 32 (0)11 29 49 81, fax: + 32 (0)11 29 49 53, **e-mail:** *Bopteijnde@mail.phl.be*

[3]Saint-Petersburg State Polytechnic University, Department of Biomechanics, 195220 Saint-Petersburg, Grashdanski Prospect 28, phone and fax: + 7 (812) 534 13 64, **e-mail:** *bioval@imop.spbstu.ru*

(Received 3 September 2007; accepted 22 October 2007)

Abstract. In this study the effects of electrovibrostimulation training are compared with classical powertraining, in a group of 18-24 years old healthy sportsmen, during the spring season of 2007.

Former studies showed the effectiveness of electrovibrostimulation on the functional condition of muscles: increase of the strength in the active insufficiency zone and increase of the elasticity in the passive insufficiency zone, consequently improving joint strength and mobility. After four weeks of electrovibrostimulation, applied twice a week, significant increases of isometric strength and explosive strength were observed, whereas the flexibility remained the same. Some hypotheses are discussed concerning the possible working mechanisms of electrovibrostimulation.

Keywords: Sportsmen training, whole body vibration, electrovibrostimulation, musculoskeletal apparatus.

Introduction

During the preparation of prominent team sports events, such as the annual Hasselt Students Regatta at Hasselt, Belgium, it was necessary to train rowing team members effectively within a relatively short period of time [8], [10]. On this occasion, during the spring trimester of 2007, it was decided to set up a study to compare the effect of the usual training of these and other sportsmen, with such training assisted by electrovibrostimulation. Recently, a series of publications demonstrated the importance of electro-vibrostimulation training with respect to the human skeletal-muscular apparatus [1]-[4]. Several authors since have suggested that for healthy sportsmen, the combination of electrostimulation and vibrostimulation might be useful to increase their strength, both in terms of endurance and power bursts [5]-[7]. This may be especially the case in powertraining and endurance training during the rowing season [8]. Contrary to the current concept of training the agonist muscles by whole body vibration, it was interesting to return to the original experimental set-up by Zinkovsky and co-workers, who trained the antagonist muscles of sportsmen by vibration, whilst training their agonist muscles and synergist muscles by electrostimulation [1]-[6], [9, *in litt.*].

Analysed material

The purpose of this study was to perform a comparison between classical powertraining and electrovibration training for sportsmen. Therefore 26 healthy volunteers with ages from 18-24 years old were selected.

As a prerequisite, all of them had to be involved in some team sport currently, like athletics, soccer, handball, rowing, and followed a training scheme of at least twice a week. Exclusion criteria were similar to those indicated by literature [5], [9, *in litt.*].

These 26 subjects were divided randomly into 3 groups: an electrovibrostimulation group, a placebo group, and a control group which continued its usual training. These groups contained 11, 10 and 5 subjects respectively.

This study design, involving human subjects, was approved by the Committee for Medical Ethics of the University of Hasselt, Belgium.

Applied methods

The study consisted of 3 consecutive parts :

1) Prestudy

Before the intervention, the 26 subjects underwent measurements of the isometric quadriceps femoris muscle strength, by means of a simple mechanical force gauge meter. Flexibility assessment of hamstring muscles was done by means of a sit-and-reach test (Sporta De Waele®), and explosive power burst capacity of both quadriceps and gastrocnemius muscles was measured by means of a vertical jump meter (Takei Jump-MD®).

2) Intervention

In this part of the study, only the first and the second group participated i.e. the electrovibrostimulation group (11 subjects) and the placebo group (10 subjects). Vibration of both hamstrings and foot- and ankle extensors as the antagonists was performed on a FitVibe® platform, as shown in Figure 1, while electrostimulation of both quadriceps and gastrocnemius muscles as the agonists took place by means of Myaction Med® devices, shown in Figure 2.

Fig. 1. FitVibe® for Whole Body Vibration (left) and operation panel (right) with electrostimulation devices lying on the vibration platform

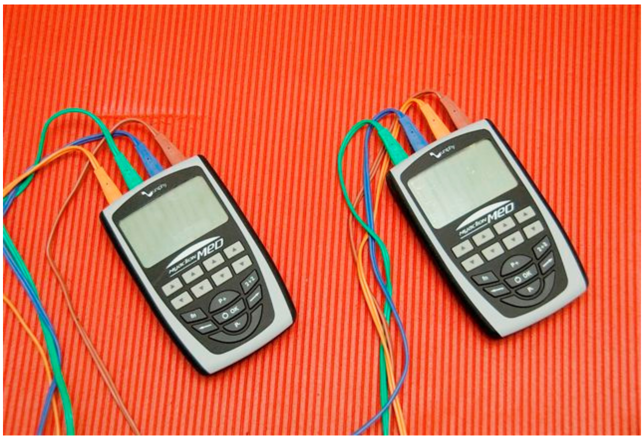

Fig. 2. Myaction Med® devices for electrostimulation

The intervention took up to 4 weeks, during which these 26 subjects had to train twice a week. The trainings were divided as follows :

Electrovibrostimulation group

- 5 minutes cycling on a home-trainer, as a warming-up of the muscles.
- exercising during electrovibrostimulation.

These exercises took place with feet unshoed, so that the vibrations were not damped differently in people wearing different kinds of shoes. This set-up is shown in Figure 3.

Placebo group

- 5 minutes cycling on a home-trainer, as a warming-up of the muscles.
- exercising without electrovibrostimulation.

The exercises were performed under identical conditions as for the electrovibrostimulation group, but with the respective devices switched off.

Reference group

The reference group consisting of 5 subjects exercised according to their usual powertraining scheme.

3) Poststudy

After the intervention the 26 subjects again underwent measurements of the isometric quadriceps femoris muscle strength, by means of a mechanical force gauge meter. Flexibility assessment of hamstring muscles was done by means of the sit-and-reach test again, and explosive power burst capacity of both quadriceps and gastrocnemius muscles was measured by means of the vertical jump meter.

Results

For the isometric strength there is a significant increase in the electrovibrostimulation group ($p < 0{,}001$). As also shown in Figure 4, this isometric strength is not significantly increased in the placebo group and the reference group. In the average values of flexibility in the three groups there is no significant modification, as indicated in Figure 5. As for the explosive strength, a significant increase in explosive strength is noticed in the electrovibrostimulation group ($p < 0{,}001$). The explosive strength is not significantly increased in the placebo group and in the reference group. This is shown in Figure 6.

Fig. 3. Vibration combined with simultaneous electrostimulation

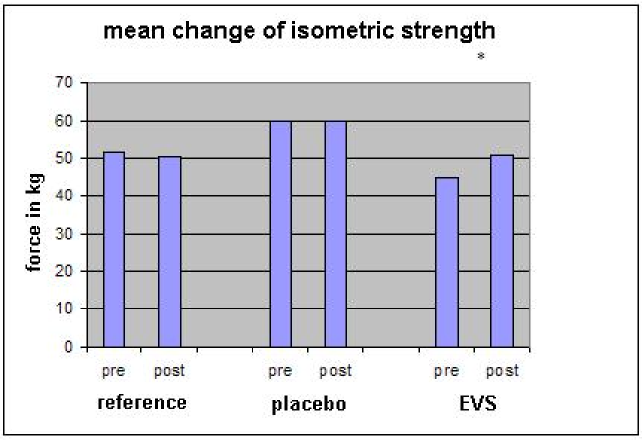

Fig. 4. Isometric strength of agonist muscles in three groups of test persons before (pre) and after (post) intervention by electrovibrostimulation (EVS)

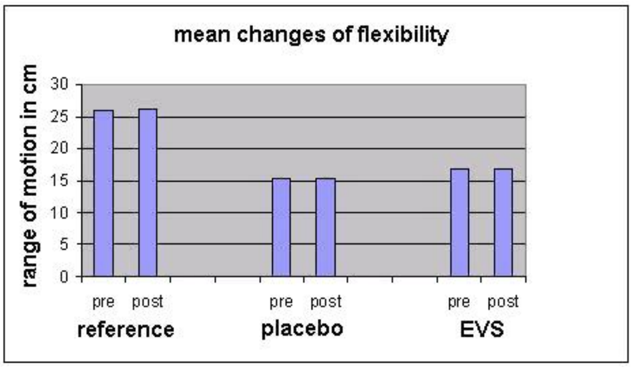

Fig. 5. Flexibility of antagonist muscles in three groups of test persons before (pre) and after (post) intervention by electrovibrostimulation (EVS)

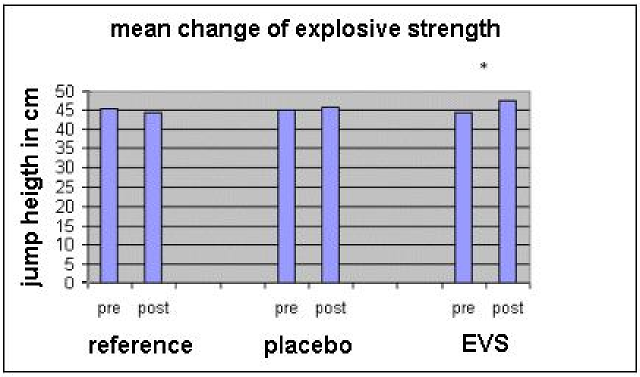

Fig. 6. Explosive strength of agonist muscles in three groups of test persons before (pre) and after (post) intervention by electrovibrostimulation (EVS)

The intensity of training of some of the muscles of upper and lower leg by electrostimulation caused muscle soreness in just a few subjects, mainly the day after their trainings. Therefore one of them was excluded from the electrovibrostimulation group, while two other ones were trained by slightly lower electrostimulation intensities since.

Discussion

Results of former studies showed the effectiveness of electrovibrostimulation on the functional state of muscles: increased muscle strength in the zone of active insufficiency and increased muscle elasticity in the zone of passive insufficiency, and in consequence improved joint strength and mobility. In many endurance sports such as running, cycling, rowing etcetera, alternations of flexor-extensor movements play a central role, especially in the lower extremities [8].

Electrovibrostimulation apparently works on this agonist-antagonist principle, by decreasing the zones of active insufficiency of the agonist and synergist muscles by electrostimulation, whilst diminishing the zones of passive insufficiency of the antagonist muscles by simultaneously applied vibrostimulation [2], [3].

The working mechanism of this apparent result has until now not been fully explained. With regard to Whole Body Vibration, many authors stress the existence of rather complex neuromuscular pathways, on the basis of proprioceptive reflexes [5].

On the level of the striated muscle cells however, it can be hypothesized from molecular points of view, that vibrations *in se* impair effective bindings of the proteins involved in the building-up of muscle contraction force, namely the binding of myosin heads to actin-g [11]. In this way, vibrations could influence the on-off mechanism of muscle contraction, thus explaining the decrease of the zones of passive insufficiency of the antagonist muscles under the influence of vibration training [2].

Of all muscle proteins, titin is a molecule that plays an important part in muscle contraction [11]. Recent studies by Kellermayer *et al.* [12] showed mechanical fatigue of titin after repeated stretchings. Extrapolating these *in vitro* data at a molecular level to our present *in vivo* study, whilst taking into account these changes of material properties, it can be expected that titin will be stretched out more easily after repetitive vibrations. Thus the sarcomere lengths of antagonists increase, so that these muscles can be stretched out more easily. In combination with electrostimulation applied to the agonist and the synergist muscles, which are simultaneously subjected to diminished antagonist forces, this will result in more efficient agonist and synergist muscle strengths.

Further research at a molecular level is urgently needed, to either confirm or reject these and other hypotheses concerning the working mechanisms of electrovibrostimulation.

Zinkovsky and co-workers [1] - [4] observed an improvement of flexibility with regard to certain joints. The present study could not confirm this. We must however take into account that the present study used a different way to test flexibility, namely the sit-and-reach test, by which is tested not only the flexibility of antagonists in the legs, but also the flexibility of muscles and other structures in the back. This can explain why the present study was not able to determine any increase of flexibility.

Conclusions

Electrovibrostimulation improved the isometric and the explosive strength, while the flexibility remained the same, in a group of 18-24 years old healthy sportsmen. There is a need for more investigations on flexibility, in which more and other tests than just the sit-and-reach test should be used for the measuring of flexibility. It is also necessary to study the effects of electrovibrostimulation using isokinetic strength measurements, by means of e.g. a Cybex-dynamometer.

The present study, based on similar research in previous years, will possibly throw new light on the applications of electrovibrostimulation and its apparent effects, and at the same time give impetus to the unravelling of its working mechanisms at a molecular level.

Acknowledgements

The authors wish to thank explicitly Rob Vliek, Frank Temmerman and Johan Ex of GymnaUniphy for kindly providing the Fitvibe® apparatus and the Myaction Med® devices, as well as for their perpetuous and invaluable help during the present study design. Raf Meesen of the Reval Research Institute is thanked for his interest and his constructive contributions. Dries Schuurmans, University of Hasselt Sports Coordinator is thanked for his stimulating help in searching the volunteering subjects. Jean Manca and Michel De Roeve, University of Hasselt, Department of Physics, are thanked for kindly making available laboratory spaces and equipment. Herbert Thijs of the Center of Statistics (CenStat) of the University of Hasselt is thanked for his clear advice during statistical data handling. We also thank volunteering person Ann Reyskens for figuring as a model, and photographer Marc Withofs, Department of Basic Medical Sciences, University of Hasselt, for making the photographs during this study.

References

[1] **Zinkovsky A. V., Eliseev S. V., Kuznetsov V. V, Zoubova I. A., Schmidt K. P.** *Training of the skeletal-muscular apparatus of sportsmen through electrovibrostimulation.* XIV International Symposium on Biomechanics in Sports, June 25-29, 1996, Lisboa, Book of Abstracts. Editor João M.C.S. Abrantes, Edições FMH Universidade Técnica de Lisboa, ISBN 972-735-029-1, 1996, p. 191.

[2] **Zinkovsky A. V., Arsenyev D. G., Kuznetsov V. V., Zoubova I. A., Schmidt K. P.** *Electro-vibrostimulation training and recuperation of the human skeletal-muscular apparatus.* 10th Conference of the European Society of Biomechanics Leuven, August 28-31, 1996, Book of Abstracts. Edited by Jos Vander Sloten, Geert Lowet, Remi Van Audekercke and Georges Van der Perre, ISBN 90-803242-1-3, 1996, p. 238.

[3] **Zinkovsky A. V., Kuznetsov V. V., Schmidt K. P., Zoubova I. A.** *Biomechanical stimulation of the human skeletal-muscular apparatus in zones of the active and passive insufficiency.* XVIth Congress of the International Society of Biomechanics, Tokyo, August 25 - 29, 1997. Book of Abstracts, 1997, p. 328.

[4] **Zinkovsky A. V ., Zoubova I. A., Schmidt K. P., Van Zwieten K. J.** *Training of the skeletal-muscle apparatus of sportsmen through electrovibrostimulation.* Tijdschrift voor Fysische Therapie 1998, 4, p. 9-11.

[5] **Delecluse C., Roelants M., Verschueren S.** *Strength increase after whole body vibration compared with resistance training.* Medicine & Science in Sports & Exercise 35, 2003, p. 1033 -1041.

[6] **Müller E., Löberbauer E., Kruk M.** *Elektrostimulation und Whole Body Vibration: zwei erfolgreiche Krafttrainingsmethoden?* Leistungssport 2003, 4, p. 4 -10.

[7] **Diricks K., Hauglustaine S., Van Zwieten K. J., Lippens P. L., Schmidt K. P., Zinkovsky A. V.** *Soft tissues possibly transducing low frequency vibrations in the human locomotor apparatus.* Proceedings of the Eleventh International Congress on Sound and Vibration, Edited by Nickolay I. Ivanov and Malcolm J. Crocker, St. Petersburg, Russia, 5 - 8 July 2004, ISBN 5-7325-0816-3, 2004, p. 1787-1790.

[8] **Lambrichts D., Van Zwieten K. J., Lippens P. L., Schmidt K. P., Hauglustaine S.** *The role of the pronator teres muscle in the arm during the rowing movement, at the end of the stroke.* Proceedings of the 2nd International Congress on "Sport and Health", April 21-23, 2005, St. Petersburg, Russia, under the auspices of the Secretary General of the Council of Europe, Mr. Terry Davis. St. Petersburg 358-3 ISBN 5-94988-012-9, 2005, p. 358-359.

[9] **Nackaerts K.** *Whole body vibration as an adjuvant therapy for treating repetitive strain injury (RSI).* MSc Thesis in Physical Therapy, Provinciale Hogeschool Limburg, Departement Gezondheidszorg, Opleiding Kinesitherapie. Hasselt, 2006. *(not formally published)*

[10] **Van Zwieten K. J., Zubova, I. A.** *Methods to improve the health of the student population at the University of Hasselt, Belgium, by means of sports and movement facilities.* In: Varzin S. A., Voronko S. E., Tarasovskaia O. U., Prus L. A., Eds. Transactions of the All-Russian Scientific Conference "Health as the basis of human potential: problems and how to solve them". September 26-28, 2006, Saint-Petersburg Polytechnic University Publishers: © Saint-Petersburg State University © Saint-Petersburg Polytechnic University, 2006, p. 194 -197.

[11] **Arseniev D. G., Aranov V. J., Bauer S. M., Biqdai E. V., Zinkovsky A. V., Ivanov A. A., Ilyin I. J., Liksonov D. V., Maslov L. B., Palmov V. A., Potekhin V. V., Samoilov V. O., Sholukha V. A.** *Matematitcheskie modeli i kompu-ternoe modelirovanie v biomechanike (Mathematical Models and Computer Modelling in Biomechanics).*
Ministry of Education and Science of Russian Federation, published in SPbSPU, St. Petersburg, 514 p. "Applied Mechanics", ISBN 5-7422-0239-3, 2004.

[12] **Kellermayer M. S. Z., Smith S. B., Bustamante C., Granzier H. L.** *Mechanical Fatigue in Repetitively Strectched Single Molecules of Titin.* Biophysical Journal, 80, February 2001, p. 852-863.