

University School of Physical Education in Wrocław  
University School of Physical Education in Poznań  
University School of Physical Education in Kraków

---



# HUMAN MOVEMENT

**HUMAN MOVEMENT**

formerly Człowiek i Ruch (Human Movement)  
vol. 11, number 2, 2010, pp. 109–216

**Editor-in-Chief      Alicja Rutkowska-Kucharska**  
University School of Physical Education, Wrocław, Poland

**Associate Editor      Wiesław Osiński**  
University School of Physical Education, Poznań, Poland  
**Andrzej Klimek**  
University School of Physical Education, Kraków, Poland

**Editorial Board**

Tadeusz Bober	University School of Physical Education, Wrocław, Poland
Jan Celichowski	University School of Physical Education, Poznań, Poland
Lechosław B. Dworak	University School of Physical Education, Poznań, Poland
Ewa Kałamacka	University School of Physical Education, Kraków, Poland
Tadeusz Koszczyc	University School of Physical Education, Wrocław, Poland
Stanisław Kowalik	University School of Physical Education, Poznań, Poland
Juliusz Migasiewicz	University School of Physical Education, Wrocław, Poland
Edward Mleczko	University School of Physical Education, Kraków, Poland
Łucja Pilaczyńska-Szcześniak	University School of Physical Education, Poznań, Poland
Zbigniew Szyguła	University School of Physical Education, Kraków, Poland
Aleksander Tyka	University School of Physical Education, Kraków, Poland
Marek Zatoń	University School of Physical Education, Wrocław, Poland

**Advisory Board**

Wojtek J. Chodzko-Zajko	University of Illinois, Urbana, Illinois, USA
Charles B. Corbin	Arizona State University, East Mesa, Arizona, USA
Gudrun Doll-Tepper	Free University, Berlin, Germany
Józef Drabik	University School of Physical Education and Sport, Gdańsk, Poland
Kenneth Hardman	University of Worcester, Worcester, United Kingdom
Andrew Hills	Queensland University of Technology, Queensland, Australia
Zofia Ignasiak	University School of Physical Education, Wrocław, Poland
Slobodan Jaric	University of Delaware, Newark, Delaware, USA
Toivo Jurimae	University of Tartu, Tartu, Estonia
Han C.G. Kemper	Vrije University, Amsterdam, The Netherlands
Wojciech Lipoński	University School of Physical Education, Poznań, Poland
Gabriel Łasiński	University School of Physical Education, Wrocław, Poland
Robert M. Malina	University of Texas, Austin, Texas, USA
Melinda M. Manore	Oregon State University, Corvallis, Oregon, USA
Philip E. Martin	Iowa State University, Ames, Iowa, USA
Joachim Mester	German Sport University, Cologne, Germany
Toshio Moritani	Kyoto University, Kyoto, Japan
Andrzej Pawłucki	University School of Physical Education, Wrocław, Poland
John S. Raglin	Indiana University, Bloomington, Indiana, USA
Roland Renson	Catholic University, Leuven, Belgium
Tadeusz Rychlewski	University School of Physical Education, Poznań, Poland
James F. Sallis	San Diego State University, San Diego, California, USA
James S. Skinner	Indiana University, Bloomington, Indiana, USA
Jerry R. Thomas	University of North Texas, Denton, Texas, USA
Karl Weber	German Sport University, Cologne, Germany
Peter Weinberg	Hamburg University, Hamburg, Germany
Marek Woźniewski	University School of Physical Education, Wrocław, Poland
Guang Yue	Cleveland Clinic Foundation, Cleveland, Ohio, USA
Wladimir M. Zatsiorsky	Pennsylvania State University, State College, Pennsylvania, USA
Jerzy Żołędź	University School of Physical Education, Kraków, Poland

Translation: Tomasz Skirecki, Agnieszka Piasecka-Ceccato

Design: Agnieszka Nyklasz

Copy editor: Beata Irzykowska

Proofreading: Halina Marciniak, Anna Miecznikowska

Indexed in: SPORTDiscus, Index Copernicus, Altis, Sponet, Scopus

© Copyright 2010 by Wydawnictwo AWF we Wrocławiu

ISSN 1732-3991

[http://www.awf.wroc.pl/hum\\_mov](http://www.awf.wroc.pl/hum_mov)

Editorial Office

Secretary: Dominika Niedźwiedź

51-684 Wrocław, ul. Mickiewicza 98, Poland, tel. 71 347 30 51

hum\_mov@awf.wroc.pl

Circulation: 200



## CONTENTS

Editorial.....	112
Maki Takei, Hideki Shimizu, Minoru Hoshiyama <b>Kinematic analysis of seating maneuver: Digitalization of movement in daily living .....</b>	114
Erika Zemková, Dušan Hamar <b>The effect of task-oriented sensorimotor exercise on visual feedback control of body position and body balance .....</b>	119
Bojan Jošt <b>The hierarchical structure of selected morphological and motoric variables in ski jumping .....</b>	124
Jaqueleine Lourdes Rios, Mário Cesar de Andrade, Aluisio Otavio Vargas Avila <b>Analysis of peak tibial acceleration during gait in different cadences .....</b>	132
Luciano Pavan Rossi, Rafael Pereira, Roberto Simão, Michelle Brandalize, Anna Raquel Silveira Gomes <b>Influence of static stretching duration on quadriceps force development and electromyographic activity .....</b>	137
Dariusz Tchórzewski, Janusz Jaworski, Przemysław Bujas <b>Influence of long-lasting balancing on unstable surface on changes in balance .....</b>	144
Erika Zemková, Oľga Kyselovičová, Dušan Hamar <b>Postural sway response to rebound jumps of different duration .....</b>	153
Carlos Ricardo Maneck Malfatti, Sivolnei Ferreira <b>Acute cardiovascular alterations in hypertensive renal patients during exercise with constant load in the interdialytic period .....</b>	157
Leonardo Antônio dos Santos Galdino, Carlos José Nogueira, Eloísa Costa e Silva Galdino, Jorge Roberto Perrott de Lima, Rodrigo Gomes de Souza Vale, Estélio Henrique Martin Dantas <b>Effects of different intensities of flexibility training on explosive force .....</b>	162
Mohammad Hassan Ferdowsi, Fateme Marashian, Seyed Hussein Marashian <b>The effects of 12-week aerobic exercises on rate of mental health in male students of Ahvaz Payam Noor University .....</b>	167
Aleksandra Stachoń, Anna Burdukiewicz, Jadwiga Pietraszewska, Justyna Andrzejewska, Krystyna Chromik <b>Biological symptoms of aging in women regarding physical activity and lifestyle .....</b>	172
Krzysztof Stec, Rajeev Choudhary, Lesław Kulmatycki <b>The effects of dynamic Surya Namaskar on differential chest circumference of physical education students .....</b>	179
Dorota Burzycka-Wilk <b>Effectiveness of visual information in the process of teaching swimming motor activities .....</b>	184
Linda Schücker, Lisa Ebbing, Norbert Hagemann <b>Learning by analogies: Implications for performance and attentional processes under pressure .....</b>	191
Alicja Kostencka, Mirosława Szark-Eckardt <b>The estimation of educational needs of physical education teachers in the light of the new educational program basis .....</b>	200
Regulamin publikowania prac/Instructions for Authors .....	212



## EDITORIAL

Dear Readers,

The current number of the journal concludes another chapter in the decade-long history of the periodical. It is the last edition published at semi-annual intervals. Starting from 2011, our journal will appear quarterly. It proves that the range of *Human Movement* is getting wider and that authors are more and more interested in publishing their papers in our journal.

The present volume of *Human Movement* deals with very interesting and multidisciplinary papers in a lot of significant fields of sport science including biomechanics, exercise physiology, sport psychology, geriatrics, motor control and learning, and sport pedagogy.

An interesting publication is "Kinematic analysis of seating maneuver: Digitalization of movement in daily living". The results showed normative values, and the method could be used to reveal abnormalities in a daily movement disability.

There is an article which concentrates on the effect of task-oriented sensorimotor exercise on visual feedback control of body position and parameters of static and dynamic balance. Another paper concerns the hierarchical factor structure in a selected sample of morphological and motor variables of ski jumpers. The objective of another study was to describe and analyze the variation of peak acceleration in the tibia by means of accelerometers during the gait cadence.

In the paper entitled "Influence of static stretching duration on quadriceps force development and electromyographic activity" the authors evaluate the influence of static stretching duration on quadriceps muscle isometric force and electromyographic (EMG) activity of the rectus femoris and vastus lateralis.

The present volume also contains two works which concern biomechanics. One discusses the qualification of changes in balance as the effect of long-lasting balancing on a movable platform alternately in sagittal and frontal planes. The other one focuses on the sway variables after continuous CMJs eliciting different levels of proprioceptive stimulation determined by percentage of max height of the jump.

Another article presents a study which investigated acute cardiovascular alterations during aerobic exercise in the interdialytic phase. The obtained results point to a significant reduction in blood pressure levels, prin-

cipally in diastolic blood pressure after 24 hours from haemodialysis.

The effects of different intensities of flexibility training on explosive force are described in the next article. The authors revealed that jumps after two stretching routines were significantly lower. The effects of 12-week aerobic exercises on the rate of mental health in male students were analyzed in the following paper. The authors observed that there were significant differences in mental health, self-esteem and social desirability.

Another article presents biological symptoms of aging in women regarding their physical activity and lifestyle. The objective of the next work was to determine the effects of dynamic Surya Namaskar (sun salutations) on the differential chest circumference of selected physical education students.

Two articles contain works which concern motor control and learning. One paper discusses the effectiveness of visual information in the process of teaching swimming motor activities. The other one presents the study on the issue whether analogy learning is a method for preventing choking under pressure.

The last article touches on the estimation of educational needs of physical education teachers in the light of the new educational program basis (on the example of the Kuyavian-Pomeranian Voivodeship in Poland). The authors conclude that physical education teachers emphasize the needs for training in the didactics of their subject and in health education.

I am convinced that the variety of topics touched on in the current volume will appeal to a wide range of readers, who are also kindly invited to publish the findings of their research in our pages.

I would like to thank the members of the Editorial Board and the Advisory Board for their help, precious observations and contribution to enhancement of our journal's position.

Publication of the received papers would not have been possible if it had not been for our reviewers' work. I hereby would like to thank very much all of you who have evaluated the papers for our periodical in the year 2010:



## EDITORIAL

Zdzisław Adach, Gorzów Wielkopolski (Poland)  
 Janusz Błaszczyk, Katowice (Poland)  
 Tadeusz Bober, Wrocław (Poland)  
 Zbigniew Borysiuk, Opole (Poland)  
 Anna Burdukiewicz, Wrocław (Poland)  
 Krzysztof Buśko, Warszawa (Poland)  
 Jan Celichowski, Poznań (Poland)  
 Henryk Duda, Kraków (Poland)  
 Zbigniew Dziubiński, Warszawa (Poland)  
 Włodzimierz S. Erdmann, Gdańsk (Poland)  
 Jan Gajewski, Warszawa (Poland)  
 Krystyna Górná-Lukasik, Katowice (Poland)  
 Henryk Grabowski, Kraków (Poland)  
 Jacek Gracz, Poznań (Poland)  
 Halina Guła-Kubiszewska, Wrocław (Poland)  
 Monika Guszkowska, Warszawa (Poland)  
 Zofia Ignasiak, Wrocław (Poland)  
 Ewa Jarocka, Wrocław (Poland)  
 Artur Jaskólski, Wrocław (Poland)  
 Jerzy Jaśkiewicz, Kraków (Poland)  
 Zbigniew Jethon, Wrocław (Poland)  
 Grzegorz Juras, Katowice (Poland)  
 Toivo Jurimae, Tartu (Estonia)  
 Roman M. Kalina, Rzeszów (Poland)  
 Ewa Kałamacka, Kraków (Poland)  
 Tadeusz Kasperczyk, Kraków (Poland)  
 Krzysztof Klukowski, Warszawa (Poland)  
 Jerzy Kosiewicz, Warszawa (Poland)  
 Tomasz Kostka, Łódź (Poland)  
 Stanisław Kowalik, Poznań (Poland)  
 Sławomir Kozięć, Wrocław (Poland)  
 Michał Kuczyński, Wrocław (Poland)  
 Lesław Kulmatycki, Wrocław (Poland)  
 Andrzej Kwolek, Rzeszów (Poland)  
 Jarosław Marusiak, Wrocław (Poland)  
 Andrzej Mastalerz, Warszawa (Poland)  
 Edward Mleczko, Kraków (Poland)  
 Eugenia Murawska-Ciąłowicz, Wrocław (Poland)  
 Zbigniew Naglak, Wrocław (Poland)

Krystyna Nazar, Warszawa (Poland)  
 Roman Nowobilski, Kraków (Poland)  
 Wiesław Osiński, Poznań (Poland)  
 Andrzej Pawłucki, Poznań (Poland)  
 Celina Pezowicz, Wrocław (Poland)  
 Jadwiga Pietraszewska, Wrocław (Poland)  
 Michał Plewa, Katowice (Poland)  
 Andrzej Rokita, Wrocław (Poland)  
 Krystyna Rożek-Piechura, Wrocław (Poland)  
 Ryszard Przeweda, Warszawa (Poland)  
 Danuta Roman-Liu, Warszawa (Poland)  
 Tadeusz Ruchlewicz, Kraków (Poland)  
 Tadeusz Rychlewski, Poznań (Poland)  
 Adam Siemieński, Wrocław (Poland)  
 Teresa Ślawińska-Ochla, Wrocław (Poland)  
 Małgorzata Śłowińska-Lisowska, Wrocław (Poland)  
 Jerzy Smorawiński, Poznań (Poland)  
 Małgorzata Sobera, Wrocław (Poland)  
 Stanisław Sterkowicz, Kraków (Poland)  
 Ryszard Strzelczyk, Poznań (Poland)  
 Andrzej Suchanowski, Gdańsk (Poland)  
 Małgorzata Syczewska, Warszawa (Poland)  
 Robert Szeklicki, Poznań (Poland)  
 Andrzej Szmajke, Wrocław (Poland)  
 Zbigniew Trzaskoma, Warszawa (Poland)  
 Czesław Urbanik, Warszawa (Poland)  
 Dariusz Wieliński, Ponań (Poland)  
 Sławomir Winiarski, Wrocław (Poland)  
 Andrzej Wit, Warszawa (Poland)  
 Edward Wlazło, Wrocław (Poland)  
 Marek Woźniewski, Wrocław (Poland)  
 Michał Wychowański, Warszawa (Poland)  
 Adam Zając, Katowice (Poland)  
 Krystyna Zatoń, Wrocław (Poland)  
 Jerzy Zawadzki, Wrocław (Poland)  
 Andrzej Ziembka, Warszawa (Poland)  
 Ewa Ziółkowska-Łajp, Poznań (Poland)  
 Maria Zowisło, Kraków (Poland)



## KINEMATIC ANALYSIS OF SEATING MANEUVER: DIGITALIZATION OF MOVEMENT IN DAILY LIVING

doi:10.2478/v10038-010-0012-4

MAKI TAKEI<sup>1,2</sup>, HIDEKI SHIMIZU<sup>1</sup>, MINORU HOSHIYAMA<sup>1\*</sup>

<sup>1</sup> School of Health Sciences, Nagoya University, Nagoya, Japan

<sup>2</sup> School of Rehabilitation, Osaka Kawasaki Rehabilitation University, Osaka, Japan

### ABSTRACT

**Purpose.** The objective of the present study was to digitally express a common daily movement of sitting down (seating maneuver), and to show an analytical example of normative indices of such a daily movement. **Basic procedures.** Sequential traces of moments and the center of pressure (COP) during the seating maneuver, approaching with steps to and sitting on a stool, were measured using two force plates, and we decided on normal ranges of parameters based on the vertical moment and lateral deviation of the COP. In addition to the normal data recorded from ten healthy subjects, a data set from a patient was plotted. **Main findings.** Normative indices to express the sequential movement were obtained. The patient showed abnormal values of the indices, which could be quantitative indicators to evaluate the normality and grade of abnormality. **Conclusions.** We introduced a method for the quantitative screening of a daily movement using force plates. The results showed normative values, and the method could be used to reveal abnormalities in a daily movement in a patient with mild movement disability.

**Key words:** force plate, sitting, pressure center, human

### Introduction

The evaluation of basic movements in daily life is important to assess the disability level of patients, and devise a plan to support their daily living. Therapists evaluate ability and disability levels of patients employing various rating scales, such as the Barthel Index [1], Functional Independence Measure (FIM) [2], and International Classification of Functioning (ICF)-based assessment [3]. These scales are useful to understand the general condition of patients. However, for each movement, the range of variation in disability is marked. Although therapists observe and detect abnormal and disabled behaviors during each movement, it is not always easy to evaluate quantitative improvement/deterioration of the movement through visual observation. In addition, the reliability and variation in skill levels among therapists are marked [4–6].

In the present study, a common daily movement, sitting down on a stool (seating maneuver), was quantitatively measured and digitally expressed by representative indices. The values could be useful to evaluate to what extent movements deviate from the normal range, as well as to assess normal or abnormal behaviors. This is a pilot study to express a common daily movement

by digitized indices and evaluate the movement. We assessed the seating maneuver to obtain indices for the movement in healthy subjects, and demonstrated abnormal patterns in a case showing disability.

We chose a sequential movement comprising the seating maneuver. Among various movements in daily life, the seating maneuver is a common movement at all ages. The maneuver included sequential movements, i.e., steps, turning, and sitting, which are basic components of body movements. To investigate the maneuver, two force plates (BP600900, AMTI, USA) were used. In addition to force plate recording, a 3-dimensional (3-D) movement analysis system (MAC 3D System, Motion Analysis, USA) was simultaneously employed to trace each subject's movements.

The main objective of the present study was not to analyze a daily movement, but to show that it was possible to express normal values of a daily movement. We proposed that abnormality in a daily movement could be detected on simple movement measurement using force plates. Such analysis could be potentially useful for screening the early stages of movement disorders on an annual health examination. Therefore, we generated a sample of representative kinematic indices to screen for abnormality in a daily movement. We did not analyze the 3-D data, but used them to trace the movement and identify movement components for the analyzed movement periods during the experimental maneuver.

\* Corresponding author.

## Material and methods

### Subjects

Ten healthy volunteers (7 men and 3 women, aged  $34.1 \pm 12.4$  years, range: 20–59 years) participated in the present study. The subjects had no history of neurological or orthopedic diseases. Written informed consent, based on the Declaration of Helsinki [7], to participate in the study, which was first approved by the Ethical Committee of Nagoya University, School of Health Sciences, was obtained from all participants prior to commencing the study.

### Force plate setting

Two force plates were positioned in parallel on the floor next to each other. The recording area of each force plate was  $900 \times 600$  mm (width × length); thus, the total recording area was  $900 \times 1,200$  mm. The floor was on a level with the front force plate, plate-1. The edge of the rear force plate, plate-2, was flush against plate-1 (Fig. 1).

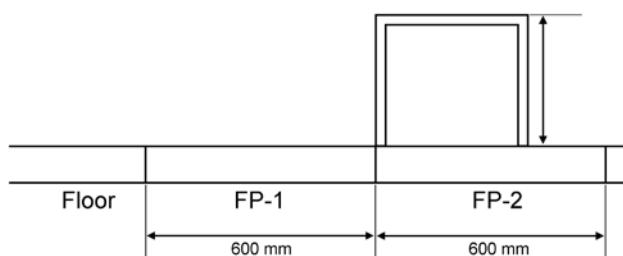


Figure 1. Placement of the two force plates and a stool.

The subject approached the front force plate (FP-1) from the left side of the figure, and sat on the stool on the rear force plate (FP-2)

The force plates measured the orthogonal center of pressure (COP) along the X (anteroposterior) and Y (left and right) axes, vertical pressure (Z), and moment about three axes: Fx (anteroposterior), Fy (left and right), and Fz (vertical), producing a total of six outputs. The zero-point of the X-Y plane was the center of each force plate, and positive values showed on anterior and right direction for X and Y axes, respectively. Raw signals from the force plates were transferred via an analog-to-digital converter (National PCI-6071E) with a sampling rate of 120 Hz. All signals were collected online with software (EVaRT5.04).

A stool was fixed on force plate-2 with its two front legs placed at the front edge of the plate (Fig. 1). The stool was 43.0 cm high, with a seat area of  $42.0 \times 40.0$  cm.

### 3-D movement analysis

The movement analysis system facilitated the recording of positions using up to thirty-five markers (Helen Hayes Set Marker) simultaneously along 3-D planes. The markers were attached to the subject's body, which enabled the monitoring of the 3-D movements of the subject's whole body and each body part. Fifteen markers were attached: top and back of the head, sacrum on the midline, and on the shoulder, elbow, wrist, knee, heel, and a toe on each side. Eight charge-coupled device (CCD) cameras (Eagle-4, NAC Image Technology, Tokyo, Japan) traced the positions of the markers. Raw signals from the kinematic system were transferred via an analog-to-digital converter (National PCI-6071E) with a sampling rate of 120 Hz. All signals were collected simultaneously with force plate recording online using software (EVaRT5.04).

### Experimental design

Movement analysis involved the act of sitting on a stool (Fig. 1). The subjects stood 3 m away in front of the stool and were asked to approach it and sit on it in a natural way as they did in daily life. Thus, on the force plates, the movement of the subjects included the last step for approaching, turning, and sitting on the stool. Subjects repeated the seating maneuver ten times with a short rest after each maneuver.

### Data analysis

#### Values from force plates

Since the objective of the present study was to express a daily movement using specific values, we first decided on a representative value obtained from the force plates. From the results of a preliminary study, we first chose the vertical direction of the force obtained from plate-1 and plate-2, Fz-1 and Fz-2, respectively, to express the movement. Although the Fz value depended on each subject's weight, the pattern of temporal change in the value was consistent among subjects, as shown in the results (Figs. 2 and 3).

The rising point of Fz-1 and Fz-2 was determined as the start of measurement, and the ten trials were averaged in each subject. For averaged waveforms, we defined values as follows:

Fz-1 from force plate-1 showed two major peaks in all subjects, and four phases of Fz-1 in its temporal change during the seating maneuver were identified. They were the onset to the initial peak (period-b), from the initial to the second peak (period-c), from the second peak to the following deflection (period-d), and from the second peak to the endpoint (period-e) (Fig. 3). The

# HUMAN MOVEMENT

M. Takei et al., Kinematic analysis of seating maneuver

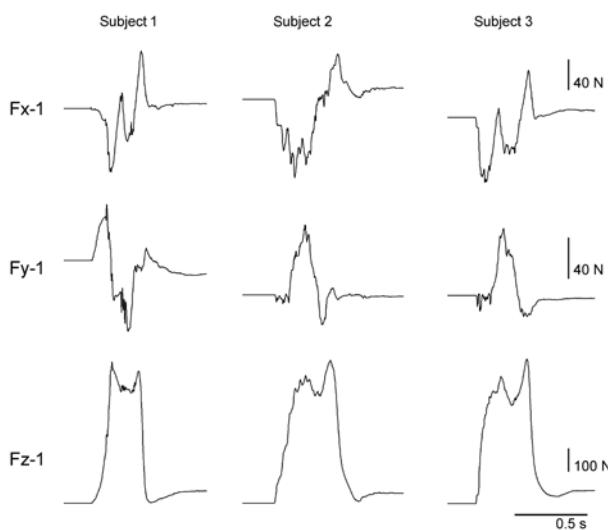


Figure 2. Averaged traces of moments recorded from force plate-1. Traces for three subjects are presented. There was a difference in the waveform of anteroposterior (Fx-1) and lateral (Fy-1) direction moments among the subjects, while vertical moment (Fz-1) showed relatively constant waveforms with two major upward peaks

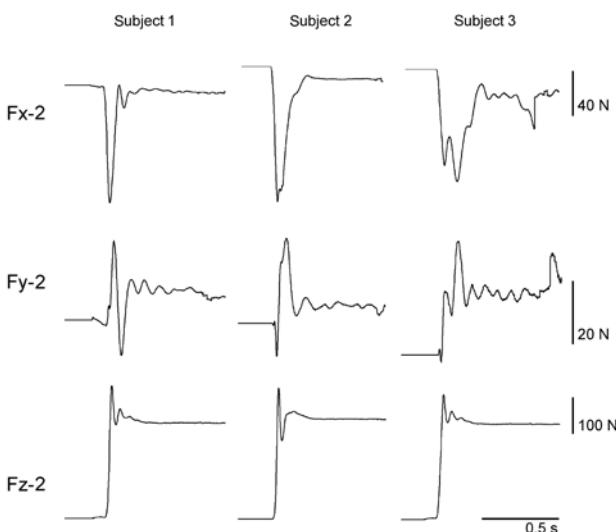


Figure 3. Averaged traces of moments recorded from force plate-2. Traces for three subjects are presented as in Fig. 2. There was a difference in the waveform of anteroposterior (Fx-2) and lateral (Fy-2) direction moments among the subjects, while vertical (Fz-2) moment also showed relatively constant waveforms with two major upward peaks

values of the periods were divided by the total period of the phases, i.e., from the onset to endpoint (period-a), to obtain standardized values, %-b, %-c, %-d, and %-e. Similarly, we determined two periods (period-g to -h) in Fz-2 obtained from force plate-2 (Fig. 3), and they were divided by period-f (Fig. 3) to obtain standardized values, %-g and %-h.

Another parameter we chose was the lateral deviation of the COP. The Y values obtained from each plate, Y-1 and Y-2, indicated the COP during the maneuver. Since the waveform of the Y value showed large inter-individual variation, we measured the maximal lateral deviation of COP during the maneuver. First, we decided on the baseline based on the plateau level of the latter part of the waveform. Excluding the initial lateral deviation caused by the first step, we measured values for the maximum lateral deviation of the COP to the left (YL-1 and YL-2) and right (YR-1 and YR-2) for Y-1 and Y-2, respectively (Fig. 4). The total lateral deviation of the COP (YD), i.e.,  $YD-1 = YL-1 + YR-1$ ,  $YD-2 = YL-2 + YR-2$ , was also measured. From the 3-D motion monitor, each period corresponded to the movement components during the seating maneuver, as shown in Table 1.

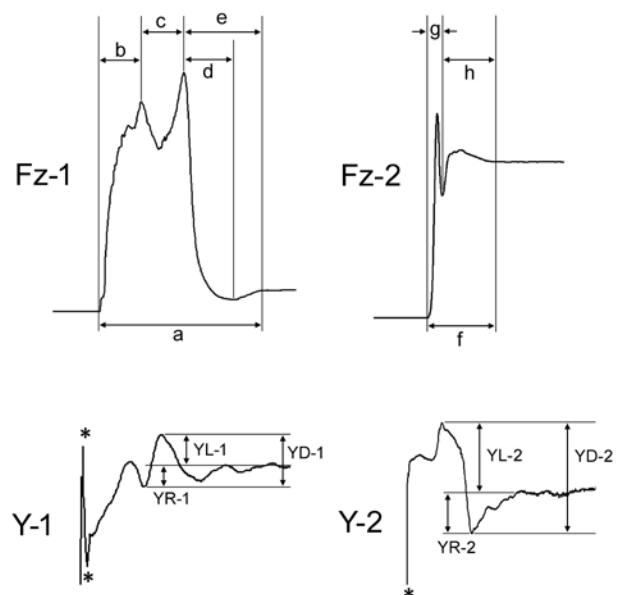


Figure 4. Definition of the analyzed values obtained from the force plates (see text and Table 1). For lateral deviation of the center of pressure (Y) and vertical moment (Fz) recorded from the front force plate, FP-1, (Y-1 and Fz-1) and the rear force plate, FP-2, (Y-2 and Fz-2) values, the initial lateral deviation of the center of pressure caused by the initial step (\*) was excluded

Table 1. Movement periods and components during the seating maneuver

Period	Movement component during seating maneuver
Period-b	From putting a foot on plate-1 and moving forward until turning.
Period-c	From the beginning of turning the body until bending the knees.
Period-d and -g	From bending the knees until contacting the stool.
Period-e and -h	From contacting the stool until a fully seated position.

### Case report

We recorded kinematic values in a case showing disability in daily movement. The case was a 54-year-old male who had suffered from polio-myelitis in childhood. He showed mild weakness in the right leg muscles innervated by L3-S1. He did not require any support for daily living, and could perform most movements independently in his daily life. However, his motor performance was somewhat abnormal and unstable in each movement. The values recorded from the patient were compared with data from the normal subjects by employing the one-sample t-test.

### Results

All subjects performed the sequential seating maneuver. Total periods of movement recorded from the force plates, i.e., period-a and period-h, were  $377.5 \pm 113.0$  and  $170.0 \pm 49.6$  ms, respectively. The standardized values of the periods are shown in Figure 5.

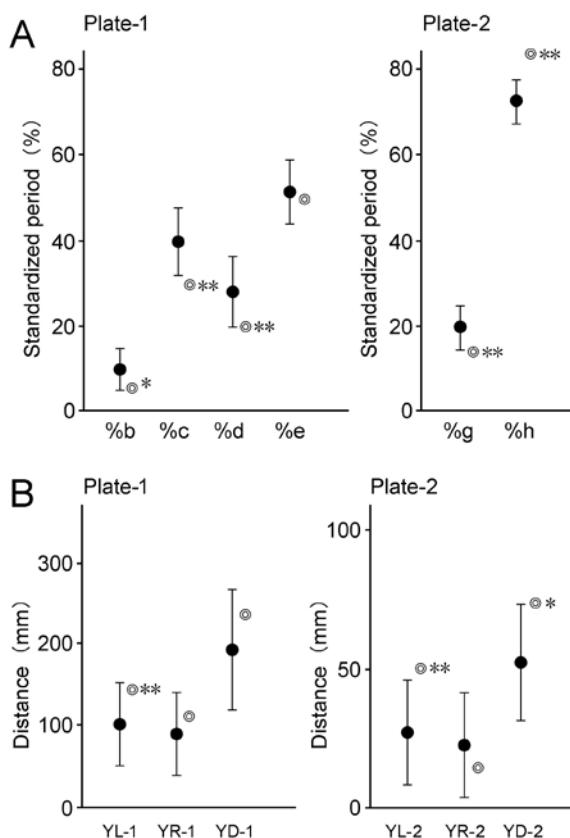


Figure 5. Standardized periods of movement components (A) and lateral deviation of the center of pressure (B). Vertical bars indicate standard deviations. Refer to the text and Fig. 4 for abbreviations. Values for the patient were plotted (◎), showing a significant difference from the range in normal subjects (\*  $p < 0.03$ , \*\*  $p < 0.01$ )

The lateral deviation during the movement is also presented in Figure 5. Data obtained from the patient are plotted in Figure 5. There was no significant difference in the values of %-e, YL-1, YD-1, and YL-2. However, other values were out of the range of the normal subjects, showing a significant difference ( $p < 0.05$ ).

### Discussion

We measured kinematic values during sitting on a stool using two force plates. We chose two factors from recorded values, Fz and Y, which expressed the components of the movement. Although the selection of factors is variable, the present study demonstrated a strategy to evaluate a sequential daily movement.

There are several ways to observe and evaluate a sequential movement. The time required to complete a movement is the most simple and conventional method to evaluate disability. However, the time to perform a movement depends on the effort of the subjects, and the same time does not always indicate the same level of ability to perform a movement [8]. Healthy subjects are easily able to perform such a movement, while persons with disabilities may require a marked effort to complete time-restricted movements. Recently, 3-D monitoring and electromyographic (EMG) techniques to analyze sequential movements have become popular in the field of kinesiology. Previous studies analyzed normative and pathological conditions in daily movements in detail, such as gait [9–12]. However, most of the kinematic and neurophysiological techniques, such as EMG, 3-D motion analysis, and arthrokinematic studies, are usually complex in terms of preparation and analysis, although these techniques are certainly powerful to analyze components of movements. On the other hand, as mentioned in Introduction, several rating scales to evaluate the general condition of patients are not suitable to express disability in a movement.

In the present study, we used data from force plates to digitize a movement. One of the most important advantages of force plate recording is that there is no requirement for subjects to measure the movement, but just perform the movement on the plates. We also used a 3-D movement analysis system to trace the movement, but a 3-D monitor analysis was not essential to define the force plate values to be analyzed. It was important to identify a sequential pattern of values, which could be recorded consistently in the subjects during a movement, as the Fz value in the present study.

An important finding in the present study was that the digitized value could indicate the “normality” of a movement. When we see a patient showing a some-

what abnormal movement on sitting, it may not be easy to point out how and what is abnormal about it. In addition, the evaluation of normality may vary among investigators [4–6]. Distinguishing between normal and pathologic movements is often difficult, and it is not easy to decide what is normal for a daily movement [13]. In fact, it is not rare in clinical situations for a patient to think his/her movement is impaired, while the investigator judges the movement to be within the normal range. Thus, we considered it important to identify simple and reliable digitized values to evaluate the normality of a movement. We think that the test movement should not be an experimental but a natural movement performed in daily life, since patients do not feel disabilities in movements in a laboratory but in their daily lives.

The method in the present study facilitates the quantitative expression of the normality of a daily movement. Since the method involved several indices, they may be applied to identify minor movement abnormalities in the early stage of diseases, as well as to evaluate improvement in a movement during rehabilitation. We considered that a combination of simple indices for screening with further kinematic studies for detailed examination would be practically useful.

We conclude that this pilot study successfully introduced a method for the screening of a daily movement using force plates. Our results showed normative values, facilitating the identification of abnormality in a daily movement performed by patients with mild movement disability.

## References

1. Sainsbury A., Seebass G., Bansal A., Young J.B., Reliability of the Barthel Index when used with older people. *Age Ageing*, 2005, 34, 228–232. doi:10.1093/ageing/afi063.
2. Gabbe B.J., Sutherland A.M., Wolfe R., Williamson O.D., Cameron P.A., Can the modified functional independence measure be reliably obtained from the patient medical record by different raters? *J Trauma*, 2007, 63, 1374–1379. doi:10.1097/01.ta.0000240481.55341.38.
3. Farin E., Fleitz A., Frey C., Psychometric properties of an International Classification of Functioning, Disability and Health (ICF)-oriented, adaptive questionnaire for the assessment of mobility, self-care and domestic life. *J Rehabil Med*, 2007, 39, 537–546. doi:10.2340/16501977-0083.
4. Swinkels R.A., Oostendorp R.A., Bouter L.M., Which are the best instruments for measuring disabilities in gait and gait-related activities in patients with rheumatic disorders. *Clin Exp Rheumatol*, 2004, 22, 25–33.
5. Spanjer J., Krol B., Brouwer S., Groothoff J.W., Inter-rater reliability in disability assessment based on a semi-structured interview report. *Disabil Rehabil*, 2008, 30, 1885–1890. doi:10.1080/09638280701688185.
6. Quinn T.J., Dawson J., Walters M.R., Lees K.R., Exploring the reliability of the modified Rankin Scale. *Stroke*, 2009, 40, 762–766. doi:10.1161/STROKEAHA.108.522516.
7. Rickham P.P., Human Experimentation. Code of ethics of the world medical association. Declaration of Helsinki. *Br Med J*, 1964, 18 (5402), 177.
8. Graham J.E., Ostir G.V., Fisher S.R., Ottenbacher K.J., Assessing walking speed in clinical research: a systematic review. *J Eval Clin Pract*, 2008, 14, 552–562. doi:10.1111/j.1365-2753.2007.00917.x.
9. Hreljac A., Marshall R.N., Algorithms to determine event timing during normal walking using kinematic data. *J Biomech*, 2000, 33, 783–786.
10. Watelain E., Barbier F., Allard P., Thevenon A., Angu   J.C., Gait pattern classification of healthy elderly men based on biomechanical data. *Arch Phys Med Rehabil*, 2000, 81, 579–586. doi:10.1053/mr.2000.4415.
11. Chester V.L., Biden E.N., Tingley M., Gait analysis. *Biomed Instrum Technol*, 2005, 39, 64–74.
12. Hodgins D., The importance of measuring human gait. *Med Device Technol*, 2008, 42, 44–47.
13. Lim M.R., Huang R.C., Wu A., Girardi F.P., Cammisa F.P. Jr., Evaluation of the elderly patient with an abnormal gait. *J Am Acad Orthop Surg*, 2007, 15, 107–117.

Paper received by the Editors: August 25, 2009.

Paper accepted for the publication: February 24, 2010.

## *Address for correspondence*

Minoru Hoshiyama Ph.D. Professor  
School of Health Sciences, Nagoya University  
1-1-20 Daiko-minami, Higashi-ku  
Nagoya 461-8673, Japan  
e-mail: hoshiyama@met.nagoya-u.ac.jp



# THE EFFECT OF TASK-ORIENTED SENSORIMOTOR EXERCISE ON VISUAL FEEDBACK CONTROL OF BODY POSITION AND BODY BALANCE

doi:10.2478/v10038-010-0013-3

ERIKA ZEMKOVÁ\*, DUŠAN HAMAR

Department of Sports Kinanthropology, Faculty of Physical Education and Sport, Comenius University, Bratislava, Slovakia

## ABSTRACT

**Purpose.** The study evaluates the effect of task-oriented sensorimotor exercise on visual feedback control of body position and parameters of static and dynamic balance. **Basic procedures.** A group of 20 PE students (aged  $21.5 \pm 1.6$  years, height  $178.2 \pm 10.6$  cm, and weight  $74.5 \pm 11.8$  kg) performed task-oriented sensorimotor exercise (20 sets of 60 stimuli with 2 min rest in-between). They had to hit the target randomly appearing in one of the corners of the screen by horizontal shifting of COM in appropriate direction. Response time, distance, and velocity of COP trajectory were registered during standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement. Postural stability was evaluated under both static and dynamic conditions (wobble board). The COP velocity was registered at 100 Hz by means of the posturography system FiTRO Sway Check based on dynamometric platform. **Main findings.** Mean response time significantly ( $p \leq 0.01$ ) decreased from  $3100.5 \pm 1019.8$  ms to  $1745.8 \pm 584.5$  ms. Substantial share of the improvements took place during initial 6 trials. At the same time also mean distance of COP movement significantly ( $p \leq 0.05$ ) decreased from  $0.767 \pm 0.340$  m to  $0.492 \pm 0.190$  m within initial 12 trials and then slightly increased up to  $0.591 \pm 0.247$  m. On the other hand, mean COP velocity significantly ( $p \leq 0.05$ ) increased from  $0.285 \pm 0.142$  m/s to  $0.395 \pm 0.182$  m/s. However, there were no changes in the COP velocity registered in static (from  $12.4 \pm 1.8$  mm/s to  $11.9 \pm 1.5$  mm/s) and dynamic conditions (from  $108.0 \pm 22.3$  mm/s to  $101.3 \pm 18.1$  mm/s). **Conclusions.** Task-oriented sensorimotor exercise acutely enhances visual feedback control of body position but not static and dynamic balance.

**Key words:** acute effect, static and dynamic balance, task-oriented sensorimotor exercise, visual feedback control of body position

## Introduction

Balance is the ability to maintain a given posture with minimal movement sway in static or dynamic conditions. Also stance symmetry in terms of weight distribution between the feet in a standing position plays a role in maintaining balance. However, it has also to be taken into account that balance in most situations is associated with other tasks (e.g., picking up an object or kicking a ball). From this point of view it is important to focus the exercise programs on improvement of postural control to be flexible and adaptable to perturbations.

Recently, various forms of balance exercises have become a part of both athletic training and rehabilitation. However, improvement after such training seems to be task-specific. For instance, no crossover effects of functionally directed instability resistance training on parameters of static balance in athletes after ACL reconstruction have been found [1]. A similar finding, an improvement of dynamic but not static balance, has been documented [2] after combined agility-balance

training in elite basketball players. Also, in untrained subjects balance exercises performed simultaneously with reaction tasks have been found [3] as an effective means of improving balance in dynamic conditions, namely when responding to visual stimuli. However, the training program applied has proved to be insufficient to improve visual feedback control of body balance.

For this purpose as a suitable alternative seems to be platform feedback exercises providing visual or auditory biofeedback to subjects regarding the locus of their centre of pressure (COP). Typical force platform biofeedback systems consist of at least two force plates to allow the weight on each foot to be determined, a computer and a monitor to allow visualization of the COP, and software that provides training protocols and data analysis capabilities. Some units allow auditory feedback in addition to the visual feedback in response to errors in performance. However, platform feedback exercises have been found [4] to improve stance symmetry but not sway in standing and clinical balance outcomes (Berg Balance Scale and Timed Up and Go). Even no changes in symmetry of weight distribution, postural sway in bilateral standing, gait and gait-related activities after visual feedback training were reported by Van Peppen et al. [5]. The authors argued that such

\* Corresponding author.

exercise performed on stable support surfaces is not superior to a conventional therapy.

Thus, even more sophisticated methods, namely those enabling both practice and assessment of visual feedback control of body position are needed. Promising seem to be those closer to functional activities like task-oriented sensorimotor exercises performed on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement [6]. Such training (3-week program consisting of 3 sets of 200 stimuli with 5 min rest in-between, 3 times a week) has been found [7] to contribute to more precise perception of COM position and regulation of its movement leading to faster responses to visual stimuli, as well as more rapid postural sway adjustments in altered surface conditions.

From practical point of view, the question remains whether similar effect may be achieved also during short-term practice. Therefore, the aim of the study was to evaluate the effect of task-oriented sensorimotor exercise on visual feedback control of body position and parameters of static and dynamic balance.

## Material and methods

### Subjects

A group of 20 PE students (aged  $21.5 \pm 1.6$  years, height  $178.2 \pm 10.6$  cm, and weight  $74.5 \pm 11.8$  kg) volunteered to participate in the study. All of them were informed about the procedures and the main purpose of

the study. The procedures presented were in accordance with the ethical standards on human experimentation.

### Study setting

Subjects performed task-oriented sensorimotor exercise (20 sets of 60 stimuli with 2 min rest in-between). They were provided with feedback on COM displacement on a computer screen while standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement (Fig. 1). Their task was to hit the target randomly appearing in one of the corners of the screen by horizontal shifting of COM in the right direction. Response time, distance, and velocity of COP trajectory between stimulus appearance and its hit by visually-guided COM movement on the screen were registered by means of the above mentioned system developed at our Department by Hamar et al. [8].

Prior to and after the last set of task-oriented sensorimotor exercises also postural stability was evaluated under both static and dynamic conditions (wobble board). Velocity of the centre of pressure (COP) was registered at 100 Hz by means of the posturography system FiTRO Sway Check based on dynamometric platform. Subjects were instructed to minimize postural sway by standing as still as possible.

### Statistical analysis

Ordinary statistical methods including average and standard deviation were used. A paired t-test was em-

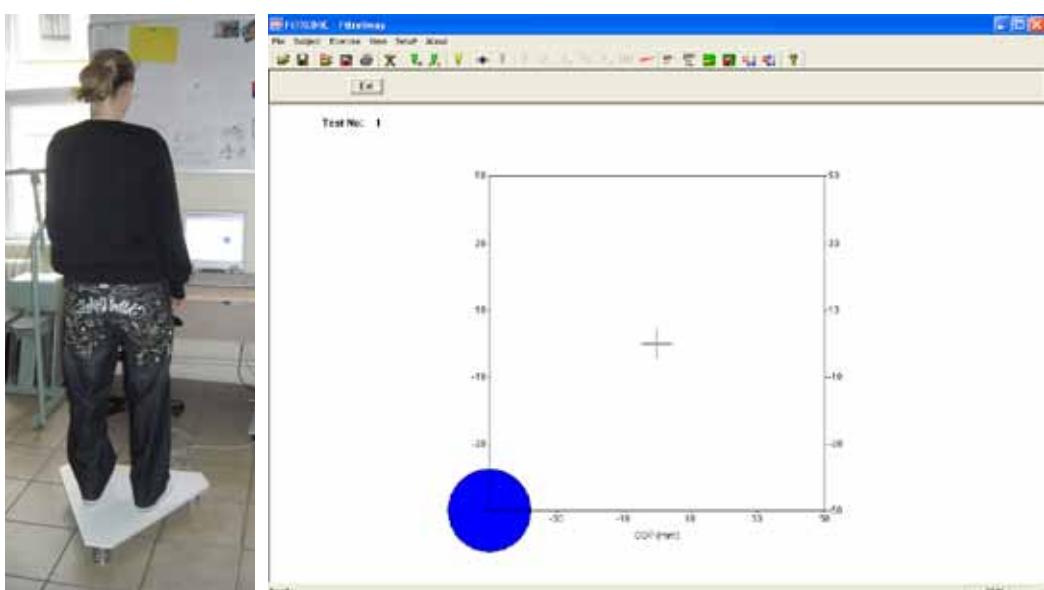


Figure 1. Task execution: hit the target by shifting COM in one of the four directions according to position of stimulus on the screen while standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement ([www.fitronic.sk](http://www.fitronic.sk))

ployed to determine the statistical significance of differences between pre- and post-exercise values of examined abilities,  $p < 0.05$  was considered significant.

## Results

It has been found that the mean response time (Fig. 2) significantly ( $p \leq 0.01$ ) decreased from  $3100.5 \pm 1019.8$  ms to  $1745.8 \pm 584.5$  ms. Substantial share of the improvements took place during initial 6 trials.

At the same time also the mean distance of COP movement (Fig. 3) significantly ( $p \leq 0.05$ ) decreased from  $0.767 \pm 0.340$  m to  $0.492 \pm 0.190$  m within initial 12 trials and then slightly increased up to  $0.591 \pm 0.247$  m.

On the other hand, the mean COP velocity (Fig. 4) significantly ( $p \leq 0.05$ ) increased from  $0.285 \pm 0.142$  m/s to  $0.395 \pm 0.182$  m/s.

However, there were no changes in the COP velocity (Fig. 5 a, b) registered in static (from  $12.4 \pm 1.8$  mm/s to  $11.9 \pm 1.5$  mm/s) and dynamic conditions (from  $108.0 \pm 22.3$  mm/s to  $101.3 \pm 18.1$  mm/s).

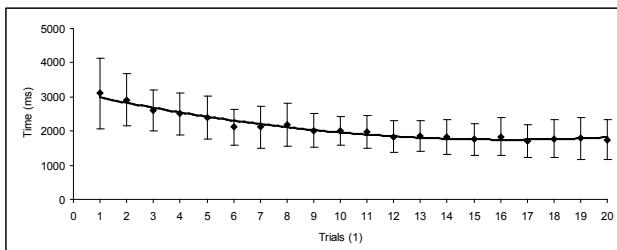


Figure 2. Response time measured during task-oriented sensorimotor exercise

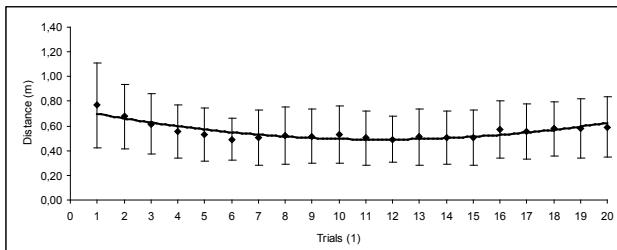


Figure 3. Distance of sway trajectory measured during task-oriented sensorimotor exercise

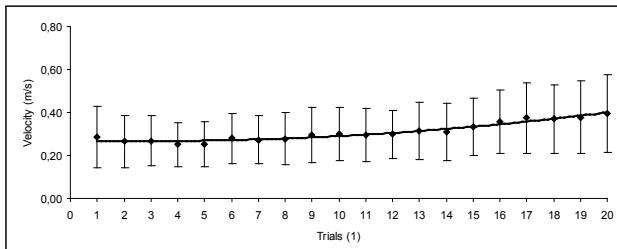


Figure 4. Sway velocity measured during task-oriented sensorimotor exercise

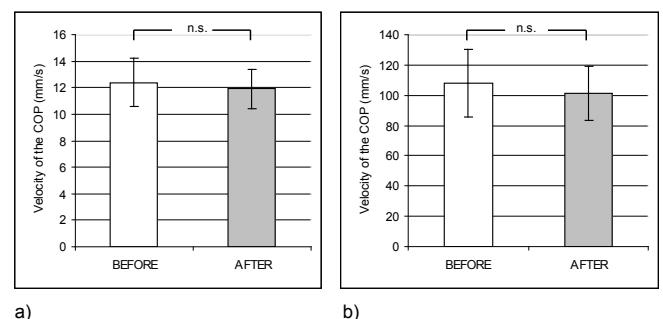


Figure 5. The COP velocity registered in (a) static and (b) dynamic conditions prior to and after 20 sets of task-oriented sensorimotor exercises

## Discussion

Task-oriented sensorimotor exercise decreased the time response from the 1<sup>st</sup> to the 20<sup>th</sup> trial by 1355 ms (44%). Also the distance of COP movement decreased from the 1<sup>st</sup> to the 12<sup>th</sup> trial by 0.275 m (36%) and then slightly increased to 0.099 m within the 20<sup>th</sup> trial (17%). On the other hand, the COP velocity increased from the 1<sup>st</sup> to the 20<sup>th</sup> trial by 0.11 m/s (28%). Such a more precise perception of COM position and regulation of its movement leading also to faster responses to visual stimuli may demonstrate the enhancement of visual feedback control of body position.

From physiology it is known that such an effect may be the consequence of enhancement in spinal excitability [9, 10]. Taube et al. [11] supposed that enhanced visual feedback interacts with the spinal reflex system in terms of facilitated Ia-afferent transmission. From a functional point of view, higher Ia-afferent transmission may be advantageous to activate easily the motoneuron pool [12–14]. This mechanism may contribute to the improvement of fine motor control in response to visual stimuli and reduction in postural sway.

More specifically, Taube et al. [11] found that the H-reflex modulation was directly opposed to the changes in COP displacement. It means, the less the subjects swayed, the greater their reflexes were. There are different supraspinal sites like the motor cortex [15], the cerebellum [16] and the basal ganglia [17] which potentially influence the spinal reflex excitability. They are all dependent on feedback from visual, vestibular, cutaneous and proprioceptive sources.

Though it is not known whether any positive adjustments would be mediated through central processing, the task-oriented sensorimotor exercise applied certainly tax a proprioceptive control of posture. Muscle proprioceptive inputs continuously inform the central nervous system about the position of each part of the body in relation to the others [18, 19]. Eklund [20] established

that oriented whole-body tilts could be induced in standing human subjects by applying vibratory stimulation to the ankle postural muscles, i.e., stimulation of the tibialis anterior muscles results in a forward tilt and stimulation of the triceps surae muscles causes a backward tilt. Similar finding was observed in other muscles, e.g., paravertebral [21, 22], cervical [23–25], and extraocular [26]. In all these cases, the induced postural responses were oriented in specific directions, depending on the vibrated muscles. Therefore, Roll and Roll [25] suggested that muscle-spindle inputs might form a continuous “proprioceptive chain” from the feet to the eyes, since applying tendon vibration at any level in the chain apparently alters the internal representation of the body posture.

Like the somatosensory [27] and vestibular system [28, 29], also the visual system may be capable of influencing the spinal reflex excitability, as proposed by Hoffman and Koceja [30]. In contrast to this study, Taube et al. [11] observed a significant interaction between the visual and the support surface conditions indicating that the H-reflex was more strongly affected by changes in visual feedback on the unstable surface. This is in line with the observation that vision is of greater relevance when the demands of the postural task are increased [31, 32]. In order to provide visual feedback in more demanding and functional balance tasks, a standing on unstable spring-supported platform may be a more appropriate alternative than systems consisting of two stable force plates.

However, in healthy subjects reduced COP amplitudes were shown when the COP was displayed on a computer screen but at the same time sway frequency increased [33, 34]. Such a change in the postural control strategy was argued to reflect a “tighter” but not essentially better control of body sway. Interestingly, “tighter” postural control during quiet stance has also been reported for cognitive dual tasks [35] and for tasks involving postural threats [36, 37]. Thus, the secondary task of hitting the target by visually-guided COM movement on the screen may not (only) alter the visual feedback control of body position but also lead to changes in the subjects’ level of attention or arousal, which in turn, may influence the postural control strategy. This assumption is in accordance with our previous findings [38] that sway velocity registered under dynamic conditions declines when concurrently performing a secondary reaction task. This effect was found to be more evident for multi-choice than simple responses.

These findings may be of some importance for the conception of visual feedback therapy interventions. This includes selection of the biofeedback system based

on either force or unstable spring-supported platform, type of task-oriented exercise (visually-guided COM tracking or target-matching task), as well as investigation of an efficient exercise mode for such a training including an optimal practice-rest ratios, and so forth. Further studies are also needed to evaluate the application of task-oriented sensorimotor exercise in rehabilitation setting for individuals after lower limb injury and in prevention of falls in elderly population.

## Conclusions

Task-oriented sensorimotor exercise acutely decreases the response time and distance of COP movement, and increases the COP velocity registered during standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement. It means that with repeated trials subjects respond to visual stimuli faster and more precisely by horizontal shifting of COM in one of the four directions according to position of stimulus on the screen. However, such an acute enhancement of visual feedback control of body position during practice is not beneficial for improvement of static and dynamic balance. As shown in our previous study long-term application of task-oriented sensorimotor exercise is needed in order to achieve adaptive changes in postural control system.

## References

1. Zemková E., Vlašič M., The effect of instability resistance training on neuromuscular performance in athletes after anterior cruciate ligament injury. *Sport Sci*, 2009, 2 (1), 17–23.
2. Zemková E., Hamar D., The effect of 6-week of combined agility-balance training on neuromuscular performance in basketball players. *J Sports Med Phys Fit*, 2010, 50 (3), 262–267.
3. Zemková E., Cepková A., Potočárová L., Hamar D., The effect of 8-week instability agility training on sensorimotor performance in untrained subjects. In: 14<sup>th</sup> Annual Congress of the European College of Sport Science, Oslo 2009, 617.
4. Barclay-Goddard R., Stevenson T., Poluha W., Moffatt M.E., Taback S.P., Force platform feedback for standing balance training after stroke. *Cochrane Database Syst Rev*, 2004, 18 (4), CD004129. doi:10.1002/14651858.CD004129.pub2.
5. Van Peppen R.P., Kortsmit M., Lindeman E., Kwakkel G., Effects of visual feedback therapy on postural control in bilateral standing after stroke: a systematic review. *J Rehabil Med*, 2006, 38, 3–9. doi:10.1080/16501970500344902.
6. Hamar D., Sensorimotor tests of postural stability [in Slovak]. In: National Congress of Sports Medicine “Aktuálne problémy telovýchovného lekárstva”. Slovak Society of Sports Medicine, Trenčín 2008, 12–13.
7. Zemková E., Hamar D., The effect of task-oriented proprioceptive training on parameters of neuromuscular function. In: 5<sup>th</sup> International Posture Symposium “Translation of posture mechanisms for rehabilitation”. Smolenice Castle, 2008, 55.
8. Hamar D., Schickhofer P., Zemková E., Gažovič O., Böhmerová L., Grmanová K., Pelikánová J., Nonharmonic proprioceptive

- stimulation as a means for the enhancement of neuromuscular function. The project of the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences, 2007-09, No. 1/4504/07.
9. Katz R., Meunier S., Pierrot-Deseilligny E., Changes in presynaptic inhibition of Ia fibres in man while standing. *Brain*, 1988, 111, 417–437.
  10. Trimble M.H., Postural modulation of the segmental reflex: effect of body tilt and postural sway. *Int J Neurosci*, 1998, 95, 85–100. doi:10.3109/00207459809000652.
  11. Taube W., Leukel C., Gollhofer A., Influence of enhanced visual feedback on postural control and spinal reflex modulation during stance. *Exp Brain Res*, 2008, 188 (3), 353–361. doi:10.1007/s00221-008-1370-4.
  12. Llewellyn M., Yang J.F., Prochazka A., Human H-reflexes are smaller in difficult beam walking than in normal treadmill walking. *Exp Brain Res*, 1990, 83, 22–28. doi:10.1007/BF00232189.
  13. Koceja D.M., Mynark R.G., Comparison of heteronymous monosynaptic Ia facilitation in young and elderly subjects in supine and standing positions. *Int J Neurosci*, 2000, 103 (1–4), 1–15. doi:10.3109/00207450009178369.
  14. Aagaard P., Simonsen E.B., Andersen J.L., Magnusson P., Dyhre-Poulsen P., Neural adaptation to resistance training: changes in evoked V-wave and H-reflex responses. *J Appl Physiol*, 2002, 92, 2309–2318. doi:10.1152/japplphysiol.01185.2001 8750-7587/02.
  15. Meunier S., Pierrot-Deseilligny E., Cortical control of presynaptic inhibition of Ia afferents in humans. *Exp Brain Res*, 1998, 119, 415–426. doi:10.1007/s002210050357.
  16. Dontsova Z.S., Shkvirskaia L.A., Characteristics of presynaptic inhibition of monosynaptic spinal cord reflexes after removal of the anterior lobe of the cerebellum [in Russian]. *Neurofiziologija*, 1980, 12 (4), 429–431.
  17. Filloux F.M., Neuropathophysiology of movement disorders in cerebral palsy. *J Child Neurol*, 1996, 11 (suppl. 1), S5–12. doi:10.1177/088307389601100102.
  18. Massion J., Movement, posture and equilibrium: interaction and coordination. *Prog Neurobiol*, 1992, 38, 35–56. doi:10.1016/0301-0082(92)90034-C.
  19. Roll J.P., Vedel J.P., Roll R., Eye, head and skeletal muscle spindle feedback in the elaboration of body references. *Prog Brain Res*, 1989, 80, 113–123. doi:10.1016/0301-0082(92)90034-C.
  20. Eklund G., General features of vibration-induced effects on balance. *Ups J Med Sci*, 1972, 77, 112–124.
  21. Gregoric M., Takeya T., Baron J.B., Bessinoton J.C., Influence of vibration of neck muscles on balance control in man. *Agressologie*, 1978, 19, 37–38.
  22. Smetanin B.N., Popov K.Ye., Shlikov V.Yu., Postural responses to vibrostimulation of the neck muscle proprioceptors in man. *Neurophysiology*, 1993, 25(2), 101–108. doi:10.1007/BF01054155.
  23. Gurfinkel V.S., Levick Y.S., Popov K.E., Smetanin B.N., Shlikov Y.V., Body scheme in the control of postural activity. In: Gurfinkel V.S., Ioffe M.E., Massion J., Roll J.P. (eds.), *Stance and motion*. Plenum Press, New York 1988, 185–193.
  24. Lund S., Postural effects of neck muscle vibration in man. *Experientia*, 1980, 36, 1398.
  25. Roll J.P., Roll R., From eye to foot. A proprioceptive chain involved in postural control. In: Amblard B., Berthoz A., Clarac F. (eds.), *Posture and gait*. Elsevier, Amsterdam 1988, 155–164.
  26. Roll J.P., Roll R., Kinaesthetic and motor effects of extreocular muscle vibration in man. In: Reagan J.K.O., Levy-Shoen A. (eds.), Eye movements, from physiology to cognition. Elsevier, North-Holland 1987, 57–68.
  27. Miyoshi T., Nozaki D., Sekiguchi H., Kimura T., Sato T., Komeda T. et al., Somatosensory graviception inhibits soleus H-reflex during erect posture in humans as revealed by parabolic flight experiment. *Exp Brain Res*, 2003, 150, 109–113. doi:10.1007/s00221-003-1414-8.
  28. Aiello I., Rosati G., Serra G., Tugnoli V., Manca M., Static vestibulospinal influences in relation to different body tilts in man. *Exp Neurol*, 1983, 79, 18–26. doi:10.1016/0014-4886(83)90375-8.
  29. Bauci A.M., Colebatch J.G., Evidence for reflex and perceptual vestibular contributions to postural control. *Exp Brain Res*, 2005, 160, 22–28. doi:10.1007/s00221-004-1982-2.
  30. Hoffman M.A., Koceja D.M., The effects of vision and task complexity on Hoffmann reflex gain. *Brain Res*, 1995, 700, 303–307. doi:10.1016/0006-8993(95)01082-7.
  31. Mergner T., Huber W., Becker W., Vestibular-neck interaction and transformation of sensory coordinates. *J Vest Res*, 1997, 7, 347–367.
  32. Buchanan J.J., Horak F.B., Emergence of postural patterns as a function of vision and translation frequency. *J Neurophysiol*, 1999, 81 (5), 2325–2339.
  33. Dault M.C., de Haart M., Geurts A.C., Arts I.M., Nienhuis B., Effects of visual center of pressure feedback on postural control in young and elderly healthy adults and in stroke patients. *Hum Mov Sci*, 2003, 22, 221–236.
  34. Anker L.C., Weerdesteyn V., van Nes I.J., Nienhuis B., Straatman H., Geurts A.C., The relation between postural stability and weight distribution in healthy subjects. *Gait Posture*, 2008, 27, 471–477. doi:10.1016/j.gaitpost.2007.06.002.
  35. Dault M.C., Geurts A.C.H., Mulder T.W., Duysens J., Postural control and cognitive task performance in healthy participants while balancing on different support-surface configurations. *Gait Posture*, 2001, 14(3), 248–255. doi:10.1016/S0966-6362(01)00130-8.
  36. Carpenter M.G., Frank J.S., Silcher C.P., Surface height effects on postural control: a hypothesis for a stiffness strategy for stance. *J Vestib Res*, 1999, 9, 277–286.
  37. Carpenter M.G., Frank J.S., Silcher C.P., Peysar G.W., The influence of postural threat on the control of upright stance. *Exp Brain Res*, 2001, 138, 210–218. doi:10.1007/s002210100681.
  38. Zemková E., Miklovič P., Hamar D., Visual reaction time and sway velocity while balancing on wobble board. *Kinesiologia Slovenica*, 2009, 15 (3), 40–47.

Paper received by the Editors: August 6, 2009.

Paper accepted for publication: February 24, 2010.

#### *Address for correspondence*

Erika Zemková, Ph.D.  
Faculty of Physical Education and Sport  
Comenius University  
Svobodovo nábrežie 9  
814 69 Bratislava, Slovakia  
e-mail: zemkova@yahoo.com



# THE HIERARCHICAL STRUCTURE OF SELECTED MORPHOLOGICAL AND MOTORIC VARIABLES IN SKI JUMPING

doi:10.2478/v10038-010-0016-0

**BOJAN JOŠT**

Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia

## ABSTRACT

**Purpose.** The main purpose of the present research paper was to establish a hierarchical factor structure in a selected sample of morphological and motor variables of ski jumpers; such variables are base constituents of the potential performance model in ski jumping. **Basic procedures.** The subject sample was Slovene ski jumpers older than 15 years ( $n = 72$ ), tested in May 2008. The research was done on a selection of 41 variables (12 basic morphological ones, seven from a special morphological index, 10 basic motoric ones and 12 special dynamic variables of take-off power). **Main findings.** Through factor analysis in the first phase, nine factors were excluded from the manifest variables of first orders: 1. Factor of velocity power (34.9% of variance); 2. Factor of longitudinal body dimensions (17.2% of variance); 3. Factor of morphological index of flight aerodynamics (12.2% of variance); 4. Factor of morphological index of take-off (7.3% of variance), 5. Factor of push-off explosive power (5.0% of variance), 6. Factor of informative component of motorics (3.5% of variance); 7. Factor of specific morphological index of thigh dimensions (3.1% of variance), 8. Factor of transversal dimensions of body (2.4% of variance), 9. Factor of flexibility of hips (2.2% of variance). All nine factors of the first order explained 88% of variance of manifest variables. On the basis of configuration of nine factors of the first order in the second phase, four components were excluded from the second order with 62.7% of total variance. The first was component of specific take-off movement (22.9% of variance), followed by component of thigh dimension (14.5% of variance), then component of specific flight potential (13.0% of variance) and finally component of basic morphology (12.1% of variance). On the third level of factor analysis, two general factors of ski jumpers with 57.1% of total variance were found. The first was the general factor of specific movement of ski jumpers (29.8% of variance) and second the general factor of morphology (27.7% of variance). **Conclusions.** The research confirms the main hypothesis that hierarchical latent factor structures of manifest motor and morphological variables exist. The independent primary factors of the first order are crucial for understanding the latent dimensions of the potential performance model on the second and third level. This factor shows the structure between manifest dimensions more clearly and their relations are more understandable.

**Key words:** ski jumping, motor behavior, morphology, hierarchical factor analysis

## Introduction

The main purpose of the present research paper was to establish a hierarchical factor structure in a selected sample of morphological and motor variables of ski jumpers; such variables are base constituents of the potential performance model in ski jumping [1]. The construction and supplementation of the potential model of athletic performance is especially productive if these are carried out by modeling of the optimal personal athletic profile in accordance with the theory of the “Champion” [2]. Many performance variables and characteristics are used to describe the model of the potential performance of elite athletes. A large number of model dimensions is the cause of many difficulties in managing such models. Often it is useful to reduce a large set of performance dimensions to a more manageable model structure. Athletes who are oriented towards competition, achievements and top-level sport must, in order to be able to attain top-level achievements, practice regularly, systematically and continuously for several years. This

preparation period is characterized by intensive growth of sports performance and, as such, represents the most complex and demanding stage of their sports life. In today’s competitive, achievement-oriented sport, success is not possible without a high level of knowledge, technological support, financial support, appropriate organization and successful management. A multitude of factors that affect achievement in sports requires that a corresponding treatment should be based on a permanent cybernetic systems approach.

In modeling athletic performance, smaller or larger problems are encountered. Larger problems occur in the study of complex fields, phenomena, objects, processes, events, whose inner workings are more or less inaccessible to us. We have only access to the observation of external behavior. We can draw conclusions about internal mechanisms, properties, characteristics only by means of external indicators.

In most cases, however, we are not able – due to the large number of variables and their mutual interactions

– to describe all of them and to place them into a coherent functional cause-and-effect whole [3]. For that reason, we attempt to form a model of potential performance that will be maximally predictable and easier to manage. The modeling of potential athletic performance is based on the model facts and rules with which we define the relations between the criterion of performance and individual constituents of the reduced potential performance model [4].

A ski jumper's movement is a complex and difficult motor task, which (in terms of motor behavior terminology) requires high levels of strength, coordination, accuracy, balance, orientation in space and appropriate morphological structure of body. These abilities could be measured with many motoric tests; such tests are the input for the hypothetical model of special motor behavior of athletes. The realization of technique depends on the morphological characteristics of athletes. However, its manifest expression can only be shown through the variables of motor behavior; their interaction affects the performance of athletes. Especially in ski jumping, technique performance depends not only on the motor abilities of the athlete, but to a large extent on the aerodynamic features of the athlete's body and his equipment [5, 6]. Morphological features play a major role in competition success of ski jumpers. A guiding concept in the modeling of the morphology profile of athletes is morphological optimization, which occurs through two mechanisms: selection and adaptation. The performance of athletes in the flying phase has greater potential when they realize the two hypothetical components. The first energy component of movement represents the total component of mechanisms which within the athletes' motorics take care of the control and regulation of energy processes. In addition to this component, there is also presumed, from the aspect of motor behavior, the existence of the information component of movement that covers the coordinate action of those latent motor mechanisms that take care of the control and regulation of information processes. In ski jumping, it is hypothesized that both components have an equally important weight in the formation of the total motor regression function.

The research findings could be significant in improving the reduced potential performance model in ski jumping, which must become more and more specifically oriented according to the criteria of optimal technique realization. The relative importance of model characteristics depends on the specific demands of the sport discipline. The structure of the potential performance model in ski jumping could be built up in both horizontal and vertical directions.

In the vertical direction, it could constitute a hierachic structure from more empirical and specialized categories to more abstract and general categories [7]. The main hypothesis of that research is that there exist a smaller independent number of latent or hidden variables on the first and higher order of the reduced potential performance model in ski jumping. This hypothesis will be tested by factor analysis. The goal of factor analysis is to discover the factors (underlying or hidden constructs) that best explain a group of manifest variables and describe the linear relation of each variable to the latent or hidden factor [8].

## Material and methods

The research was conducted on a sample of 72 ski jumpers, members of the Slovene junior-men and senior-men team selections, tested in May 2008. The sample included almost all elite Slovene ski jumpers aged between 16 and 29 years. Table 1 contains the list of all the manifest variables applied in this study as well as the corresponding codes, which will be consistently used throughout the text. The research was done on sample of 41 elementary variables (12 basic morphological, 7 special morphological indexes, 10 basic motoric, and 12 special dynamic variables of special take-off power measured in laboratory conditions). Anthropometric measures were chosen and their measuring was carried out in accordance with the methodology presented in the International Biological Program recommendations (IBP). Ski jumpers executed a vertical jump from a specific in-run position on a Kistler Force Plate. Based on the achieved and calculated take-off parameters, the following variables were selected for the purpose of this research: push-off height, push-off time, ratio between push-off height and time (also called index of take-off explosive power) and acceleration of the first part of push-off (also called index of explosive power of the first part of take-off). Factorial analysis (principal component analysis) was used to determine the latent ski jumping motoric and morphological structure. The Guttman-Kaiser criterion was used to determine the significance of the extracted factors and components. The algorithm (Oblimin rotation method with Kaiser Normalization), consisted of Oblimin transformation of latent dimensions obtained by orthoblique transformation of the characteristic vectors (rotation converged in nine iterations) of the variable inter-correlation matrix. The component correlation analysis was done to determine the dependency between latent vectors. The matrices of orthogonal (a structure matrix) loadings were computed.

## Results

The results of the factor analysis on the first order are shown in Table 1a and Table 1b.

Through factor analysis in the first phase, nine factors were excluded from the manifest variables of first order: 1. Factor of velocity power (34.9% of variance); 2. Factor of longitudinal body dimensions (17.2% of variance); 3. Factor of morphological index of flight aerodynamics (12.2% of variance); 4. Factor of morphological index of take-off (7.3% of variance); 5. Factor of push-off explosive power (5.0% of variance); 6. Factor of informative component of motorics (3.5% of variance); 7. Factor of specific morphological index of thigh dimensions (3.1% of variance); 8. Factor of transversal dimensions of body (2.4% of variance); 9. Factor of flexibility of hips (2.2% of variance). All

nine factors of the first order explained 88% of variance of manifest variables.

On the basis of configuration of nine factors of the first order in the second phase, four components were excluded from the second order with 62.7% of variance (see Tab. 2). The first was **component of specific take off movement** (22.9% of variance), followed by **component of thigh dimension** (14.5% of variance), then **component of specific flight potential** (13.0% of variance) and finally **component of basic morphology** (12.1% of variance).

On the third level of factor analysis, two general factors of ski jumpers with 57.1% of total variance was determined (see Tab. 3). The first was the **general factor of specific movement of ski jumpers** (29.8% of variance) and the second was the **general factor of morphology** (27.7% of variance). The results of this

Table 1a. Structure of factors of selected morphological and motoric variables of ski jumpers ( $n = 72$ ), part one

Manifest variables	M	SD	Factor scores of the first order										
			F1	F2	F3	F4	F5	F6	F7	F8	F9		
FACTOR 1													
Factor of velocity power													
MOC – Power of take-off (W)	1842.3	301.0	<b>0.89</b>	0.31	-0.21	-0.07	-0.10	0.11	-0.04	-0.01	0.09		
SMABAVO – Vertical push-off height (cm)	45.3	6.5	<b>0.86</b>	0.29	-0.09	0.33	0.52	<b>-0.61</b>	-0.21	-0.11	0.28		
HODR – Velocity of take-off (m/s)	2.9	0.2	<b>0.86</b>	0.30	-0.10	0.34	0.52	<b>-0.61</b>	-0.19	-0.13	0.27		
MMENSDM – Horizontal jump length (cm)	258.1	21.9	<b>0.62</b>	<b>0.58</b>	-0.11	0.43	0.44	<b>-0.71</b>	-0.22	-0.19	0.28		
MMEN3SM – Elastic power in triple jump (cm)	805.3	70.7	<b>0.60</b>	<b>0.55</b>	-0.14	0.43	0.42	<b>-0.73</b>	-0.22	-0.23	0.28		
SUN – Impulse of the push-off force (Ns)	187.8	30.6	<b>0.48</b>	<b>0.72</b>	<b>-0.58</b>	0.47	0.33	-0.41	-0.15	-0.23	0.22		
FACTOR 2													
Factor of longitudinal body dimensions													
ADV – Absolute body height (cm)	225.0	11.0	0.13	<b>0.97</b>	-0.21	0.28	-0.01	-0.26	-0.15	-0.21	0.28		
ADN – Right leg length (cm)	90.4	4.5	0.06	<b>0.95</b>	-0.19	-0.07	-0.11	-0.14	-0.26	-0.11	13		
AV – Body height (cm)	175.0	8.4	0.14	<b>0.95</b>	-0.28	0.37	0.02	-0.24	-0.19	-0.20	0.27		
ADG – Right shank length (cm)	42.5	2.2	0.10	<b>0.93</b>	-0.19	-0.05	-0.08	-0.12	-0.06	-0.15	0.16		
ADR – Right arm length (cm)	79.4	4.3	0.16	<b>0.92</b>	-0.26	0.17	0.04	-0.28	-0.10	-0.14	0.26		
AT – Body mass (kg)	60.6	7.7	0.15	<b>0.78</b>	<b>-0.71</b>	0.43	0.16	-0.23	-0.06	-0.24	0.12		
FACTOR 3													
Factor of morphological index of flight aerodynamics													
INDPLOV – Aerodynamic index (I = (ASR+ASM)*AV/ 2 AT)	1016.6	70.9	-0.06	-0.14	<b>0.94</b>	-0.22	-0.19	0.04	-0.06	-0.17	0.09		
BMI – Body mass index (kg/m <sup>2</sup> )	19.7	1.3	0.10	0.12	<b>-0.93</b>	0.30	0.30	-0.11	0.12	-0.20	-0.13		
AOS – Right thigh girth (cm)	51.6	3.0	0.04	0.42	<b>-0.83</b>	0.33	0.21	-0.04	0.06	-0.14	-0.08		
MORIND – Morphological index of rotation (I = ADT/ADS)	112.7	10.1	-0.08	<b>-0.63</b>	<b>0.83</b>	-0.12	-0.09	0.11	0.09	-0.07	-0.01		
FACTOR 4													
Factor of morphological index of take-off													
INDVZG – Morphological index of lift force (I = ADT/ADN)	59.9	3.8	0.15	0.07	-0.22	<b>0.96</b>	0.24	-0.17	0.10	-0.10	0.24		
INDODSK – Ski-jumping morphological take-off index (I = AV/ADN)	193.6	4.8	0.15	-0.07	-0.17	<b>0.90</b>	0.28	-0.19	0.16	-0.16	0.25		
ADT – Trunk length (cm)	54.2	4.0	0.17	<b>0.72</b>	-0.31	<b>0.76</b>	0.11	-0.25	-0.10	-0.17	0.30		

M – mean value, SD – standard deviation, F1 to F9 – orthogonal loadings, the values typed in bold are the extracted factor saturation scores which determine the theoretical mean of the factors

Table 1b. Structure of factors of selected morphological and motoric variables of ski jumpers of the first order ( $n = 72$ ), part two

Manifest variables	M	SD	Factor scores of the first order									
			F1	F2	F3	F4	F5	F6	F7	F8	F9	
<b>FACTOR 5</b>			Factor of push-off explosive power									
SMABATO – Push-off time in vertical take-off (s/1000)	422.5	43.0	-0.22	0.06	0.18	-0.22	<b>-0.96</b>	0.27	-0.01	-0.06	0.08	
EKSPLO – Index of explosive power of take-off	72.1	11.0	<b>0.55</b>	0.05	-0.19	0.31	<b>0.91</b>	-0.46	-0.07	-0.01	0.07	
EKSPLO1 – Index of explosive power of take-off in the first phase	5.8	1.1	0.26	0.06	-0.04	0.31	<b>0.91</b>	-0.44	-0.01	-0.21	0.28	
POSP – Acceleration of take-off ( $m/s^2$ )	7.1	1.0	<b>0.55</b>	0.05	-0.19	0.30	<b>0.91</b>	-0.46	-0.06	-0.01	0.07	
STMOR – Starting acceleration in push-off ( $m/s^2$ )	1.4	0.8	0.15	0.14	-0.05	0.20	<b>0.81</b>	-0.29	-0.06	-0.24	0.31	
FPOPR – Acceleration in take-off in the second part ( $m/s^2$ )	6.9	1.0	<b>0.63</b>	-0.20	-0.11	-0.15	<b>0.68</b>	-0.25	-0.00	0.24	-0.26	
MGGOLS – Ankle flexibility (angle degrees)	42.3	4.6	0.31	0.05	0.27	-0.16	<b>-0.40</b>	-0.15	0.03	-0.28	0.25	
<b>FACTOR 6</b>			Factor of informative component of motorics									
MHFNTL – Speed of left leg frequency (rep.)	34.2	3.1	0.39	0.10	0.03	0.15	0.29	<b>-0.87</b>	-0.12	0.01	0.31	
MHFNTD – Speed of right leg frequency (rep.)	35.3	3.3	0.33	0.00	0.01	0.08	0.28	<b>-0.79</b>	-0.06	0.02	0.38	
MKPOLN – Co-ordination of atypical movement (s/10)	6.8	1.1	-0.44	-0.17	-0.04	-0.23	-0.20	<b>0.79</b>	0.00	0.24	-0.43	
MMRNPK3 – Repetitive leg power (rep.)	101.7	14.8	0.38	0.28	-0.14	0.43	0.26	<b>-0.77</b>	-0.07	-0.43	0.38	
MFE50 – Co-ordination in jumping (s/10)	5.0	0.5	-0.35	-0.38	-0.04	-0.44	-0.23	<b>0.75</b>	0.09	0.17	-0.38	
MRSAGIT – Balance in sagittal plane (s/10)	9.5	7.8	0.29	0.32	0.21	0.16	0.19	<b>-0.69</b>	-0.21	0.23	0.38	
MRFRONT – Balance in frontal plane (s/10)	7.9	7.8	0.21	0.38	0.25	0.13	0.20	<b>-0.56</b>	-0.21	0.21	0.49	
MKKROSP – Coordination in an “eight” (s/10)	15.5	0.7	-0.30	-0.17	-0.00	-0.16	-0.26	<b>0.74</b>	0.08	0.05	-0.04	
MMRTDT45 – Repetitive power of abdominal muscles (rep.)	18.8	20.5	0.23	0.14	-0.12	0.02	0.30	<b>-0.55</b>	-0.06	-0.18	-0.25	
<b>FACTOR 7</b>			Factor of specific morphological index of thigh dimension									
INDSTEG – Index of thigh length	130.1	11.1	0.04	0.09	-0.27	<b>0.79</b>	0.19	-0.12	<b>0.64</b>	-0.11	0.16	
ADS – Right thigh length (cm)	41.7	2.7	0.12	<b>0.70</b>	-0.04	-0.12	-0.09	-0.12	<b>-0.78</b>	-0.05	0.12	
<b>FACTOR 8</b>			Factor of transversal dimensions of body									
ASR – Shoulder width (cm)	380.9	2,4	0.28	<b>0.70</b>	-0.12	0.36	0.03	-0.28	-0.04	<b>-0.60</b>	0.15	
ASM – Pelvis width (cm)	30.9	10.9	0.00	<b>0.71</b>	-0.30	0.41	0.24	-0.26	-0.09	<b>-0.55</b>	0.20	
<b>FACTOR 9</b>			Factor of flexibility of hips									
MGGTPKR – Relative index of flexibility	252.0	21.4	0.20	0.30	0.05	0.32	0.13	-0.38	-0.09	-0.13	<b>0.86</b>	
MGGTPK – Flexibility of hips (cm)	62.8	5.8	0.21	0.26	0.03	0.48	0.17	-0.40	-0.02	-0.16	<b>0.85</b>	
SPZ – Force ratio in the first and second parts of push-off (in %)	122.8	20.9	0.22	0.25	-0.03	-0.28	<b>-0.45</b>	0.27	-0.09	<b>0.51</b>	<b>-0.57</b>	
% OF VARIANCE				<b>34.9</b>	<b>17.2</b>	<b>12.2</b>	<b>7.3</b>	<b>5.0</b>	<b>3.5</b>	<b>3.1</b>	<b>2.4</b>	<b>2.2</b>

M – mean value, SD – standard deviation, F1 to F9 – orthogonal loadings, the values typed in bold are the extracted factor saturation scores which determine the theoretical mean of the factors

research showed the hierarchical structure of manifest dimensions of the potential model of performance in ski jumping.

## Discussion and conclusions

Through factor analysis in the first order, nine factors were excluded out of 42 manifest variables, which

explained 88% of the total variance of manifest variables (see Tab. 1a and 1b).

The first dominant was **factor of velocity power**, accounting for 34.9% of the total explained variance. The highest projection was discovered in the power of take-off (0.89) which was strongly connected to the variables of vertical push-off height and push-off velocity [9]. The success rate in ski jumping is strongly affected by this factor [10].

Table 2. Factor structure of selected morphological and motoric variables of ski jumpers of the second order ( $n = 72$ )

Factor analysis of the second order	C1	C2	C3	C4	Cum.
Component 1	Component of specific take-off movement				
F4 – Factor of morphological index of take-off	<b>-0.73</b>	-0.12	0.31	0.20	0.64
F5 – Factor of push-off explosive power	<b>0.70</b>	-0.24	0.03	0.18	0.60
F9 – Factor of flexibility of hips	<b>0.70</b>	0.04	-0.02	-0.20	0.52
Component 2	Component of thigh dimension				
F7 – Factor of specific morphological index of thigh dimension	-0.06	<b>0.88</b>	0.05	-0.04	0.79
Component 3	Component of specific flight potential				
F1 – Factor of velocity power	0.23	0.35	<b>-0.67</b>	-0.09	0.64
F3 – Factor of morphological index of flight aerodynamic	0.03	0.14	<b>0.63</b>	-0.04	0.43
F6 – Factor of informatic component of motorics	0.42	-0.38	<b>-0.50</b>	0.27	0.56
Component 4	Component of basic morphology				
F2 – Factor of longitudinal body dimensions	-0.12	-0.12	-0.12	<b>0.82</b>	0.71
F8 – Factor of transversal dimensions of body	0.12	-0.36	<b>-0.53</b>	<b>-0.57</b>	0.73
% OF VARIANCE	<b>22.9</b>	<b>14.5</b>	<b>13.0</b>	<b>12.1</b>	<b>62.7</b>

C1, C2, C3, C4 – orthogonal loadings of components, Cum. – cumulative loadings of components, the values typed in bold are the extracted factor saturation scores which determine the theoretical mean of the factors

Table 3. Structure of factors of selected morphological and motoric variables of ski jumpers of the third order ( $n = 72$ )

Factor analysis of the third order	GF1	GF2	Cum.
General factor of specific movement of ski jumpers			
C3 – Component of specific flight potential	<b>0.72</b>	-0.09	0.52
C1 – Component of specific take-off movement	<b>-0.70</b>	-0.07	0.51
General factor of morphology			
C4 – Component of basic morphology	0.26	<b>0.75</b>	0.64
C2 – Component of thigh dimension	0.31	<b>-0.71</b>	0.59
% OF VARIANCE	<b>29.8</b>	<b>27.3</b>	<b>57.1</b>

GF1, GF2 – orthogonal loadings of general factors, Cum. – cumulative loadings of general factors, the values typed in bold are the extracted factor saturation scores which determine the theoretical mean of the factors

The second was determined to be the **factor of longitudinal body dimensions**, which explained 17.2% of variance. With this factor, the basic projections of morphological variables of body were primarily defined by high projections of longitudinality (body height and total arm & body height and tibia length, leg length), projections of transversality (bipolar diameter and biaxial diameter) and projection of body mass (body weight). The success rate in ski jumps is only in one part affected by the general morphological factor. Other spe-

cific morphological factors of ski jumpers have a strong impact on the success of ski jumping technique [11].

The third was the more specific **factor of morphological index of flight aerodynamics** which explained 12.2% of variance, the projection of morphological aerodynamic index (0.94) was prevalent. A high factor saturation was also seen in body mass (-0.67) and body mass index (-0.93). From the point of view of aerodynamics, the existence of independent specific morphological factors has to be taken into account. These factors have a strong impact on the execution of ski jumping technique. The morphological aerodynamic index plays an important aerodynamic role in the central phase of flight. Ski jumpers with higher aerodynamic indexes show higher potential capacity for successful execution of a jump in the flight phase. This finding is of great importance in selection of talented jumpers and their training. In that factor, the body mass index (BMI) is important. It is defined as the individual's body weight divided by the square of their height. In ski jumping, from the aspect of aerodynamics, lower values of BMI are much better than higher ones [12]. A BMI of 18.5 to 25 indicates optimal weight in the general population. The best ski jumpers have BMI near to the value of 18.5, i.e., on the border of the underweight [13]. The Fédération Internationale de Ski (FIS) has regulated this extremely negative BMI trend with the shortening of ski lengths.

The fourth was the **factor of morphological index of take-off**, accounting for 7.3% of variance. The morphological take-off index plays an important role in achieving rapid transition to flight. With this factor, there was dominant projection of morphological index of take off (0.90). Morphological index of the take-off expresses a relation between the height of a ski jumper and the lower limb length. Ski jumpers with relatively shorter legs according to their body height have hypothetically better torque of the body weight force. This torque acts before and during the take-off in a negative way in the knee joint, where the muscular force action at the take-off is the highest. The result of the vertical velocity of the take-off does not only depend on the muscular force of the take-off, but predominantly on the torque, at which this force acts. This factor is responsible for potential performance of the ski jumper in take-off phase. It plays an important role in achieving rapid transition to flight from the aspect of aerodynamics (minimization of the air resistance and maximization of the lift force during the take-off).

With the fifth **factor of push-off explosive power**, accounting for 5.0% of variance, there were dominant variables of starting acceleration in push-off. The variables of the push-off explosive power formed a homogeneous structure. In analyzing the push-off power in a ski jumper's take-off, one has to consider the factor of explosive push-off power. Explosiveness of take-off is particularly important in the first phase of ski jumper's push-off [13]. In ski jumping, take-off action is the most important factor for having ascent force. Ascent force acts on the ground and is required for a jumper to obtain initial velocity and angular momentum [14].

The projection of the basic motoric variable was strongly prevalent in the sixth **factor of the informative component of motorics**, representing 3.5% of variance. The information component of movement covers the coordinated actions of those latent motor mechanisms that take care of the control and regulation of information processes. Coordination may be defined as the concerted action of the muscles in producing the movement. As such, it is ultimately determined by timing, sequencing and amplitude of muscle activation [15]. The coordination was represented by three manifest variables indicating three typical forms of coordination. For all three forms, characteristic is the requirement for the fastest possible execution of motor tasks, which are complex in some way. Of course, the manifestation of the coordination abilities depends on the plasticity of the mechanism for the regulation of the synergistic and antagonistic muscle groups. On the phenomenological level, a domination of the ability of the speed of alter-

native movements of lower extremities was discovered. However, the sixth factor also obtained quite considerable orthogonal loadings of the balance tests in the sagittal plane and balance in the frontal plane.

The seventh factor was the **factor of specific morphological index of thigh dimensions**, accounting for 3.1% of the total explained variance. This factor defines the potential performance from the aspect of knee angular velocity in the take-off phase in ski jumping technique. Take-off force is produced by joint movement [16]; most of the power from initial action until take-off is produced by two joints, the hip and the knee [17]. The knee joint power is important for achievement of the optimum level of angular momentum in the forward direction [18]. There are two important factors that determine how much knee inertia a rotating ski jumper will have: the mass of the ski jumper and the radial distribution of body mass. The term "radial distribution of body mass" refers to how the mass of a ski jumper is distributed, or positioned, relative to the knee axis about which it is rotated. The ski jumpers with the high level of morphological factor of knee angular velocity have better potential to reach higher knee extension velocity, which is a proven factor for successful ski jumping technique.

The eighth was the **factor of transversal dimensions of body**, accounting for 2.4% of variance. The last, ninth factor was the **factor of flexibility of hips**, accounting for 2.2% of variance. This factor is important for good realization of ski jumping technique in the inrun phase and especially in take-off phase. This factor is connected to the force ratio in the first and second parts of push-off. The jumpers with better flexibility of hips could hypothetically produce more power in the first part of take-off phase.

Hoteling's method of principal components, according to the Guttman-Kaiser criterion, resulted in extraction of 9 principal factors of the manifest motor and morphological measure correlation matrix. The number of the principal factors corresponds to the hypothesis according to which the manifest variables were selected. The results were very similar as in study [19] where eight principal factors were ruled out (factor of velocity power, factor of morphological lengthiness, factor of morphological aerodynamics, factor of flexibility of ski jumpers, factor of explosive power of take-off, factor of ski jumping morphological take-off index, factor of balance of ski jumpers, factor of coordination and motor velocity).

The factor analysis made on factors of the first order produced four components on the second order. From Table 2 it is obvious that 62.7% of the total variability

was explained by four components. The results are interesting primarily because they reflect more generality in expressing specific factors of the first order. The first **component of specific take-off movement** obtained quite considerable orthogonal loadings of the factors of specific motor behavior of ski jumpers especially in take-off phase. The second **component of thigh dimension** is strongly connected to the factor of specific morphological index of thigh dimension (0.88). The third isolated component can be interpreted as **component of specific flight potential** with dominant projection of factor of morphological index of flight aerodynamic. This factor has opposite projections to other two factors belonging to motor variables. In the last **component of basic morphology** the projections of two basic morphological factors dominated. The factor of longitudinal body dimensions has positive projection (0.82). On the other hand, the factor of transversal dimensions of body has negative projection (-0.53). The structure of components on second level is very interesting for ski jumping training theory. Today, it is more and more important to know specific factors which determine the successfulness in ski jumping. The combination of those specific factors significantly influence the whole performance in ski jumping competitions. The specific motor and morphological features or components play a major, arguably critical, role in competition success of ski jumpers. And this is an important fact for the specific motor & morphological optimization of the ski jumper's personal profile. This optimization occurs through two mechanisms: selection and adaptation. Adaptation refers to the physique-modeling of ski jumping performance.

At the third, highest level, the hypothetical statement that there exist two independent general factors could be defined (see Tab. 3): the first one **general factor of specific movement of ski jumpers** is regulated by motoric actions or behavior and the second one **general factor of morphology** is regulated by morphological processes. Both general factors explained only 57.1% of the total variance. The structure of the first general factor is very interesting for development of the performance theory in ski jumping. The general personality profile of ski jumper is influenced by technique nature of ski jumping. Some dimensions are more connected to the take-off phase and some to the flight phase of ski jumping. A reduced potential performance model (RPPM) for ski jumpers was set up on the concept of multidimensionality of psychosomatic status. The number of performance model dimensions depends on the level of hierachic structure. The bigger number of elementary dimensions could be condensed to a smaller

number of derived dimensions at a higher level. The results of research have shown the need for a new concept of modeling performance in ski jumping. With nine primary factors 88% of total variance manifest variables could be explained. The independent primary factors of the first order are crucial in understanding the latent dimensions of the potential performance model at the second and third levels. This primary factor shows the structure between manifest dimensions more clearly and their relations are more understandable.

At the second level the number of factors and the percentage of total variance falls down rapidly. The interpretation of derived factors at the higher level of the hierachic factor model is difficult. At the higher level, we do not have the possibility of recognizing the realistic nature of latent variables. The relationships between latent dimensions at the second and third levels are complex, and behave in different and often contradictory ways [20]. Therefore we can look in the latent dimensions of hierachic model of reduced potential performance only over empirical manifest dimensions. These manifest and latent motorical and morphological model dimensions have to be explored further from the point of view of biomechanics, physiology and other special sciences.

## References

1. Ulaga M., Čoh M., Jošt B., Validity of the dimensional configuration of the reduced potential performance model in ski jumping. *Kinesiology*, 2006, 38 (2), 185–192.
2. Virmavirta M., Komi P.V., Take-off analysis of a champion ski jumper. *Coaching and Sport Science Journal*, 1994, 1, 23–27.
3. Blahuš P., Hrúby J., Kvapil J., Paichl J., Systems theory approach to using statistics in social sciences. Charles University, Prague 1988.
4. Jost B., Tušák M., The structure of reduced potential performance model in ski jumping. *J Hum Kinetics*, 2002, 8, 3–15.
5. Schmölzer B., Müller W., The importance of being light: aerodynamic forces and weight in ski jumping. *J Biomech*, 2002, 35, 1059–1069.
6. Müller W., Determinants of ski-jump performance and implications for health, safety and fairness. *Sports Med*, 2009, 39 (2), 85–106.
7. Gredelj M., Metikoš D., Hošek A., Momirović K., A model of hierachic structure of motoric abilities [in Croatian]. *Kinezologija*, 1975, 5 (2), 8–84.
8. Thomas J.R., Nelson J.K., Research methods in physical activity. 3<sup>rd</sup> edition, Human Kinetics, Champaign 1996.
9. Vaverka F., Biomechanics of Ski jumping [in Czech] Univerzita Palackeho, Olomouc 1987.
10. Virmavirta M., Komi P.V., The take-off forces in Ski jumping. *Int J Sport Biomech*, 1989, 5, 248– 257.
11. Jost S., The factor structure of selected morphological variables in Ski jumpers. In: Milanović D., Prot F. (eds.), Proceedings book of the 5th International Scientific Conference on Kinesiology "Kinesiology research trends and applications", September 10–14, 2008. Faculty of Kinesiology, Zagreb 2008, 929–932.

12. Müller W., Gröschl W., Müller R., Sudi K., Underweight in Ski jumping: The Solution of the Problem. *Int Sports Med*, 2006, 27 (11), 926–934. doi:10.1055/s-2006-923844.
13. Komi P.V., Virmavirta M., Ski-jumping take-off performance: Determining factors and methodological advances. In: Müller E., Schwameder H., Kornexl E., Rascher C. (eds.), *Science and skiing*. E & FN Spon, London 1997, 3–26.
14. Virmavirta M., Komi P.V., Measurement of take-off forces in ski jumping – part I. *Scand J Med Sci Sports*, 1993, 3, 229–236. doi:10.1111/j.1600-0838.1993.tb00387.x.
15. Bobbert F.M., Schenau G., Coordination in vertical jumping. *J Biomech*, 1988, 21 (3), 249–262.
16. Sasaki T., Tsunoda K., Uchida E., The relation of muscle activity and joint power during ski jump takeoff action. In: Häkkinen K., Keskinen K.L., Komi P.V., Mero A. (eds.), *Proceedings Book of abstracts, the XV<sup>th</sup> Congress of the International Society of Biomechanics, July 3–6, 1995 Jyväskylä*. Department of Biology of Physical Activity, University of Jyväskylä, Jyväskylä, 1995, 800–801.
17. Sasaki T., Tsunoda K., Uchida E., Hoshino H., Ono M., Joint power production in take-off action during ski-jumping. In: Müller E., Schwameder H., Kornexl E., Rascher C. (eds.), *Science and skiing*. E & FN Spon, London 1997, 49–60.
18. Virmavirta M., Komi P.V., Measurement of take-off forces in ski jumping – part II. *Scand J Med Sci Sports*, 1993, 3, 237–243. doi:10.1111/j.1600-0838.1993.tb00388.x.
19. Jošt B., Pustovrh J., Ulaga M., Jošt P., The latent dimensions of selected morphological and motor variables in ski jumpers. *Studies in Physical Culture & Tourism*, 2006, 13 (suppl.), 137–140.
20. O'Connor H., Olds T., Maughan J.R., Physique and performance for track and field events. *J Sports Sci*, 2007, 25 (S1), S49–S60. doi:10.1080/02640410701607296.

Paper received by the Editors: January 22, 2010.

Paper accepted for publication: April 12, 2010.

*Address for correspondence*

Prof. Dr Bojan Jošt  
Faculty of Sport  
University of Ljubljana  
Gortanova 22, 1000 Ljubljana, Slovenia  
e-mail: bojan.jost@fsp.uni-lj.si



# ANALYSIS OF PEAK TIBIAL ACCELERATION DURING GAIT IN DIFFERENT CADENCES

doi:10.2478/v10038-010-0018-y

JAQUELINE LOURDES RIOS\*, MÁRIO CESAR DE ANDRADE, ALUISIO OTAVIO VARGAS AVILA

Physical Education Department, Science Center for Health and Sport, State University of Santa Catarina, Santa Catarina, Brazil

## ABSTRACT

**Purpose.** The gait is the most common human movement, a functional task that requires complex and coordinated interactions of the body. This activity has been the subject of various studies, both in relation to descriptions of typical body movements as in pathological conditions and therapeutic interventions. The objective of this study was to describe and analyze the variation of peak acceleration in the tibia by means of accelerometers during the gait cadence induced in normal subjects. **Basic procedures.** Nine subjects walked on a catwalk on a straight line for 8 meters at 4 km/h ( $\pm 5\%$ ), 5 km/h ( $\pm 5\%$ ) and 6 km/h ( $\pm 5\%$ ) using uniaxial piezoelectric accelerometers with scale 7g set at the midpoint of both tibiae. **Main findings.** It was observed that there was no difference in peak acceleration between dominant and non-dominant limbs, however, there was significant difference ( $p < 0.05$ ) among all the velocities with which the subjects were analyzed. **Conclusions.** It is suggested that the variation of 1 km/h is enough to change the peak acceleration of the tibia.

**Key words:** gait, tibial peak acceleration, different cadences

## Introduction

The gait is the most common human movement [1], a functional task that requires coordinated and complex interactions between many of the major joints of the body [2, 3], in particular the lower limbs [2].

This activity has been the subject of various studies, both in relation to descriptions of typical body movements as in pathological conditions and therapeutic interventions [2, 4].

In almost all movements of human locomotion, the ground reaction force is acting on the subject. This force of ground reaction is an application of Newton's third law of motion, also known as action-reaction law. The person exerts a force on the ground with a certain intensity, and the ground returns to the individual a force of equal intensity, but in the opposite direction [5].

According to Winter [1], the most common force acting on the human body is the force of ground reaction, which acts while it is in the static position, walking or running. This vector of force consists of a vertical component and two horizontal components acting parallel to the surface of the platform of strength or of the measuring instrument. These shared horizontal forces are usually described as fore-aft and medial-lateral.

According to Perry [6], the normal pattern of vertical

forces obtained during the support phase at a normal running speed of 1.36 m/s has two peaks separated by a valley. Thus, the value of the peaks is close to 110% of the body mass, while the force in the valley is around 80%.

Viel [3] defines the force of shear as a force of laceration that is exerted when two solid bodies are animated by inverted parallel sliding movements, causing then a distension in the means of union (joint capsule, ligaments). Perry [6] affirms that when the force of shear is excessive it can cause injuries in the bone structures, muscle and ligaments.

Nigg and Herzog [7] argue that such a force can be analyzed by accelerometry, and they cite the work of Gage (1967), where accelerometers were used during the gait to check the vertical and horizontal accelerations of the head, trunk and ankle.

Accelerometers are sensors that measure acceleration. Typically, these are made of a reaction mass suspended by a stationary structure, and the same can be viewed as a mass-spring system. The force exerted by the weight is balanced by the spring, the displacement allowed by the spring being proportional to the force applied, and the acceleration of the body proportional to the displacement of the mass [8].

In piezoelectric accelerometers the mass is attached to a piezoelectric crystal. When the body undergoes a vibration, the mass follows the laws of inertia and the crystal is subjected to traction and compression forces, generating loads, and this force is proportional to the second Newton's law [8].

\* Corresponding author.

Since 1988, studies of Lafourche and Hennig have described the tibial accelerometry during walking and running [9, 10].

For the importance of movement, the aim of this study is to describe and analyze the variation of peak acceleration in the tibia by using accelerometers during the gait cadence induced in normal subjects.

### Material and methods

This research was reviewed and approved by the Ethics Committee on Human Research at the University of the State of Santa Catarina – UDESC, Florianópolis-SC reference number N° 184 on October 22, 2008.

#### Study participants

According to Cervo and Bervian [11], the population of scientific research comprises a group of people who are potential subjects in various studies, and the participants in this study belong to this group.

The sample was intentionally non-probabilistic, so 9 male subjects, with fixed residence in Florianópolis-SC, were selected. The criteria for inclusion in the study were as follows: healthy individuals interested in participating in the research with an average age of 21.67 ( $\pm 3.57$ ) years, academics from the University of Santa Catarina, Center for Health Science and Sport. The criteria for exclusion from the study were as follows: subjects who used orthosis or prosthesis in the lower limbs, who had presented a problem in the lower limbs in the previous six months or were using any medication that could interfere with balance and/or muscle tone.

#### Location

Data acquisition was performed at the Biomechanics Laboratory of CEFID-UDESC in Florianópolis-SC.

#### Instruments for data collection

For this study two uniaxial piezoelectric accelerometers with scale 7 g were used, sensitivity 952.1 mV/g, cross sensitivity < 5%, frequency range from 0.4 to 0.6 kHz. (1 × 1 × 1 cm, mass = 4.6 g – Brüel & Kjær model DeltaTron ® 4507 B 005, Fig. 1).

#### Variables analyzed

The peak acceleration was analyzed during gait through the software developed in LabVIEW environment (G-Power-Analysis v0.3). The first two and last two peaks of each sample were excluded from the analysis. These data were exported to a spreadsheet in

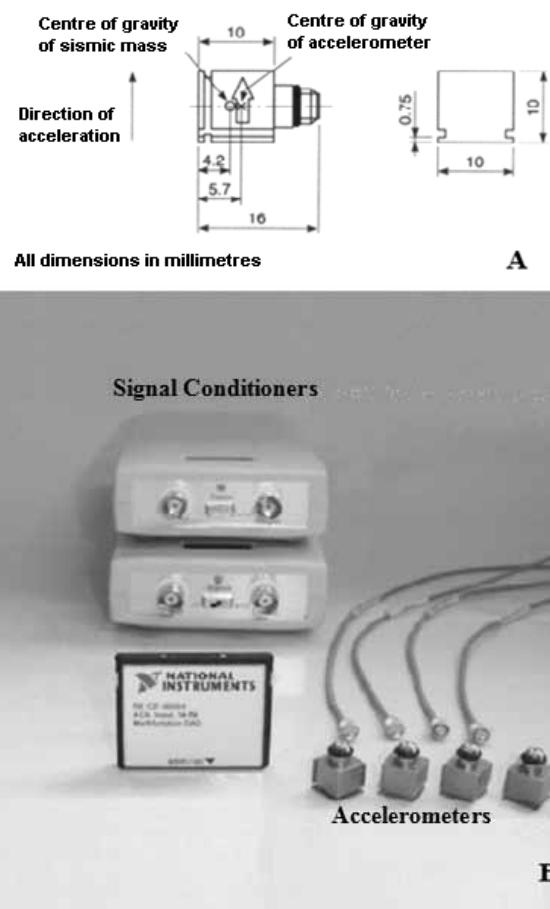


Figure 1. (A) Accelerometer Brüel & Kjær, model DeltaTron ® 4507 B 005. All dimensions are in millimeters. The “arrow” shows to the direction of acceleration (image taken from the manual of the accelerometer), (B) Set of four accelerometers Brüel & Kjær, model DeltaTron ® 4507 B 005 and the signal conditioner

SPSS 17.0, where an exploratory descriptive statistics was performed, followed by one-way ANOVA and Scheffe post hoc test.

#### Procedure for data collection

First, the objectives of the study and the sequence of evaluations were presented to the subjects. Then, the participants were asked to sign an informed consent form. Next, the identification form was filled, which contained anthropometric information, as well as a questionnaire about the laterality of the lower limbs. Afterwards, we asked the subjects to put on swimming trunks (in the locker room of the laboratory of biomechanics) and to sit on a chair so that accelerometers could be positioned on the lower limbs. Two accelerometers were used: one at the midpoint of the dominant member tibia and another at the midpoint of the non-dominant member tibia.

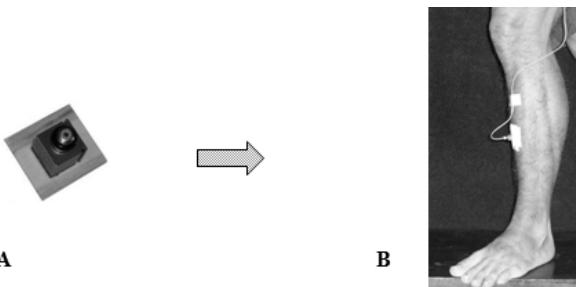


Figure 2. (A) Accelerometer fixed on balsa wood using double-sided tape before being engaged in the subject's leg, (B) Accelerometer fixed in the middle third of the tibia

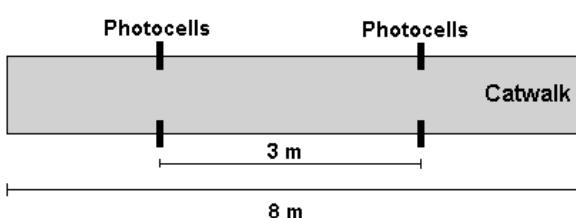


Figure 3. Catwalk where individuals walked for the signal acquisition: the system of photocells to control the speed was positioned 2.5 m from the start and end of the catwalk

Accelerometers were fixed with double sided adhesive tape on the balsa wood (wood used in airplane models, in order to avoid injury to the skin, since the accelerometer has corners that may damage the tissue) and this was fixed on the skin with tape (Fig. 2). The subjects wore a vest where, in the pockets of it, were placed two signal conditioners that were linked to the two accelerometers fixed on the lower limbs. A thin wire connected each accelerometer to its signal conditioner without interfering with movement of the subject. The subjects walked on a catwalk (on a straight line for 8 meters) at 4 km/h ( $\pm 5\%$ ), 5 km/h ( $\pm 5\%$ ) and 6 km/h ( $\pm 5\%$ ); the photocells that monitored the speed were positioned two and a half meters from the start and end of the catwalk (Fig. 3). The attempts where the subjects did not achieve the target speed were discarded. This course was conducted with subjects barefoot and repeated 5 times for each speed. The peaks of tibial acceleration were measured while the subjects walked on the catwalk. After completion of the course, the accelerometers were removed from the subjects and assessment was completed.

## Results

Initially, we compared the peak acceleration of the tibia of the dominant and non-dominant limb of each subject in each of the three speeds adopted. As can be seen by comparing the averages with t-test (Fig. 4), the

difference between the limbs is not significant ( $p > 0.05$ ), there is no need to differentiate between dominant and non-dominant limbs. Therefore, all further analysis was made with both data put together.

Table 1 shows the average of peak tibial acceleration in the lower dominant and non-dominant limbs, the standard deviation and the average trimmed by 5% at the extremes at the speed of 4 km/h, 5 km/h and 6 km/h. At all speeds there is a similarity between the regular average and the trimmed average, suggesting that there were no values of peak acceleration high enough to raise or lower the average.

The statistical test Analysis of Variance (ANOVA) one-way was performed (Tab. 2), where significant difference, in at least one of the groups, was observed. Therefore, Scheffe post hoc test was applied to de-

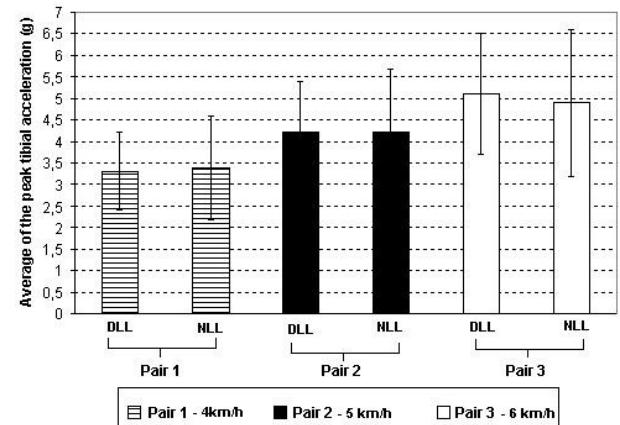


Figure 4. Average of the peak tibial acceleration in g (gravity) and standard deviation in the dominant lower limb (DLL) and non-dominant lower limb (NLL) at speeds of 4, 5 and 6 km/h

Table 1. Comparison between the average ( $\bar{x}$ ) and the trimmed average with less 5% of the extremes (TA -5%) of peak acceleration in the dominant and non-dominant limb tibia with the person walking at 4 km/h, 5 km/h and 6 km/h; the similarity of values is visible.  
"s" means the standard deviation

Subject	4 km/h		5 km/h		6 km/h	
	$\bar{x}$ (s)	TA -5%	$\bar{x}$ (s)	TA -5%	$\bar{x}$ (s)	TA -5%
1	1.6 (0.3)	1.5	2.1 (0.4)	2.1	3.1 (0.7)	3.1
2	2.7 (0.5)	2.7	4.3 (1.6)	4.2	4.5 (1.8)	4.4
3	5.2 (0.9)	5.3	6.5 (0.7)	6.6	7.7 (0.8)	7.7
4	3.8 (0.6)	3.8	4.6 (0.7)	4.6	6.6 (1.1)	6.7
5	3.2 (0.7)	3.3	3.8 (0.8)	3.8	5.2 (1.7)	5.2
6	3.9 (0.8)	3.9	4.9 (1.3)	4.8	4.7 (1.1)	4.6
7	4.0 (0.3)	4.0	4.8 (0.6)	4.8	5.1 (0.7)	5.6
8	3.5 (0.4)	3.5	4.1 (0.7)	4.1	4.5 (0.6)	4.5
9	2.7 (0.6)	2.7	2.8 (0.5)	2.7	3.3 (0.5)	3.2

termine between which groups the difference occurred. In Table 3 significant difference in all groups can be observed ( $p < 0.05$ ). This suggests that the variation of 1 km/h is enough to cause significant change in peak tibial acceleration.

Table 2. One-way ANOVA between the different speeds

	SQ	df	MQ	F	p
Between groups	318.9	2	159.4	67.8	0.001
Within groups	1584.6	674	2.3		
Total	1903.4	676			

SQ – sum of squares, df – degrees of freedom, MQ – mean square, F – F test, p – significance value

Table 3. Scheffe post hoc test where there is significant difference between all the different speeds ( $p < 0.05$ )

Speed	Speed	Multiple comparisons			
		Average difference	p	95% Confidence interval of the difference	
				Upper	Lower
4 km/h	5 km/h	-0.9	0.001*	-1.3	-0.6
	6 km/h	-1.7	0.001*	-2.0	-1.3
5 km/h	4 km/h	0.9	0.001*	0.6	1.3
	6 km/h	-0.7	0.001*	-1.1	-0.4
6 km/h	4 km/h	1.7	0.001*	1.3	2.0
	5 km/h	0.7	0.001*	0.4	1.1

\* The average difference is significant at a .05 level.

## Discussion

To meet the objectives proposed in the study, subjects underwent three procedures: first, they walked at a speed of 4 km/h, then 5 km/h and finally, at 6 km/h, where each subject was numbered from 1 to 9.

By comparing the peak tibial acceleration of the dominant and non-dominant limbs for each subject using the t-test, it is verified that there is no need to analyze the limbs separately in the data analysis, as there was no statistical difference between them. When comparing the average peak tibial acceleration with the peak tibial acceleration trimmed by 5% at the extremes – at all speeds – a similarity is observed, suggesting that there were no values of peak acceleration high enough to raise or lower the average.

There was significant difference in all speeds ( $p < 0.05$ ). This suggests that the variation of 1 km/h is enough to cause a significant change in peak acceleration of the tibia. When the study of Lafourture and Hennig [12] – speed of 1.5 m/s (5.4 km/h) – is compared

with this study, by t-test, no significant difference is found at the speeds of 5 and 6 km/h ( $p > 0.05$ ), but a significant difference is found when compared to speed of 4 km/h ( $p < 0.05$ ), confirming the findings of this study, which suggests that from 1 km/h onward there is already a significant change in peak tibial acceleration (Tab. 4).

But when compared with the study by Lafourture et al. [13], where speed was 1.05 m/s (3.78 km/h), there was significant difference for all three speeds adopted in this study, including the speed of 4 km/h (Tab. 5); considering that the population and conditions of the sample were similar, it confirms again the findings of this study and indicates that a smaller percentage of the variation in speed may be sufficient to generate a significant difference in peak tibial acceleration.

Table 4. T-test between the average peak tibial acceleration found by Lafourture and Hennig [12] and the averages found at speeds of 4, 5 and 6 km/h

Test value = 4.68 g						
t	gl	p	Average difference	95% Confidence interval of the difference		
				Lower	Upper	
4 km/h	-3.7	8	0.005*	-1.3	-2.1	-0.5
5 km/h	-1.0	8	0.321	-0.5	-1.5	0.5
6 km/h	0.6	8	0.535	0.3	-0.8	1.5

Table 5. T-test between the average peak tibial acceleration found by Lafourture, Lake and Hennig [13] and the averages found at speeds of 4, 5 and 6 km/h

Test value = 8.80 g						
t	gl	p	Average difference	95% Confidence interval of the difference		
				Lower	Upper	
4 km/h	-15.4	8	0.001	-5.4	-6.2	-4.6
5 km/h	-10.4	8	0.001	-4.6	-5.6	-3.6
6 km/h	-7.6	8	0.001	-3.8	-4.9	-2.6

Table 6. T-test between the average peak tibial acceleration found by Wüst, et al. [14] and the averages found at speeds of 4, 5 and 6 km/h

Test value = 2.80 g						
t	gl	p	Average difference	95% Confidence interval of the difference		
				Lower	Upper	
4 km/h	1.6	8	0.145	0.6	-0.2	1.4
5 km/h	3.2	8	0.012	1.4	0.4	2.4
6 km/h	4.4	8	0.002	2.2	1.0	3.4

In the study by Wüst et al. [14], a subject walked at 5 km/h in conditions similar to those of this work. The average peak tibial acceleration was 2.80 g, approaching the value obtained at 4 km/h in this study, the differences being significant for all other velocities (Tab. 6). However, the gait in that study was performed on a treadmill. Milani et al. [15] and Lafortune et al. [16] have already discussed the existence of a significant difference in peak acceleration between walking held on the ground and on the treadmill. The authors also suggest the project “Projeto Final de Instrumentação e Aquisição de Sinais”, Instituto Superior Técnico (Instrumentation and Signal Acquisition Final Project, Superior Technical Institute) should continue for further explanation about the difference found between this study and Wüst et al. study [14].

### Conclusions

Based on the proposed objectives, one can observe that the values of peak tibial acceleration during gait in normal subjects walking at speeds of 4, 5 and 6 km/h did not differ statistically between dominant and non-dominant limbs, and in the t-test,  $p$  was higher than 0.05.

On the other hand, when the peak acceleration was compared at different speeds, it was observed that an increase of 1 km/h was enough to change the peak acceleration of the tibia significantly, as shown by the comparison test of averages applied: ANOVA.

Comparing the results of this study to the literature on the speed of 5.4 km/h, one can observe that this study is consistent, since by t-test application no significant difference was found at the speeds of 5 and 6 km/h ( $p > 0.05$ ). A significant difference was found when compared to speed of 4 km/h ( $p < 0.05$ ), suggesting that, starting from 1 km/h, there is already significant change in peak acceleration of the tibia.

But when the speed of 5 km/h is correlated with the gait performed on the treadmill, it is observed that the peak values of acceleration are similar to the values obtained at 4 km/h in this study; but the kinetic and kinematic differences between gait on the ground and on the treadmill are already known.

To further complement the study, there is suggested a population expansion and a reduction in the speed range.

### References

- Winter D.A., Biomechanics and motor control of human movement. 2<sup>nd</sup> edition. John Wiley & Sons, New York 1990.
- Nordin M., Frankel V.H., Basic biomechanics of the musculoskeletal system. 3<sup>rd</sup> edition. Lippincott Williams & Williams Wilkins. Philadelphia 2001.
- Viel E., The human gait, running and jumping: biomechanics, research, standards and disorders [in Portuguese]. Manole, São Paulo 2001.
- Smith L.K., Weihs E.L., Don Lehmkul L., Brunnstrom's clinical kinesiology. 5<sup>th</sup> edition. F.A. Davis, Philadelphia 1996.
- Vaughan C.L., Davis B.L., O'Connor J.C., Dynamics of human gait. Human Kinetics, Champaign 1992.
- Perry J., Gait analysis: System analysis of gait. Volume 3 [in Portuguese]. Manole, Barueri 2005.
- Nigg B.M., Herzog W., Biomechanics of the musculo-skeletal system. John Wiley & Sons, Toronto 1994.
- Figueiredo L.J., Gafaniz A.R., Lopes G.S., Pereira R., Applications of accelerometers: instrument and signal acquisition – Final design of instrumentation and signal acquisition [in Portuguese]. Higher Technical Institute: Technical University of Lisbon, Lisbon 2007, 1–12.
- Hennig E., Lafortune M.A., Tibial bone and skin accelerations during running. V<sup>th</sup> Biennial Conference of Canadian Society of Biomechanics, Spodym Publ., Ottawa 1988, 74–75.
- Lafortune M.A., Hennig E., Effects of velocity and uphill slope on tibial shock during running. V<sup>th</sup> Biennial Conference of the Canadian Society of Biomechanics. Spodym Publ., Ottawa 1988, 94–95.
- Cervo A.L., Bervian P.A., Scientific methodology for use of college students [in Portuguese]. 3<sup>rd</sup> edition. MacGraw-Hill from Brazil, São Paulo 1983.
- Lafortune M.A., Hennig E.M., Cushioning properties of footwear during walking: accelerometer and force platform measurements. *Clin Biomech*, 1992, 7 (3), 181–184. doi:10.1016/0268-0033(92)90034-2.
- Lafortune M.A., Lake M.J., Hennig E.M., Differential shock transmission response of the human body to impact severity and lower limb posture. *J Biomech*, 1996, 29 (12), 1531–1537. doi:10.1016/S0021-9290(96)80004-2.
- Wüst E., Robinson C.C., Palhano R., Zaro M., Bruxel Y., Nabiner E., Andrade M.C., Repeatability of peak acceleration through the tibial accelerometry for women's shoes and men's footwear [in Portuguese]. Tecnicouro, Novo Hamburgo 2009, 104–108.
- Milani T.L., Hennig E.M., Riehle H.J., A comparison of locomotor characteristics during treadmill and overground running. In: Groot G.d., Hollander P., Huijing P., Schenau G.v.I. (eds.), Biomechanics XI-B. Free University Press, Amsterdam 1988, 655–659.
- Lafortune M.A., Hennig E.M., Milani T.L., Comparison of treadmill and overground running. In: Herzog W., Nigg B.M., Bogert T.v.d. (eds.), 8<sup>th</sup> Biennial Conference of the Canadian Society of Biomechanics, Organizing Committee, Calgary 1994, 90–91.

Paper received by the Editors: January 15, 2010.

Paper accepted for publication: April 21, 2010.

#### *Address for correspondence*

Jaqueleine Lourdes Rios  
R: Bernardo Scheidt, 192. Centro  
CEP: 88131-020  
Palhoça, Santa Catarina, Brazil  
e-mail: jaquelrios@gmail.com



# INFLUENCE OF STATIC STRETCHING DURATION ON QUADRICEPS FORCE DEVELOPMENT AND ELETROMYOGRAPHIC ACTIVITY

doi:10.2478/v10038-010-0020-4

**LUCIANO PAVAN ROSSI<sup>1\*</sup>, RAFAEL PEREIRA<sup>2,3</sup>, ROBERTO SIMÃO<sup>4</sup>, MICHELLE BRANDALIZE<sup>5</sup>, ANNA RAQUEL SILVEIRA GOMES<sup>1</sup>**

<sup>1</sup> Biomechanics Laboratory, Physical Education Department, Physical Education and Sports School, Federal University of Paraná, Curitiba, Brazil

<sup>2</sup> Research Group in Neuromuscular Physiology, Department of Biological Sciences, State University of South-West Bahia, Jequié, Bahia, Brazil

<sup>3</sup> Department of Biomedical Engineering, Camilo Castelo Branco University, São Paulo, Brazil

<sup>4</sup> Biomechanics Laboratory, Bioscience Department, Physical Education and Sports School, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

<sup>5</sup> Biomechanics Laboratory, Physiotherapy Department, Guaíracá Faculty, Guarapuava, Brazil

## ABSTRACT

**Purpose.** The purpose of the present study was to analyze the influence of static stretching duration on quadriceps muscle isometric force and electromyographic (EMG) activity of the *rectus femoris* and *vastus lateralis*. **Basic procedures.** Twenty recreationally-active healthy men were selected for the study. On two separate days, participants took part in two stretching protocols of different durations. Following a specific warm-up, participants performed isometric strength assessments of the dominant leg before and after a bout of quadriceps stretching. The stretching protocol consisted of two stretches for the quadriceps muscle for three repetitions of 30 seconds on one visit, and 60 seconds on the other. **Main findings.** The results revealed a significant reduction in quadriceps muscle mean and peak forces and EMG activity for the *rectus femoris* with both 30- and 60-second stretching protocols ( $p \leq 05$ ). However, EMG activity of the *vastus lateralis* decreased significantly only in the 60-second protocol ( $p \leq 05$ ). **Conclusions.** Both stretching protocols induced significant decreases in strength and EMG activity, although the stretching duration ( $60 \times 30$ ) did not appear to be a major influencing factor for the current strength reductions. In this perspective, coaches and athletes should avoid flexibility training which consists in stretching repetitions of 30 seconds or longer prior to competitions.

**Key words:** stretching, force, peak force, isometric, electromyography

## Introduction

Stretching is commonly performed in sports due to its effectiveness in the maintenance and improvement of joint range of motion. Strength and conditioning professionals, coaches, athletic trainers, and physical therapists recommend stretching prior to competition or a strenuous activity because of the common belief that it can improve athletic performance and/or reduce the risk of musculoskeletal injuries [1].

Recent studies have suggested static stretching performed before an exercise can temporarily compromise the muscle's ability to produce force [2–7] and reduce the electromyographic (EMG) activity of the muscle [5, 6]. Conversely, other studies have not reported significant performance decrements following static stretching on vertical jump [8], eccentric peak torque [9], concentric peak torque and muscular power in elite athletes [10], dynamic balance [3], tennis serve [11] and kicking

performance [12], and the hamstrings-to-quadriceps (H:Q) ratio during maximal concentric isokinetic muscle actions [13].

Avela et al. [2] and Fowles et al. [14] found significant reductions in strength and EMG activity of the plantarflexor muscles after an hour of fast and repeated stretching and with a protocol of 13 repetitions of 135 seconds, respectively. Likewise, Weir et al. [15] reported similar results using a stretching protocol of 5 repetitions of 120 seconds in plantarflexor muscles. However, Behm et al. [16] reported that static stretching for periods of 45 seconds did not cause significant differences in strength, despite the findings of a decrease in balance performance along with increases in reaction time and movement time. Similarly, Alpkaya and Kocceja [17] found no significant changes using 15 seconds of stretching, in which there were no positive or negative effects on reaction time or explosive force.

Ogura et al. [18] reported a significant decrease in knee flexor muscle strength using 60 seconds of stretching. However, no decreases in strength were found for a 30-second stretch duration. In addition, when com-

\* Corresponding author.

paring four different stretching periods of 10, 20, 30 and 60 seconds, Siatras et al. [7] revealed peak force decreased only with the 30- and 60-second stretch repetitions. Thus, there may be a direct relationship between the stretch duration and stretching-induced decreases in performance. Conversely, these data are not in agreement with the findings of Brandenburg, who reported that both 15 and 30 seconds of stretching caused decreases in hamstrings strength, although there were no significant differences between these stretching durations [19].

To our knowledge, only one study has examined the effects of different durations of static stretching on EMG activity [20]. However, we are unaware of this type of study for the quadriceps muscle, which is an important knee extensor and has a role in sports requiring jump, kicks, and running. Otherwise, most of studies that found decreases in strength after static stretching used longer durations allowing some controversy regarding short duration stretching on performance impairment.

In this context, the present study aimed to investigate the acute influence of static stretching durations of 30 and 60 seconds, commonly recommended for warm-up [18], on isometric force of the quadriceps muscle and EMG activity of the *rectus femoris* (RF) and *vastus lateralis* (VL) muscles in young recreationally-active healthy males. We hypothesize that the longer stretching would be able to cause a greater decrease in muscle strength and EMG activity.

## Material and methods

### Subjects

The sample consisted of 20 males ( $22 \pm 3$  years;  $174 \pm 6$  cm;  $72.4 \pm 11.4$  kg;  $23 \pm 3$  Kg/m $^2$ ;  $19.1 \pm 5.3\%$ ). The study inclusion criteria had the following characteristics: a) all the subjects were physically active, but not athletes, and had not taken part in a formal structured flexibility or strength training program during the previous 12 months; b) did not perform any type of exercise activity for 48 hours prior to the strength assessments; c) participants could not have any functional limitations for the flexibility training or the performance of the isometric strength test; and d) did not present any medical condition that could influence the collection or interpretation of the data. After informing subjects of the testing and training procedures to be performed during the study, all participants read and signed an informed consent form approved by the Human Subjects Institutional Review Board. This study was approved by the Ethics Committee.

## Experimental design

### Experiment layout

A randomized, pre-experimental repeated measures (pre- vs. post-stretching) cross-over design was used to investigate the acute effects of quadriceps static stretching duration on knee extension strength and EMG activity. All subjects performed two protocols of static stretching (30 and 60 seconds) on two separate days with an interval of 48 hours between testing sessions (Fig. 1). All procedures were carried out on the same time of day and in a controlled environment with temperature between 23°C and 25°C.

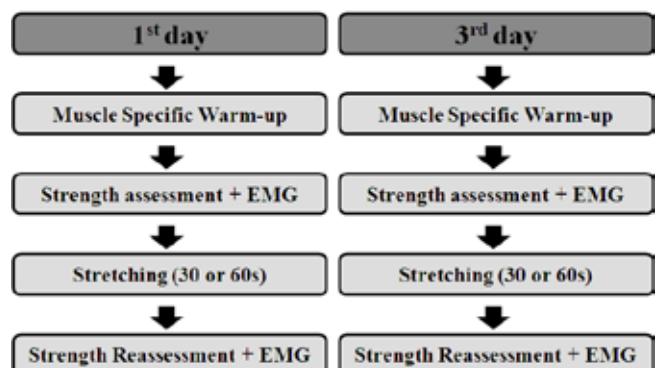


Figure 1. Experimental design with a 48-hour interval between testing sessions

### Measurements

Strength assessments were performed using a Knee Extension Machine, adjusted to fit individual anthropometric characteristics, adapted with thoracic and abdominal stabilization strips. Once the subjects were positioned appropriately, a specific warm-up of the quadriceps muscle of the dominant leg was performed, following the recommendation of the American College of Sports Medicine [21], which advocates warming-up prior to any type of physical activity. The load was set at 10% of total body mass and consisted of 3 sets of 10 repetitions performed in a dynamic knee extension apparatus.

The warm-up was immediately followed by a rest period of 2 minutes. After the warm up and rest period, a maximum isometric voluntary contraction (MIVC) of the knee extensors was tested, lasting 10 seconds. Subjects were positioned at 70° of static knee flexion (0° = full knee extension). Surface EMG signal was collected for the RF and VL simultaneously with the strength assessment. During testing, participants were instructed to keep both arms crossed over the chest in order to ensure consistency and optimal movement performance. The MIVC ( $r = 0.92$ ) tests revealed high intra-class

correlation coefficients, respectively while paired t-tests demonstrated no significant difference.

The mean strength of the MVIC (mean of MIVC) and peak force (PF) were identified by the load cell signal. The mean MIVC, PF, and EMG signal of RF and VL were analyzed in pre- and post-stretch of two different stretching durations (30 and 60 seconds) separately. To compare the influence of two different stretching durations, EMG values were normalized to the pre-stretching values.

#### *Stretching protocols*

Two different stretches were performed for the quadriceps muscle based on previous research [4, 6, 9]. Each stretch was repeated three times lasting 30 or 60 seconds depending on the condition for that particular day. In the first stretching exercise, the subject remained standing and in the second exercise, the subject laid in a prone position. In both stretches, the same investigator performed a passive unilateral (dominant leg) knee flexion and a hip extension on the subject, with one hand on the ankle causing a knee flexion and the other hand was holding the knee, forcing a hip extension. A 20-second rest interval between each repetition was provided. The total mean duration for the entire stretching procedure was  $4.1 \pm 1.3$  min (mean + SD) using the 30-second protocol and  $8.1 \pm 1.4$  min using the 60-second protocol.

During the stretching protocol, the targeted limb was moved slowly until a mild discomfort was acknowledged by the subject, who was instructed to relax while the stretched position was maintained for 30 or 60 seconds depending on which stretching intervention was being performed. Immediately after the stretching ( $\sim 1$  min), EMG signal and quadriceps MVIC were collected again, using the same methods as the pre-stretching assessment. Since the main objective was to examine the acute effects of stretching on the strength and EMG activity, flexibility (i.e. range of motion) was not assessed before and particularly after the stretching protocol to avoid increasing the time elapsed between stretching and strength assessments. All procedures and measurements were carried out by two trained investigators. In order to minimize bias and maintain consistency, the anthropometric data were evaluated by a single examiner and stretching procedures were conducted by the same investigator.

#### Equipment and analysis

A load cell (EMG System, São Paulo, Brazil) was used to capture the maximal isometric voluntary contraction. The EMG signals were acquired using an

8-channel electromyography equipment (EMG System, São Paulo, Brazil), consisting of a signal conditioner with a band pass filter with cut-off frequencies at 20–500 Hz, an amplifier gain of 2000x, and a common mode rejection ratio  $> 120$  dB. All data were processed using specific software for acquisition and analysis (AqData5 for Windows®, Ohio, USA), a converting plate for A/D 12 bits signal to convert analog to digital signals with a sampling frequency of anti-aliasing 2.0 kHz for each channel, and an input range of 5 mV. Pre-amplified bipolar superficial electrodes of Ag/AgCl (MEDITRACE®, USA) with an interelectrode (center-to-center) distance of 20 mm were used. The EMG signal was full wave rectified and the electrical activity was measured using the root mean square (RMS) values.

In order to achieve an optimal EMG signal and low impedance ( $< 5$  kΩ), two  $4 \text{ cm}^2$  areas of skin were shaved, abraded, and cleaned, as recommended by the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) recommendations [22].

Electrodes were fastened to the skin guided by bone prominences [22]. The electrodes of the RF muscle were placed at 50% of the distance between the anterior superior iliac spine and the superior border of the patella. For the VL, the electrode was placed at the 66% distal distance between the anterior superior iliac spine and the side border of the patella. The anatomical reference method is recommended by SENIAM [22], in order to avoid the innervated zones and reduce the influence of cross-talk. As data were collected on different days, the exact positions of the electrodes were marked with a dermatographic pen, and electrodes placed in such a manner as to prevent artifacts resulting from the electrode sliding during the muscle actions. In all procedures, the recording and analysis of EMG signals were carried out as recommended by the International Society of Electrophysiology Kinesiology (ISEK) [23].

#### Statistical analysis

All EMG data (VL and RF) were normalized to the pre-test values. A test for normality of the EMG activity and strength data using the Shapiro-Wilk tests yielded significant evidence of normality. Three separate multi-factor two-way ANOVAs were used to identify the interaction in muscle  $\times$  time intervention for strength and normalized EMG values. When necessary, post-hoc paired t-tests were used to compare pre- and post-stretching strength and EMG activity for the two stretching durations (30 and 60 seconds) separately. All statistical procedures were carried out with a significance level of  $p \leq 0.05$ .

## Results

The results of MVIC mean and PF before and after stretching are shown in Figures 2 and 3, respectively. Changes in mean and PF were observed with both stretching protocols. Mean of MVIC decreased by 6% and 9%, in the 30- and 60-second durations, respectively ( $p \leq 0.05$ ). Likewise, PF also decreased by 4% and 8% after 30 and 60 seconds of stretching, respectively ( $p \leq 0.05$ ).

The average EMG values (RMS) of the RF were significantly reduced after stretching with both the 30- and 60-second protocols (Fig. 4). However, VL mean EMG (RMS) was significantly reduced only after 60 seconds of static stretching (Fig. 5).

A comparison of the normalized values of strength and mean EMG (RMS) for both stretching durations is shown in Table 1. No differences were identified in

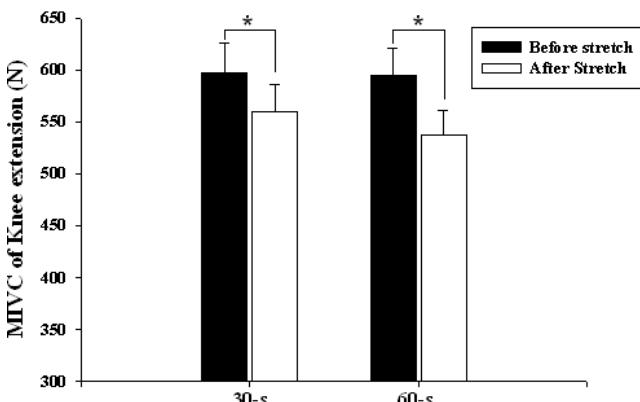


Figure 2. Mean of knee extension MIVC before and after static stretching for 30 ( $n = 20$ ) and 60 seconds ( $n = 20$ ).

(\*) Significant difference from pre- to post-stretching ( $p < 0.05$ )

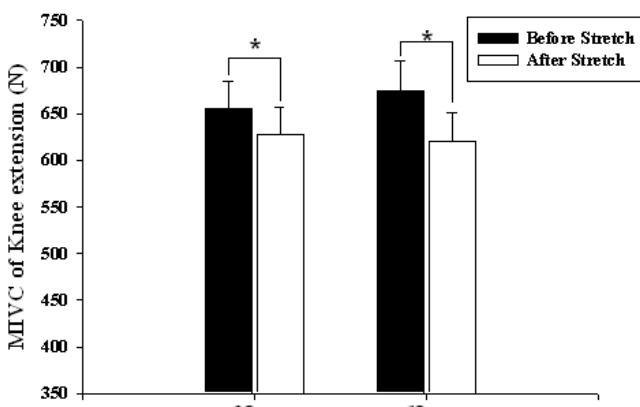


Figure 3. Peak force of knee extension maximal voluntary isometric force (MIVC) before and after static stretching for 30 ( $n = 20$ ) and 60 seconds ( $n = 20$ ). (\*) Significant difference from pre- to post-stretching ( $p < 0.05$ )

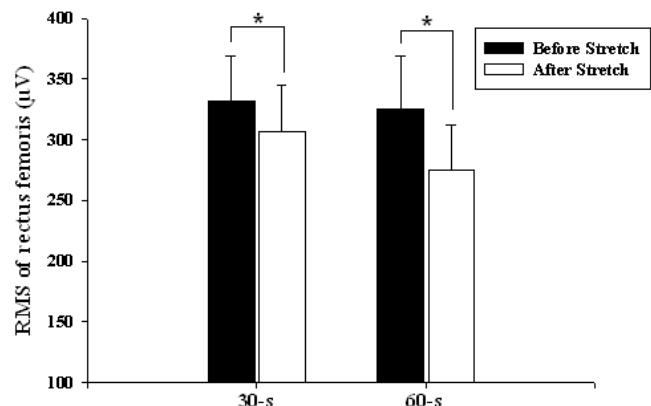


Figure 4. EMG activity of the *rectus femoris* before and after static stretching for 30 ( $n = 20$ ) and 60 seconds ( $n = 20$ ).

(\*) Significant difference from pre- to post-stretching ( $p < 0.05$ )

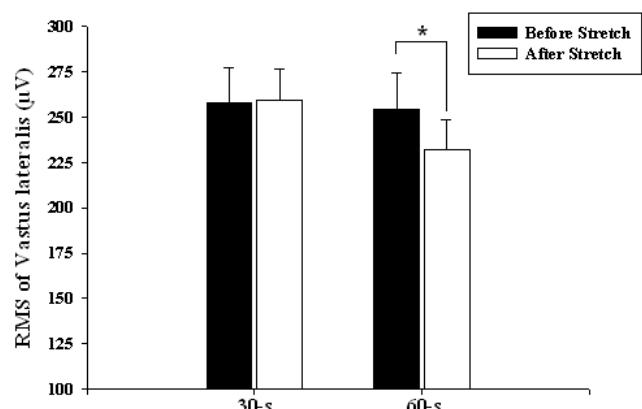


Figure 5. EMG activity of *vastus lateralis* before and after static stretching for 30 ( $n = 20$ ) and 60 seconds ( $n = 20$ ).

(\*) Significant difference from post-stretching for 60 seconds to pre-stretching for 60 seconds, and to pre- and post-stretching for 30 seconds ( $p < 0.05$ )

relative force or peak force between the two stretching durations used ( $p > 0.05$ ). In addition, the EMG values for RF decreased significantly in both stretching durations ( $p > 0.05$ ). However, the multifactorial ANOVA revealed a significant difference in time intervention and muscles, where a significant decrease in EMG activity was only observed in the VL when stretched for 60 seconds, but not for the 30-second protocol.

## Discussion

The results of the current study demonstrate decreases in muscle performance after both stretching procedures. This reduction in muscle performance is in agreement with the findings of other authors who used several stretching protocols [2, 3, 5–7, 12–15, 18, 24, 25].

Different stretching repetition durations have been found in the literature, ranging from 10 seconds [7],

Table 1. Mean  $\pm$  Standard Deviation (confidence interval at 95%) of normalized force and EMG activity before and after stretching for 30 and 60 seconds

	30 seconds	60 seconds
<b>Changes in normalized force<sup>1</sup></b>		
Force	0.94 $\pm$ 0.05 (0.91 – 0.95)	0.91 $\pm$ 0.06 (0.89 – 0.92)
Peak force	0.96 $\pm$ 0.05 (0.94 – 0.97)	0.92 $\pm$ 0.07 (0.88 – 0.94)
<b>Changes in normalized EMG<sup>2</sup></b>		
RF	0.94 $\pm$ 0.16 (0.86 – 1.0)	0.87 $\pm$ 0.16 (0.80 – 0.91)
VL	1.02 $\pm$ 0.13* (0.96 – 1.06)	0.93 $\pm$ 0.13 (0.86 – 0.96)

<sup>1</sup> Normalized data were used for analysis of the force variation. Percentages of variation between force before and after stretching were used

<sup>2</sup> Normalized data were used for analysis of the EMG activity variation. Percentages of variation between EMG activity before and after stretching were used

\* Significant difference from 30 to 60 seconds ( $p < 0.05$ )

15 seconds [8, 19, 25], 30 seconds [4–7, 9, 13, 19], 45 seconds [3, 16], 60 seconds [7, 18], up to 120 seconds [15]. In the current study, significant reductions in mean and peak muscle strengths were found with both stretching repetition protocols (30 and 60 seconds), demonstrating that the stretch duration did not influence the decreases in strength. These results do not corroborate the findings of Ogura et al. [18], who compared stretching durations of 30 and 60 seconds in college football players. These authors reported that only the 60-second stretching protocol caused a reduction in isometric force of the knee flexor muscles, despite a significant increase in muscle flexibility with both stretching durations. Nevertheless, another study which used the same amount of stretching repetitions as the present study, revealed significant decreases in eccentric, concentric, and isometric forces with 15 and 30 seconds of stretching, however, there were no significant differences between the two duration lengths of stretching repetitions [19]. Similarly, when comparing four different stretching durations of 10, 20, 30, and 60 seconds, Siatras et al. [7] reported an isometric peak torque reduction with only 30 (8.5%) and 60 seconds (16%), assuring the duration of static stretching influenced the muscle peak torque. Finally, Unick et al. [8] found no changes in vertical jump performance using stretching duration of 15 seconds in trained women.

It is postulated that mechanical factors are responsible for the reduction of force by altering the viscoelastic properties of the muscle and muscle stiffness [2, 6, 14, 15]. The connective tissue, through musculotendinous stiffness, is important for strength transmission to bone [24]. Thus, a more compliant musculotendinous unit can cause an alteration on reaction time and muscle activation [16]. Fowles et al. [14] stated after the release of the fascia through surgical procedure,

there is a loss of 15% of muscle strength in dogs, followed by a decrease of 50% in intracompartmental pressure during the contraction. Other mechanical factors such as increasing sarcomere length, hence increasing the sarcomere, shortening distance and changing the muscle length–tension relationship, may decrease the muscle contractile capacity to produce force [2]. As a result, stretching may induce changes in the length–tension relationship, adversely affecting muscle performance [2, 4, 5, 15, 16].

Zakas et al. [25] studied the effect of different amounts of stretching on muscle strength at various isokinetic velocities in young male soccer players using two static stretching protocols of the quadriceps, 3 repetitions of 15 seconds and 20 repetitions of 15 seconds. Significant reductions in force at all angular velocities were found only with the protocol of 20 repetitions, thus, demonstrating that stretching may have a cumulative effect on the muscle and/or connective tissue, particularly when using a large number of repetitions. According to the authors [26], one of the primary factors leading to a decrease in muscle strength is the occurrence of micro injuries in the muscle during the stretch, mainly by increasing the creatine kinase enzyme found in the blood of subjects who had performed the stretching. Their results revealed that stretching can generate an intense mechanical effect on the muscle fibers and that this effect may be another possible causal factor in post stretching muscle strength reduction.

It has been found that the effect of stretching on muscle strength may be temporary [14]. Fowles et al. [14] measured muscle strength before, immediately after, and at certain intervals up to 60 minutes after stretching. Their results demonstrated that force was reduced by 28% immediately after stretching, 21% in the 5<sup>th</sup> minute, 13% in the 15<sup>th</sup> minute, 12% in the 30<sup>th</sup>

minute, 10% in the 45<sup>th</sup> minute, and 9% after the 60<sup>th</sup> minute. These data revealed that stretching induced temporary changes in muscle strength, with the greatest decrease in strength observed immediately after stretching. Thus, it is understood that not only mechanical factors but also neural factors may have an influence on the strength reduction [2, 5, 14, 15].

Regarding our EMG findings, many studies report a reduction of EMG activity after stretching, which corroborates the findings of this study [2, 5, 14, 15]. Conversely, others have found no decreases in EMG activity following stretching [13, 20]. Nonetheless, we are unaware of any studies that have analyzed the influence of stretching duration on EMG activity of the quadriceps muscle.

The current results demonstrate that the normalized EMG (RMS) of the RF decreased in both durations of stretching, whereas the VL EMG activity decreased only in the 60-second repetition duration protocol. Hence, a longer period (180 seconds) was necessary for a significant reduction in the EMG activity of the VL muscle, which appears to have a time-dependent behavior. We hypothesized that this can be explained by the anatomical position of the VL, a monoarticular muscle which stretches only when the knee is flexed. Instead, the RF is a biarticular muscle stretching over two joints during both hip extension and knee flexion. Thus, the RF muscle can be lengthened to a greater degree during stretching allowing for more stretching-induced inhibition independently of intervention time.

Avela et al. [2] studied the neural responses of soleus and gastrocnemius muscles after 1 hour of rapid and repeated stretching. These authors reported a reduction in force and EMG activity of the soleus and medial gastrocnemius muscles due to a change in the behavior of the tendon-aponeurosis system, particularly a plastic deformation, which combined affected the proprioceptive "feedback" leading to a decrease in muscle recruitment. However, the current study used more practical stretching durations and a number of repetitions similar to interventions used by coaches and athletes, allowing the results to be more applicable to sports settings.

The reduction of EMG activity found in the study can be explained by a change in neural factors that led to changes in neuromuscular recruitment strategies [2, 14, 15]. These peripheral neural factors include: changes in muscle fiber firing rates [6], activation of the autogenic inhibition reflex involving the Golgi tendon organs stimulated during the stretch [2, 14, 15], activation of joint mechanoreceptors (type III afferent) and pain receptors (type IV afferent) stimulated during the stretching providing a reduction of nerve impulses to the stretched muscle [5, 14], and muscle inhibition by

joint compression caused by stretching due to excessive joint range of motion [4]. In the present study, both stretching times of 30 and 60 seconds were enough to stimulate the aforementioned afferent pathways and consequently reduce RF muscle performance.

The results of the current study indicate an acute influence of stretching on muscle activation, suggesting that changes in proprioceptive "feedback" can lead to failure in the strategies of muscle recruitment, hence reducing its activation [14]. In the classic study of Fowles et al. [14], it is reported that 60% of the stretching-induced reduction of force up to 15 minutes is due to neural factors. Thus, neural factors affect the strength initially and mechanical factors may last for a longer period, affecting the strength for up to one hour.

Since most exercise and sports activities are dynamic, the isometric muscle strength assessment may be seen as one possible limitation of the present study. Nevertheless, this procedure was used based on the belief that isometric muscle actions increase the reliability for EMG data collection as proposed by De Luca [26]. In this study, the contralateral leg was not used as a control because decreases of muscle strength in the unstretched contralateral limb have been reported [2, 5]. The main cause for this phenomenon could be a deficit originated from central nervous system, through fatigue in the supraspinal centers [2, 5]. Therefore, it was decided to measure only the dominant leg.

The results of current study suggest that an acute bout of static stretching can lead to a significant decrease in muscle strength and EMG activity in young men. In addition, stretching duration does not appear to have a direct influence on reductions in strength and EMG activity, thus demonstrating that other factors may be involved. It is recommended that more studies should be developed to analyze variables not yet studied, such as the influence of different types, durations, and intensities of stretching on strength and EMG activity and in other population aimed at promoting the scientific knowledge pertaining to the influence of stretching on muscle performance.

Limitation of our study was that only one muscle group underwent the static stretching trial, which is a rare situation in the practical athletic field. In addition, it is important to note that the isometric contraction duration was short (10 seconds) so as not to induce muscle fatigue, because otherwise there would be expected an increase of EMG amplitude associated to muscle fatigue, which was not observed, but we think other studies should consider the possibility of fatigue development when using maximal isometric contractions and they might adopt shorter contraction duration than 10 seconds.

## Conclusions

Several studies have reported that acute static muscle stretching may temporarily reduce muscle activation and impair a muscle's capacity to produce force, thus affecting athletes' performance in sports and exercises requiring maximal muscular strength and power development. Our results confirm this hypothesis and reveal that stretching for repetitions of 30 seconds is sufficient to cause a reduction in muscle force. For this reason, coaches and athletes should avoid flexibility training which consists in stretching repetitions of 30 seconds or more prior to competitions. Other suggestion is that more reasonable stretching protocols or post-exercise stretching may provide a useful alternative while attempting to avoid stretching-induced performance decrements.

## References

1. Witvrouw E., Mahieu N., Danneellls L., McNair P., Stretching and injury prevention: An obscure relationship. *Sports Med*, 2004, 34, 443–449.
2. Avela J., Finni T., Liikavaiimio T., Niemeläv E., Komi P.V., Neural and mechanical responses of the triceps surae muscle group after 1h of repeated fast passive stretches. *J Appl Physiol*, 2004, 96, 2325–2332. doi:10.1152/japplphysiol.01010.2003.
3. Costa P.B., Graves B.S., Whitehurst M., Jacobs P.L., The acute effects of different durations of static stretching on dynamic balance performance. *J Strength Cond Res*, 2009, 23, 141–147. doi:10.1519/JSC.0b013e31818eb052.
4. Cramer J.T., Housh T.J., Johnson G.O., Miller J.M., Coburn J.W., Beck T.W., Acute effects of static stretching on peak torque in women. *J Strength Cond Res*, 2004, 18, 236–241.
5. Cramer J.T., Housh T.J., Weir J.P., Johnson J.G.O., Coburn J.W., Beck T.W., The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. *Eur J Appl Physiol*, 2005, 93, 530–539. doi:10.1007/s00421-004-1199-x.
6. Marek S.M., Cramer J.T., Fincher L., Massey L.L., Dangelmaier S.M., Purkayastha S. et al., Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *J Athl Train*, 2005, 40, 94–103.
7. Siatras T.A., Mittas V.P., Mamiletzzi D.N., Vawakoudis E.A., The duration of the inhibitory effects with static stretching on quadriceps peak torque production. *J Strength Cond Res*, 2008, 22, 40–46. doi:10.1519/JSC.0b013e31815f970c.
8. Unick J., Kieffer S., Cheesman W., Feeney A., The acute effects of static and ballistic stretching on vertical jump performance in trained women. *J Strength Cond Res*, 2005, 19, 206–212.
9. Cramer J.T., Housh T.J., Coburn J.W., Beck T.W., Johnson G.O., Acute effects of static stretching on maximal eccentric torque production in women. *J Strength Cond Res*, 2006, 20, 353–358.
10. Egan A.D., Cramer J.T., Massey L.L., Marek S.M., Acute effects of static stretching on peak torque and mean power output in National Collegiate Athletic Association Division I women's basketball players. *J Strength Cond Res*, 2006, 20, 778–782.
11. Knudson D.V., Noffal G.J., Bahamonde R.E., Bauer J.A., Blackwell J.R., Stretching has no effect on tennis serve performance. *J Strength Cond Res*, 2004, 18, 654–656.
12. Young W., Clothier P., Otago L., Bruce L., Liddell D., Acute effects of static stretching on hip flexor and quadriceps flexibility, range of motion and foot speed in kicking a football. *J Sci Med Sport*, 2004, 7, 23–31.
13. Costa P.B., Ryan E.D., Herda T.J., Defreitas J.M., Beck T.W., Cramer J.T., Effects of stretching on peak torque and the H:Q ratio. *Int J Sports Med*, 2009, 30, 60–65. doi:10.1055/s-2008-1038738.
14. Fowles J.R., Sale D.G., MacDougall J.D., Reduced strength after passive stretch of the human plantarflexors. *J Appl Physiol*, 2000, 89, 1179–1188.
15. Weir D.E., Tingley J., Elder G.C.B., Acute passive stretching alters the mechanical properties of human plantar flexors and optimal angle for maximal voluntary contraction. *Eur J Appl Physiol*, 2005, 93, 614–623.
16. Behm D.G., Bamby A., Cahill F., Power K., Effect of acute static stretching on force, balance, reaction time, and movement time. *Med Sci Sports Exerc*, 2004, 36, 1397–1402.
17. Alpkaya U., Koceja D., The effects of acute static stretching on reaction time and force. *J Sports Med Phys Fitness*, 2007, 47, 147–150.
18. Ogura Y., Miyahara Y., Naito H., Katamoto S., Aoki J., Duration of static stretching influences muscle force production in hamstring muscles. *J Strength Cond Res*, 2007, 21, 788–792.
19. Brandenburg J.P., Duration of stretch does not influence the degree of force loss following static stretching. *J Sports Med Phys Fitness*, 2006, 46, 526–534.
20. Ryan E.D., Beck T.W., Herda T.J., Hull H.R., Hartman M.J., Stout J.R., Ramer T.J., Do practical durations of stretching alter plantar flexion strength? A dose-response study. *Med Sci Sports Exerc*, 2008, 40, 1529–1537.
21. American College of Sports Medicine. Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc*, 1998, 30, 975–991.
22. Hermens H.J., Frekis B., Merletti R., Stegman D., Blok J., Rau G. et al., Results of the SENIAM project. Enschede, Netherlands: Roessingh Research and Development, 1999.
23. Williams K.R., Standardizing biomechanical testing in sport. *Res Q Exerc Sport*, 1987, 58, 286–287.
24. Young W., Elliott S., Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jump performance. *Res Q Exerc Sport*, 2001, 72, 273–279.
25. Zakas A., Dogani G., Galazoulas C., Vamvakoudis E., Effect of acute stretching duration on isokinetic peak torque in pubescent soccer players. *Ped Exerc Sci*, 2006, 18, 252–261.
26. De Luca C.J., Use of the surface electromyography in biomechanics. *J Appl Biom* 1997, 13 (2), 135–163.

Paper received by the Editors: February 26, 2010.

Paper accepted for publication: May 12, 2010.

### *Address for correspondence*

Luciano Pavan Rossi  
Universidade Federal do Paraná  
Rua Jaguariaíva, 512  
Balneário Caiobá  
83260-000 Matinhos, PR, Brazil  
e-mail: lucianofisioo@yahoo.com.br



# INFLUENCE OF LONG-LASTING BALANCING ON UNSTABLE SURFACE ON CHANGES IN BALANCE

doi:10.2478/v10038-010-0022-2

DARIUSZ TCHÓRZEWSKI<sup>1\*</sup>, JANUSZ JAWORSKI<sup>2</sup>, PRZEMYSŁAW BUJAS<sup>2</sup>

<sup>1</sup> Department of Winter Sports Theory and Methodology, University School of Physical Education, Kraków, Poland

<sup>2</sup> Department of Antropomotorics, University School of Physical Education, Kraków, Poland

## ABSTRACT

**Purpose.** The goal of this thesis is to test the qualification of changes in balance as the effect of long-lasting balancing on a movable platform alternately in sagittal and frontal planes. It was expected to find answers to the following problems: 1. Does the effort caused by a 10-minute balancing in the given planes and in the given pattern have an influence on dynamic balance parameters? 2. Till which moment are the subjects able to improve their balancing skills in the given planes? 3. Do the possible changes progress in the same way in both planes considered? **Basic procedures.** 28 men aged between 24.3 and 33.8 years took part in this test. Average age of the subjects was 25.2 years. The tests were made on EasyTech Balance Platform. Tests consisted of a trial of balancing in a standing position with feet placed parallel on the platform. The subjects' task was to operate the platform through the right foot pressure to make the same sinusoid line as the pattern was. A ten-minute trial was made alternately in the sagittal and frontal planes. Individual dynamic parameters were recorded each minute of the test. **Main findings.** Significant improvement was noted in the first three minutes of the test. Between the 4<sup>th</sup> and 7<sup>th</sup> minutes parameters were relatively stable. The best results were recorded in the 8<sup>th</sup> minute of the test and this level was kept till the end of the trial. The character of the observed changes was analogous in the case of both planes.

**Conclusions.** There was a statistically significant improvement in the dynamic body's stability noted in both planes in the test. Best results were recorded in the 8<sup>th</sup> minute of the test. The test used in the trial was long enough to establish the borderline between motor learning and the beginning of tiredness. The higher level of stability in the sagittal plane was affirmed in all successive minutes of the trials made.

**Key words:** coordination motor ability (CMA), body balance, motor learning, fatigue

## Introduction

Human motor activity is mostly conditioned by keeping the upright posture, therefore keeping it is considered natural. Balance is only a momentary state of the postural system when the forces acting on the man and their moments counteract each other. Stability is a larger term; it is understood as an ability to return actively to the typical human body posture in space, which was lost either because of the human's motor activity or because of some external forces developed in the interaction with the environment [1, 2].

Body balance is regulated by the nervous system and it depends, to a great extent, on its efficiency. The regulation is based on processing signals arriving from four sensorial entrances: labyrinth, sight organ, proprio-receptors and tactile receptors [3]. Signals from all the sensorial entrances constitute a source of information about the body posture and its orientation relative to

the specific frames of reference: internal and external. The central body representation is being formed on the basis of signals from muscle, tendon, joint and skin receptors. These receptors transmit to the brain information about the positions of different parts of the body in relation to each other and about their movements; moreover, the receptors send to the executive organs (muscles) feedback signals which control balance keeping [2, 4]. Deviations from the intended state initiate a stimulation whose aim is to introduce the right muscle correction [3, 4]. Due to the muscle contractions, forces indispensable to compensate all the disturbing factors are developed [5, 6]. Limiting any of these control mechanisms can influence the overall efficiency of the balance system.

When there are no sudden and unpredictable external disturbances, the main mechanisms of posture correction which make balance keeping possible are anticipative and corrective actions. Recovering balance is a sequential process. After the sensorial systems detect the kind, size and direction of the disturbance, an adequate reaction is adopted to recover balance. The reaction has to be set in motion and completed in a strictly limited time [2].

\* Corresponding author.

Regulation of the body balance while any movements are being performed requires anticipative adjustment. However, maintaining the body posture is, first of all, an effect of the functioning of correction adjustment mechanisms [2, 3]. Anticipative adjustments do not exclude the possibility of a feedback position adjustment occurring in a further phase of a movement, which is a reaction to stimuli coming from proprioceptors informing about the occurrence of disturbing factors [7, 8]. Probably, both position correction mechanisms can act simultaneously, which depends on the kind of the initial signal indicating its constant or momentary disturbance occurrence [9, 10]. One mechanism introduces constant corrections of the position by making use of the close feedback loop. The other one is responsible for adjusting a posture during its sudden and short-lasting disturbances [11].

In a standing position, in order to keep or recover balance it is possible to apply two strategies depending on the degree of its disturbance: an ankle or a hip joint [12–14]. One strategy refers to a minor balance disturbance and it is initiated by a contraction of ankle muscles. The other one refers to bigger disturbances and it is initiated by an activity of thigh and trunk muscles, and then moves downwards to other leg muscles [14–16].

Stability is, undoubtedly, an important physiological reaction, which is influenced by numerous factors including tiredness. However, its importance has not been examined enough. Few studies deal with types of tiredness, its influence on stability, and a response of the control system to disturbances of the internal environment [17]. According to many researchers, tiredness influences balance negatively and may cause injuries or wounds [18, 19]. The influence on the change in a balance level caused by aerobic efforts performed in the form of long-distance runs was studied by Nardone et al. [20, 21]. Similar research has been carried out by Pendergrass et al. [22]. Lepers et al. [23] dosed the effort of the subjects applying an intensive 25-minute walk or exercise bike ride (cycloergometer). It was stated that both tiredness [20, 21, 24] and hyperventilation [25] caused by an effort can have a negative influence on stability depending on its kind, intensity and duration. It was noted that running weakens the balance parameters much more than marching or cycling [26, 27]. Short-lasting, suddenly done intensive work has a more negative impact on balance than an effort of an aerobic character, i.e. an exercise done within a longer period of time and of moderate intensity [23].

Moreover, sports disciplines in which even small changes in stability after an effort influence negatively the performance were defined, for example: biathlon,

gymnastics, figure skating, rock-and-roll, basketball, tennis, windsurfing [28–30]. Therefore, the assessment of stability is considered an important element in functional diagnostics of persons practising these sports.

The influence of anaerobic efforts on the level of balance was studied by Waśkiewicz [17]. However, he has not received an unequivocal answer as to whether they have a positive or negative influence on balance. Also, the influence of local tiredness of feet muscles on changes in the sagittal amplitude of movements has been studied [31]. Zemková et al. [30] have done interesting research based on EquiTTest, where they have compared the influence of tiredness caused by an intensive effort on an exercise bike on the level of balance in the static and dynamic conditions. The experiment has not shown any differences in the balance levels on the stable surface measured before and after the effort. Whereas, in the dynamic conditions the obtained results indicated a significant drop in the balance level. Unlike the well-known, commonly used method of static posturography, presently, in literature there are few reports concerning the influence of such exercises on balance on the unstable surface [23, 30].

Mere keeping a stable position, especially in the dynamic conditions, involves a significant effort and related to it progressing tiredness. If, additionally, it is connected to the performance of an imposed motor task, tiredness should increase more quickly. Thus, the aim of this work is to try to define changes in balance in the condition of long-lasting balancing on a movable platform examined separately in the frontal plane and the sagittal one. Answers to the following questions were expected to be found:

1. Does the effort caused by a 10-minute balancing in given conditions have any influence on changes in the balance parameters?
2. Till which moment of the test are the subjects able to improve their skills of balancing in each movement plane?
3. Do the possible changes progress in the same way in both planes examined?

## Material and methods

### Subjects

Twenty eight male students of the University School of Physical Education in Kraków took part in the experiment. None of the people invited for the test complained of balance disturbances and had had any injuries which could have influenced the results of the measurements. All the participants were volunteers.

The subjects' average age was 25.2 years and ranged from 24.3 to 33.8. Their average height was 180.5 cm and their average weight 77.7 kg (BMI 23.8).

#### *Research apparatus*

In order to examine the dynamic balance, a balancing platform Libra of an Italian company EasyTech was used. The measuring station consisted of: a platform with USB interface and a notebook with a 15" screen connected to it. The device has three possible settings of the balance base diameter: 10, 25 and 40 cm. The software provides for application of one of the four kinds of pattern lines for the trial course: straight line, sinusoid, square wave and triangular wave. Trials can be conducted in standing, sitting and lying positions. In the standing position it is possible to place feet: parallel in the frontal and sagittal planes, as well as at a 45° angle. The operator has the possibility of setting amplitude and frequency of the lines emitted on the screen, as well as the possibility of using an appropriate degree of difficulty corresponding to the angular sway range. Exceeding the range of the difficulty degree is shown on the screen as two parallel lines placed on each side of the pattern. Each time one goes beyond the borderline, an acoustic signal turns on. In this experiment the pattern line adopted was a sinusoid of amplitude 5° and frequency 10 cycles/min. The balance curve was  $r = 40$  cm and the 6<sup>th</sup> difficulty degree (deviation from the pattern line  $\pm 5^\circ$ ) applied. These parameters were set taking into consideration the previous tests conducted on the platform Libra [32].

The final result of the measurement is the mean calculated (within the range from 0 to 100) on the basis of the eight examined parameters (the value 100 means the poorest balance, 0 means the best). The parameters

are: **total area** – contained between the line of the movement course obtained by the subject, which is the function of the angular sway and time (°s), and the model sinusoid (all the parameters are measured separately for deviations to the left and to the right in the frontal plane, as well as forward/backward deviations in the sagittal plane); **external area** – comprised between the line of the movement course obtained by the subject and the line of the given difficulty degree (°s); **external time** – the total period of time the subject spends outside the area of the given degree of difficulty (s) and **reaction time** – the longest time the subject spends outside the area of the given degree of difficulty (s). The subject's better stability is characterised by the lowest possible values of all the parameters.

#### *Research procedures*

Measurements were taken in two trials, separately for the frontal plane and the sagittal one. Each trial was preceded by a 60-second warm-up in the same settings as in the real trial. The test lasted 10 minutes for each movement plane. The first trial was conducted in the frontal plane, whereas the trial in the sagittal plane was held the day after to avoid cumulating tiredness. The values of the trial parameters were recorded after each minute of the test.

The subject was standing barefoot on the platform, in a stance with the feet placed apart at hips' width and parallel to each other. During the trial the subject was watching his trial's graph on the monitor placed at his eye level and at a distance of 1 meter, which served as feedback. The subject's task was to move the platform by pressing it with his feet in such a way that the line drawn on the computer screen was as close as possible to the pattern sinusoid (coincided with it). During the

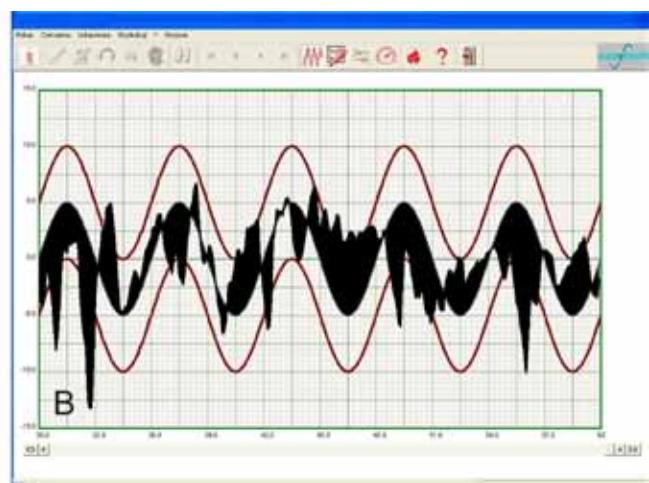
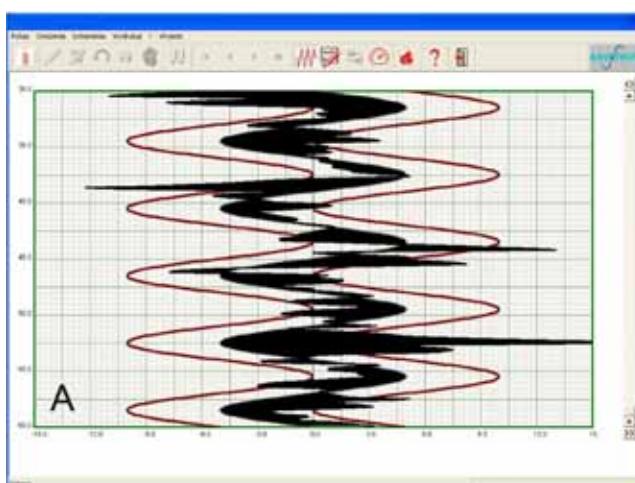


Figure 1. An example of a graph of the trial's course. A – frontal plane; B – sagittal plane

trials in the frontal plane, the graph moved vertically from top to bottom, whereas in the sagittal plane the graph moved horizontally from left to right (Fig. 1).

#### Data analysis

First, the results were worked out by means of generally used methods of descriptive statistics. Basic numerical characteristics of the tested variables were determined, i.e. arithmetic mean ( $\bar{x}$ ) and standard deviation (SD).

Due to the fact that it was impossible to obtain the normal layout for all the analysed variables and confirm them by Shapiro-Wilk test, in further analysis non-parametric tests were used.

In order to show the significance of the differences between successive measurements on the same movement plane, Friedman test from ANOVA group was applied.

Differences between the results in each movement plane in consecutive minutes of the trial were verified by Wilcoxon's test. The difference was considered statistically significant if the value of the significance level was  $p < 0.05$ . Calculations were done using the program Statistica 7.0.

In order to present the direction of the observed

changes graphically, the results of the trials in the sagittal plane compared to those in the frontal plane were standardized according to the pattern:

$$SI = \frac{\bar{X}_{\text{sagittal-pl.}} - \bar{X}_{\text{frontal-pl.}}}{S_{\text{sagittal-pl.}}}$$

$SI$  – standardized index,  
 $\bar{X}_{\text{sagittal-pl.}}$  – arithmetic mean of the results of a given balance parameter in the sagittal plane,  
 $\bar{X}_{\text{frontal-pl.}}$  – arithmetic mean of the results of a given balance parameter in the frontal plane,  
 $S_{\text{frontal-pl.}}$  – standard deviation of the results of a given parameter in the frontal plane.

## Results

In the group examined, results of some chosen balance parameters obtained in the platform during a 10-minute balancing, considered individually for each movement plane, were analysed. Basic descriptive statistics of the obtained results are presented in Table 1.

The most representative variables, which reflect the point why the work was undertaken and the research

Table 1. Descriptive statistics of the results obtained in the dynamic balance test in the consecutive minutes of the trial in the frontal and sagittal planes

Parameters	stat.	Frontal plane (n = 28)									
		1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Stability index	$\bar{x}$	10.10	9.44	9.09	8.57	9.08	8.14	8.53	7.50	7.71	7.44
	SD	2.77	2.77	2.48	2.70	3.09	2.26	2.58	2.65	2.28	2.10
Total area R + L (°s)	$\bar{x}$	186.67	176.38	173.00	166.56	170.38	158.06	162.99	149.88	152.74	150.42
	SD	32.23	32.02	29.96	33.88	36.79	29.23	32.92	33.81	29.00	27.53
External area R + L (°s)	$\bar{x}$	20.23	17.50	16.16	13.85	18.03	12.90	15.20	10.90	11.52	10.39
	SD	14.37	12.89	11.14	11.53	14.62	8.39	11.41	10.60	9.00	8.11
External time R + L (s)	$\bar{x}$	10.48	9.48	8.77	8.03	8.93	7.56	7.97	6.48	6.84	6.31
	SD	5.05	4.93	4.39	4.64	5.26	3.99	4.23	4.41	3.80	3.65
Sagittal plane (n = 28)											
Stability index	$\bar{x}$	8.51	7.76	7.05	7.05	7.24	7.15	6.50	6.05	6.51	6.05
	SD	2.53	2.44	2.41	2.41	2.14	2.11	2.10	1.77	2.13	1.88
Total area F + B (°s)	$\bar{x}$	164.40	154.21	144.10	143.70	146.15	144.53	136.75	130.24	136.66	129.49
	SD	30.06	31.30	31.24	31.50	28.42	27.03	28.04	25.80	27.95	25.57
External area F + B (°s)	$\bar{x}$	13.87	12.16	9.14	9.13	9.72	9.87	7.69	6.49	8.06	6.23
	SD	11.26	10.65	9.11	8.42	8.41	8.68	7.71	6.95	8.33	6.25
External time F + B (s)	$\bar{x}$	8.07	6.79	5.80	5.76	6.02	6.03	4.77	4.16	4.84	4.25
	SD	4.55	4.14	4.18	4.24	3.60	3.74	3.45	2.54	3.48	3.17

R, L – right, left side; F, B – front, back

questions asked, turned out to be: **final result, combined total area** – defining the range of lateral sways in the frontal plane (total area R + L) and forward–backward sways in the sagittal plane (total area F + B), **combined external area** that extends beyond the area delineated by the difficulty degree of the test (area R + L and F + B) – defining the precision of adjusting movements made and the total time the subject spends beyond the difficulty area (external time R + L and F + B).

In order to verify if the observed differences between the measurements taken at one minute intervals are statistically significant, a non-parametric statistical test for multiple dependent variables of Friedman ANOVA group was used (Tab. 2).

In all the cases statistical significance of the observed differences is unquestioned. In the case of both planes they are significant – over 99% probability ( $p < 0.0001$ ). Particularly significant changes were stated in the case

Table 2. Significance of the changes in parameters of dynamic balance achieved by the subjects in the course of a 10-minute balancing trial conducted in the frontal and sagittal planes

Plane	Parameter	Friedman ANOVA test and Kendall's $\tau$			
		n	$\chi^2$	p	$\tau$
Frontal	stability index	28	72.57	<b>0.00000</b>	0.29
	total area R + L	28	82.27	<b>0.00000</b>	0.33
	external area R + L	28	35.93	<b>0.00004</b>	0.14
	external time R + L	28	57.35	<b>0.00000</b>	0.23
Sagittal	stability index	28	73.62	<b>0.00000</b>	0.29
	total area F + B	28	83.13	<b>0.00000</b>	0.33
	external area F + B	28	40.83	<b>0.00000</b>	0.16
	external time F + B	28	55.83	<b>0.00000</b>	0.22

statistically essential values were distinguished in bold type

R, L – right, left side; F, B – front, back; p – significance level;

$\chi^2$  – chi-squared statistics;  $\tau$  – Kendall's coefficient of concordance

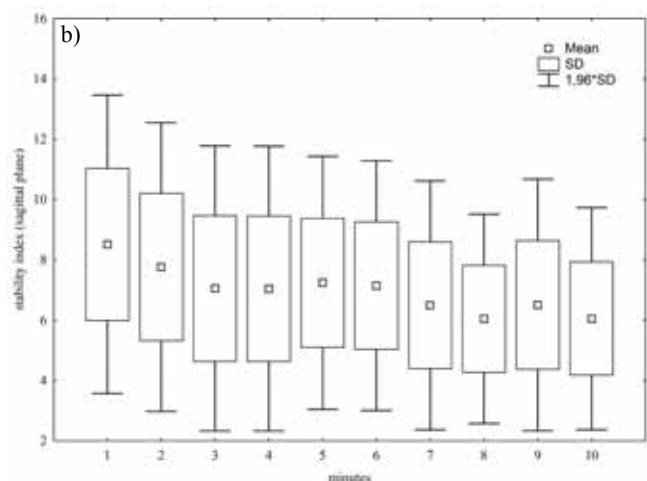
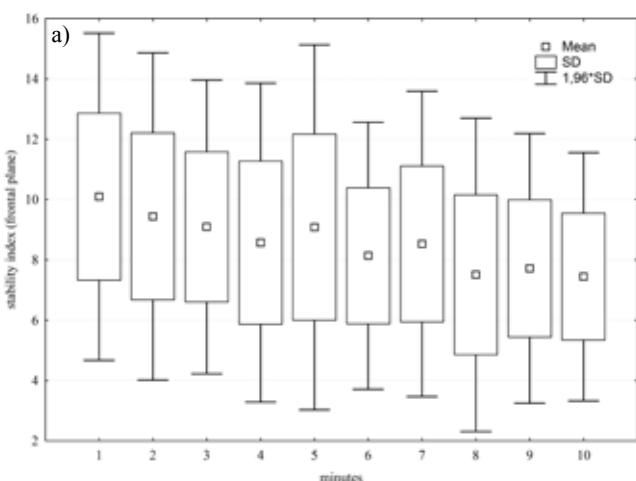


Figure 2. Changes in the arithmetic mean of the final result in a balancing trial on Libra platform in the consecutive minutes of the test: a) frontal plane; b) sagittal plane

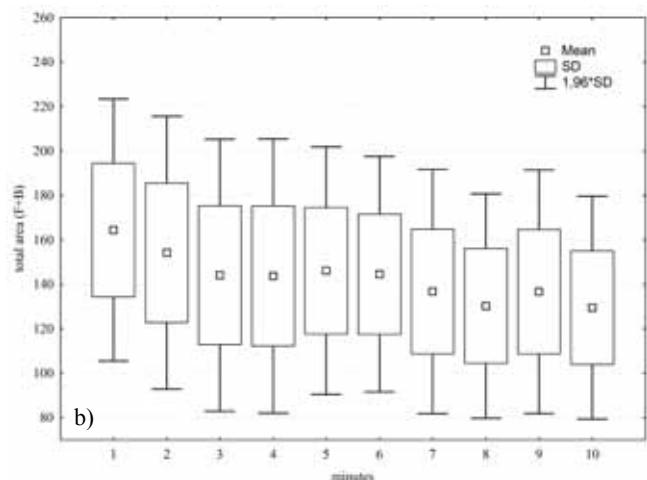
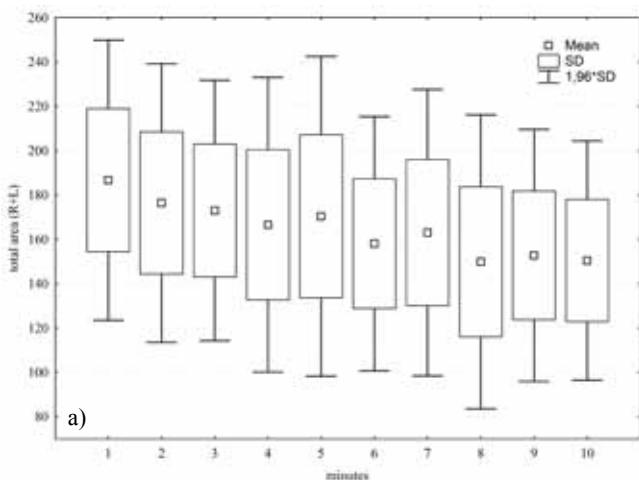


Figure 3. Changes in the arithmetic mean of total area (°s) in balancing trial on Libra platform in the consecutive minutes of the test: a) frontal plane; b) sagittal plane

of the basic index of the conducted test (independent of the difficulty degree) – total area. The values of Kendall's conformity coefficient  $\tau$  exceeded 0.3, and in the case of the statistics coefficient  $\chi^2$  exceeded 80.

Comparing the Friedman test results to the raw data, it was stated that there was a significant improvement

in balance during the 10-minute balancing trial. In that time the total area in the frontal plane decreased by 19%, while in the sagittal one by 21%.

However, the changes did not proceed in a linear way, but in a similar way in all the parameters analysed (Tab. 1, Fig. 2 and 3). An essential improvement was

Table 3. Significance of changes in the consecutive minutes of the trial in relation to the dynamic balance parameters achieved by the subjects in the frontal and sagittal planes

	Parameters (variables) compared	Wilcoxon's test			
		n	T	Z	p
1 minute	stability index (frontal) & stability index (sagittal)	28	73.50	2.9489	<b>0.0032</b>
	total area R + L & total area F + B	28	51.00	3.4613	<b>0.0005</b>
	external area R + L & external area F + B	28	92.00	2.5276	<b>0.0115</b>
	external time R + L & external time F + B	28	96.50	2.4252	<b>0.0153</b>
2 minute	stability index (frontal) & stability index (sagittal)	28	68.50	3.0628	<b>0.0022</b>
	total area R + L & total area F + B	28	56.00	3.3474	<b>0.0008</b>
	external area R + L & external area F + B	28	100.00	2.3455	<b>0.0190</b>
	external time R + L & external time F + B	28	81.50	2.7667	<b>0.0057</b>
3 minute	stability index (frontal) & stability index (sagittal)	28	38.00	3.6278	<b>0.0003</b>
	total area R + L & total area F + B	28	30.50	3.9281	<b>0.0001</b>
	external area R + L & external area F + B	28	63.00	3.0271	<b>0.0025</b>
	external time R + L & external time F + B	28	64.50	3.1538	<b>0.0016</b>
4 minute	stability index (frontal) & stability index (sagittal)	28	84.50	2.5106	<b>0.0121</b>
	total area R + L & total area F + B	28	68.00	3.0741	<b>0.0021</b>
	external area R + L & external area F + B	28	121.50	1.8559	0.0635
	external time R + L & external time F + B	28	91.00	2.3544	<b>0.0186</b>
5 minute	stability index (frontal) & stability index (sagittal)	28	72.00	2.9831	<b>0.0029</b>
	total area R + L & total area F + B	28	62.00	3.2108	<b>0.0013</b>
	external area R + L & external area F + B	28	58.00	3.3019	<b>0.0010</b>
	external time R + L & external time F + B	28	80.00	2.8009	<b>0.0051</b>
6 minute	stability index (frontal) & stability index (sagittal)	28	110.50	2.1064	<b>0.0352</b>
	total area R + L & total area F + B	28	104.00	2.2544	<b>0.0242</b>
	external area R + L & external area F + B	28	123.00	1.8217	0.0685
	external time R + L & external time F + B	28	118.00	1.9356	0.0529
7 minute	stability index (frontal) & stability index (sagittal)	28	34.00	3.8484	<b>0.0001</b>
	total area R + L & total area F + B	28	33.00	3.8711	<b>0.0001</b>
	external area R + L & external area F + B	28	35.00	3.8256	<b>0.0001</b>
	external time R + L & external time F + B	28	38.50	3.7459	<b>0.0002</b>
8 minute	stability index (frontal) & stability index (sagittal)	28	64.00	2.8319	<b>0.0046</b>
	total area R + L & total area F + B	28	81.00	2.7781	<b>0.0055</b>
	external area R + L & external area F + B	28	98.50	2.3796	<b>0.0173</b>
	external time R + L & external time F + B	28	88.00	2.6187	<b>0.0088</b>
9 minute	stability index (frontal) & stability index (sagittal)	28	108.00	2.1633	<b>0.0305</b>
	total area R + L & total area F + B	28	104.00	2.2544	<b>0.0242</b>
	external area R + L & external area F + B	28	125.50	1.7648	0.0776
	external time R + L & external time F + B	28	117.00	1.9583	0.0502
10 minute	stability index (frontal) & stability index (sagittal)	28	37.00	3.5176	<b>0.0004</b>
	total area R + L & total area F + B	28	29.00	3.9622	<b>0.0001</b>
	external area R + L & external area F + B	28	90.00	2.5732	<b>0.0101</b>
	external time R + L & external time F + B	28	76.00	2.8920	<b>0.0038</b>

statistically essential values were distinguished in bold type

R, L – side right, left; F, B – front, back; p – significance level; T – Wilcoxon's test value  $n \leq 25$ ; Z – Wilcoxon's test value  $n > 25$

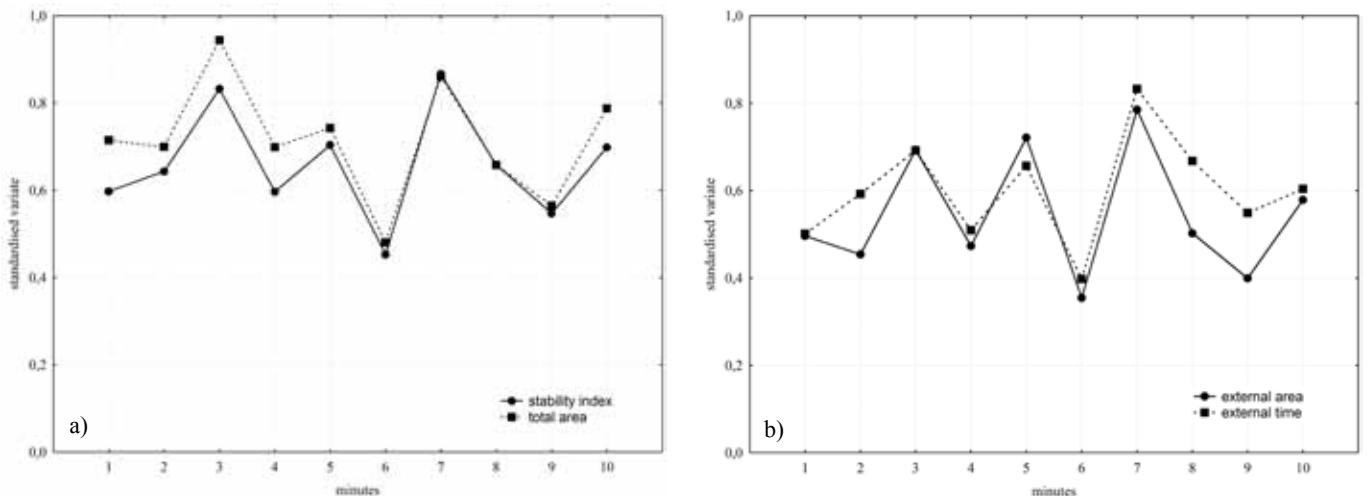


Figure 4. Standardized values of balance parameters in the trial of balancing on Libra platform in the consecutive minutes of the test (standardization of results in the sagittal plane in comparison to the frontal one): a) performance and total area; b) external area and external time

observed in the first three minutes of the trial. Between the 4<sup>th</sup> and 7<sup>th</sup> minutes the balance parameters underwent a relative stabilization. The subjects achieved the best results in the 8<sup>th</sup> minute of the test and kept this level till the end. The character of the changes was the same in both movement planes.

In order to compare the results obtained by the subject in the frontal and sagittal planes, Wilcoxon's test of succession was used. The significance of differences was defined in each minute of the test. The results obtained in a comparative analysis are shown in Table 3.

In each minute of the test the diversity between the test results in the frontal plane and in the sagittal one are statistically significant. The few cases where such difference was not noticed concern the parameters dependent on the difficulty degree of the test. In the case of statistics  $Z$ , the highest degree of diversity concerns almost exclusively the total area.

Comparing Wilcoxon's test to the raw data, it was stated that in the examined group there was a higher level of dynamic balance in the sagittal plane. These relations undergo minor oscillations during the trial. In the normalized values, the advantage of the sagittal plane fluctuates between 0.4 and 0.9 s (Fig. 4).

## Discussion

The reason why the present study was undertaken was the result of the previous research done by the same authors [32], where the subjects balanced on the platform alternately in the frontal plane and in the sagittal one with a 20-second break between the trials. The test applied in that experiment turned out to be too short (to-

tally 10 minutes, alternately 5 minutes for each plane) to determine the borderline between motor learning and initial symptoms of tiredness. That is why, in the present study, the measurements have been taken during a continuous 10-minute trial separate for each plane.

The results of the present study, like those of the previous one, have not shown unequivocally a negative influence of the effort caused by long-lasting balancing on the platform on dynamic balance in the subjects. On the contrary, during a 10-minute balancing trial significant improvements in the performances have been noted. However, now, the increase has not been regular. Its 56% in the frontal plane and almost 60% in the sagittal plane occurred in the first three minutes of the trial. Between the 4<sup>th</sup> and 7<sup>th</sup> minutes it did not exceed 20%. The subjects achieved the best results in the 8<sup>th</sup> minute of the test and kept them till the end. The character of the observed changes has been the same in reference to both movement planes.

The reason of such a significant improvement in the first minutes of the test can be explained by the strategy of the balance keeping adopted by the subjects. Standing on the platform and having difficulty in keeping balance, in almost all the cases, they were making active movements of the trunk. It is a typical way of regulating balance in the strategy of the hip joint when a person, keeping balance by making dynamic movements of different parts of the body, makes use of the resistance of moments of inertia to move other parts of the body. In this strategy the person making movements in the hip joints, while the lower part of the body rests on the surface, becomes support for the movements performed by the upper part of the body [33].

In the successive minutes of the trial, trunk movements were decreasing, which suggests a change of strategy. As a result of the trunk stiffness, the balance control was held by the ankle area. The new strategy allowed the subjects to control balance precisely stabilizing its level until the 8<sup>th</sup> minute of the test.

Also, it should be taken into consideration that both the change of strategy and the further improvement in the performance could have been the effect of motor learning. The process continued until the 8<sup>th</sup> minute and then, because of the fatigue, the subjects did not reach their best performances. Finishing the trial they complained about fatigue they felt in lower limbs. A similar effect of learning how to balance has been achieved by Juras [4], based on the blocked practice method which consists of six series of five 30-second repetitions with 15-second intervals between them and 2-minute rests between the series.

In the conditions of the balance measurement on stabilographic platforms, a wider range of sways and higher oscillation frequency of the centre of gravity projection onto the base is observed in the sagittal plane. Stability in the static conditions, in a stance in the frontal plane is much better [13, 16], which is mainly related to the anatomic structure of the feet and the adopted strategy of balance keeping. In the condition of the movable surface the relations discussed are not that explicit.

In the presented study it was stated that there was a higher level of balance parameters in the sagittal plane in all the successive minutes of the conducted trials. The mutual relations did not undergo significant fluctuations and stayed within the limits of the standard deviation, i.e. 0.5. Similar results in the dynamic conditions have been obtained by Zemková et al. [30]. In their case, measurements were taken before and after the effort of an anaerobic character. The authors did not find differences between the movement planes in the static conditions. In their opinion, evaluation of sways in the dynamic conditions can be considered to be more sensible and suitable, especially for sports' needs. Moreover, a dynamic posturography provides additional useful information concerning preferences in choosing strategies of keeping balance and ability to use the information coming from vestibular, sensorial and visual entrances in order to keep balance.

Lundin et al. [31] claim that balance in the sagittal plane is controlled by the ankle strategy. A decrease in preferences of the ankle strategy in this movement plane can be caused by tiredness [14], which, in consequence, can result in deterioration in stability. However, in some works, like in our research, it was observed that there was a more considerable increase in sways after an

effort in the frontal plane than in the sagittal one. It took place while aiming a rifle after a simulation of a ski race [28] or after certain tasks in acrobatic sports [29]. Kuczyński and Wieloch [34] obtained similar results studying an influence of quickened breathing on postural stability. Quickened breathing had little influence on deterioration in stability in the sagittal plane in comparison to the frontal one. Our own measurements and the quoted examples of other authors' studies, performed both on stabilographic platforms and in dynamic conditions, may suggest a lower stability (caused by an effort put in keeping the upright posture) in the frontal plane. To state explicitly such correlations requires further research.

## Conclusions

The influence of the effort caused by balancing on the movable platform on the male subjects' stability is not unequivocal. In the first minutes there was a considerable improvement in stability in both planes, only after the 8<sup>th</sup> minute the first symptoms of adverse effect of tiredness on the balance level appeared. The improvement in stability, observed regularly from the 1<sup>st</sup> to 8<sup>th</sup> minute of the trial duration, could have had a relationship with the change of strategy of balance keeping and, related to it, motor learning.

The fatigue caused by a 10-minute balancing did not result in a visible deterioration in the analysed parameters, but only their stabilization at a much higher level than at the moment when the test started. The applied test does not answer the question of after how long the effort related to a performance of an equivalent task will lead to such fatigue that the subjects' stability will deteriorate significantly. However, the test appeared to be long enough to delineate a borderline of motor learning and appearance of the first symptoms of tiredness.

The direction of the changes during the whole experiment was very close in both analysed movement planes. Nevertheless, better results of stability were noted in the case of the sagittal plane.

## Acknowledgements

The authors would like to thank the company Technomex for providing the equipment for the experiment.

## References

1. Raczek J., Mynarski W., Ljach W., Developing and diagnosing of co-ordination motor abilities [in Polish]. AWF, Katowice 2002, 11–25.
2. Błaszczyk W., The clinical biomechanics [in Polish]. PZWL, Warszawa 2004, 197–202.

3. Peterka R.J., Loughlin P.J., Dynamic regulation of sensorimotor integration in human postural control. *J Neurophysiol*, 2004, 91, 410–423. doi:10.1152/jn.00516.20030022-3077/04.
4. Juras G., Aspects of motor co-ordination determining human balance [in Polish]. AWF, Katowice 2003, 64–127.
5. Keshner E.A., Kenyon R.V., Langston J., Postural responses exhibit multisensory dependencies with discordant visual and support surface motion. *J Vestib Res*, 2004, 14, 307–319.
6. Roth A.E., Miller M.G., Ricard M., Ritenour D., Chapman B.L., Comparisons of static and dynamic balance following training in aquatic and land environments. *J Sport Rehabil*, 2006, 15, 299–311.
7. Latash M.L., Aruin A.S., Shapiro M.B., The relation between posture and movement: a study of a simple synergy in a two-joint task. *Hum Mov Sci*, 1995, 14, 79–107.
8. Loram I.D., Maganaris C.N., Lakie M., Human postural sway results from frequent, ballistic bias impulses by soleus and gastrocnemius. *J Physiol*, 2005, 564 (1), 295–311. doi:10.1113/jphysiol.2004.076307.
9. Diener H.C., Dichgans J., Pathophysiology of posture. In: Ambillard B., Berthoz A., Clarac F. (eds.), Posture and gait: Development, adaptation and modulation. *Excerpta Medica*, Amsterdam–Oxford 1988, 229–235.
10. Carpenter M.G., Frank J.S., Adkin A.L., Paton A., Allum J.H.J., Influence of postural anxiety on postural reactions to multi-directional surface rotations. *J Neurophysiol*, 2004, 92, 3255–3265. doi:10.1152/jn.01139.2003.
11. Massion J., Movement, posture and equilibrium: interaction and coordination. *Prog Neurobiol*, 1992, 38, 35–56.
12. Gatev P., Thomas Sh., Kepple Th., Hallett M., Feedforward ankle strategy of balance during quiet stance in adults. *J Physiol*, 1999, 514.3, 915–928. doi:10.1111/j.1469-7793.1999.915ad.x.
13. Błaszczyk J., Static and dynamic stability of the upright posture. *J Human Kinetics*, 2000, 4 (Supplement), 97–106.
14. Winter D.A., Patla A.E., Rietdyk Sh., Ishac M.G., Ankle muscle stiffness in the control of balance during quiet standing. *J Neurophysiol*, 2001, 85, 2630–2633.
15. Henry S.M., Fung J., Horak F.B., Effect of stance width on multidirectional postural responses. *J Neurophysiol*, 2001, 85, 559–570.
16. Masani K., Popovic M.R., Nakazawa K., Kouzaki M., Nozaki D., Importance of body sway velocity information in controlling ankle extensor activities during quiet stance. *J Neurophysiol*, 2003, 90, 3774–3782. doi:10.1152/jn.00730.2002.
17. Waśkiewicz Z., The influence of anaerobic efforts on chosen aspects of motor control [in Polish]. AWF, Katowice 2002, 98–105.
18. Cox E.D., Lephart S.M., Irrgang J., Unilateral balance training of noninjured individuals and the effects on postural sway. *J Sport Rehabil*, 1993, 2, 87–96.
19. Johnston R.B., Howard M.E., Cawley P.W., Losse G.M., Effect of lower extremity muscular fatigue on motor control performance. *Med Sci Sports Exerc*, 1998, 30, 1703–1707.
20. Nardone A., Tarantola J., Giordano A., Schieppati M., Fatigue effects on body balance. *Electroencephalogr Clin Neurophysiol*, 1997, 105, 309–320.
21. Nardone A., Tarantola J., Galante M., Schieppati M., Time course of stabilometric changes after a strenuous treadmill exercise. *Arch Phys Med Rehabil*, 1998, 79, 920–924.
22. Pendergrass T.L., Moore J.H., Gerber J.P., Postural control after a 2-mile run. *Mil Med*, 2003, 168 (11), 896–903.
23. Lepers R., Bigard A.X., Diard J.P., Gouteyron J.F., Guezenne C.Y., Posture control after prolonged exercise. *Eur J Appl Physiol Occup Physiol*, 1997, 76 (1), 55–61.
24. Seliga R., Bhattacharya A., Succop P., Wickstrom R., Smith D., Willeke K., Effect of work load and respirator wear on postural stability, heart rate, and perceived exertion. *Am Ind Hyg Assoc J*, 1991, 52, 417–422.
25. Zemková E., Hamar D., Postural sway response to exercise bouts eliciting the same heart rate with different energy yield from anaerobic glycolysis. *Med Sportiva*, 2003, 7 (4), 135–139.
26. Hashiba M., Transient change in standing posture after linear treadmill locomotion. *Jap J Physiol*, 1998, 48 (6), 499–504.
27. Derave W., Tombeau N., Cottyn J., Pannier J.L., De Clercq D., Treadmill exercise negatively affects visual contribution to static postural stability. *Int J Sports Med*, 2002, 23, 44–49. doi:10.1055/s-2002-19374.
28. Niinimaa V., McAvoy T., Influence of exercise on body sway in the standing rifle shooting position. *Can J Appl Sport Sci*, 1983, 8 (1), 30–33.
29. Vuillerme N., Danion F., Marin L., Boyadjian A., Prieur J.M., Weise I., Nougier V., The effect of expertise in gymnastics on postural control. *Neurosci Lett*, 2001, 303, 83–86.
30. Zemková E., Viitasalo J., Hannola H., Blomqvist M., Konttinen N., Mononen K., The effect of maximal exercise on static and dynamic balance in athletes and non-athletes. *Med Sportiva*, 2007, 11 (3), 70–77. doi:10.2478/v10036-007-0014-2.
31. Lundin T.M., Feuerbach J.W., Grabiner M.D., Effect of plantar flexor and dorsiflexor fatigue on unilateral postural control. *J Appl Biomech*, 1993, 9, 191–201.
32. Tchorzewski D., Jaworski J., Bujas P., Changes of the body's dynamic stability under the influence of balancing on movable platform. In: Juras G., Stomka K. (eds.), Current Research in Motor Control III from theories to clinical applications. AWF, Katowice 2008, 105–112.
33. Golema M., The range of transpositions of respective body segments in human balancing in an upright position [in Polish]. *Studia i Monografie Politechniki Opolskiej*, Opole 2003, 148, 133–141.
34. Kuczyński M., Wieloch M., Effects of accelerated breathing on postural stability. *Human Movement*, 2008, 9 (2), 107–110. doi:10.2478/v10038-008-0012-9.

Paper received by the Editors: January 22, 2010.

Paper accepted for publication: May 21, 2010.

#### *Address for correspondence*

Dariusz Tchorzewski  
ul. Wrzosowa 22  
42-622 Świerklaniec, Nowe Chechło, Poland  
e-mail: dariusz.tchorzewski@awf.krakow.pl



# POSTURAL SWAY RESPONSE TO REBOUND JUMPS OF DIFFERENT DURATION

doi:10.2478/v10038-010-0017-z

ERIKA ZEMKOVÁ<sup>1\*</sup>, OL'GA KYSELOVIČOVÁ<sup>2</sup>, DUŠAN HAMAR<sup>1</sup>

<sup>1</sup> Department of Sports Kinanthropology, Faculty of Physical Education and Sport, Comenius University Bratislava, Slovakia

<sup>2</sup> Department of Gymnastics, Faculty of Physical Education and Sport, Comenius University Bratislava, Slovakia

## ABSTRACT

**Purpose.** The study compares the sway variables after continuous CMJs eliciting different level of proprioceptive stimulation determined by percentage of max height of the jump. **Basic procedures.** A group of 11 aerobic dancers performed in random order repeated jumps with maximal effort until the jump height dropped to 75%, 50%, and 25% of previously established max jump achieved in non-fatigued conditions. The height of CMJs was calculated from flight times registered by FiTRO Jumper. Thirty seconds prior to and two minutes after exercises the COP velocity was registered at 100 Hz by means of posturography system FiTRO Sway Check based on dynamometric platform. **Main findings.** Results showed that max height of the jump (MJ) decreased from  $27.7 \pm 2.8$  cm to  $20.1 \pm 2.6$  cm when subjects matched 75% of 1MJ, to  $13.8 \pm 1.6$  cm at 50% of 1MJ, and to  $6.9 \pm 0.8$  cm at 25% of 1MJ. The COP velocity was significantly ( $p \leq 0.01$ ) higher after jumps dropped to 75% of 1MJ as compared to baseline (from  $9.2 \pm 1.6$  mm/s to  $14.5 \pm 2.4$  mm/s). Its further significant ( $p \leq 0.05$ ) increase was observed after jumps dropped to 50% of 1MJ (to  $19.6 \pm 2.6$  mm/s). However, there was only slight increase in COP velocity after jumps dropped to 25% of 1MJ (to  $21.4 \pm 3.2$  mm/s). **Conclusions.** Taking into account a gradual increase in sway velocity after jumps matched 75% and 50% of 1MJ and its no further increase after jumps matched 25% of 1MJ, it may be assumed that post-exercise balance impairment is not linearly related to the level of proprioceptive stimulation.

**Key words:** aerobics, jumps, postural sway, proprioceptive stimulation

## Introduction

Landings are common part of the performance in sports, such as gymnastics, rock and roll, and aerobics. From biomechanical analyses it is known that ground reaction forces in aerobics may reach 3-, 4-, and even 5-times the body weight [1]. A substantially higher peak forces have been recorded in gymnasts' landing ranged from 8.2 to 11.6 times the body weight [2]. They often land with minimal flexion at the hip, knee, and ankle, which is a primary means of attenuating energy during landings [3, 4]. In addition, gymnasts expose higher ground reaction forces during drop landings from heights of 60 to 90 cm (40.3 N/kg and 56.0 N/kg, respectively) than recreational athletes (27.0 N/kg and 37.4 N/kg, respectively) [5].

It may be assumed that repetitive exposure to such high loads may contribute to the incidence of lower limb injuries. These injuries account for 50% [6] to 64% [7] of all injuries. Among those the most frequent site of trauma is the ankle [8], followed by the knee [9].

In particular, functional instability of the ankle joint is a later complication of 10% to 30% of acute ankle

sprains [10]. Functional instability is associated with decreased strength of ankle musculature, impaired proprioception, loss of balance and ligamentous laxity [11]. Decades ago it was postulated [e.g., 12] that these injuries could result from delayed reflex responses to stress on ankle ligaments as a result of damage to ankle joint receptors at the time of initial injury. However, recent evidence [e.g., 13] suggests that dynamic control of ankle stability is achieved by feedforward mechanisms of the central nervous system rather than by means of feedback effected by peripheral reflexes.

Caulfield and Garrett [14] have documented that lateral and anterior force peaks occurred significantly earlier in subjects with functional instability of the ankle joint. Significant differences were seen between groups' time-averaged vertical, frontal and sagittal components of ground reaction force. These ranged from 5% (frontal force) to 100% (vertical force) of body mass. According to authors the disordered force patterns observed in subjects with functional instability are likely to result in repeated injury due to significant increase in stress on ankle joint structures during jump landing. They suggest that these injuries are, most likely, to result from deficit in feedforward control of ankle joint movement. This is important also for initiation of a vertical jump because of the human body's upward propulsion that has been found [15] to depend

\* Corresponding author.

on control of forward equilibrium. Due to biomechanical constraints, balance is first lost through a backward center of pressure shift. The COP is then moved forward so as to reach a position favorable to produce a vertical jump.

However, intensive jumping may not only increase the risk of injuries but can also negatively affect the performance. More specifically, intensity of proprioceptive stimulation during jumps has been found [16] to significantly influence feedback mechanisms involved in balance control. Its effect depends not only on the type of exercise but likely also on height of the jumps and their duration. For instance, a greater postural sway was documented [16] after jumps than calf rises, both eliciting the same ventilation. Also more profound balance impairment has been found [17] after about 3-times higher maximal jumps than aerobic jumps, both eliciting the same ventilation.

However, there is no information of how duration of the jumps influences postural stability in aerobic dancers. Experience showed that in 1.45 min aerobic routine from 352 difficulty elements in total (balance, flexibility, static and dynamic strength) there is more than half – 182 jumps.

Therefore the aim of the study was to compare the parameters of balance after continuous CMJs eliciting different levels of proprioceptive stimulation determined by percentage of max height of the jump.

## Material and methods

### Subjects

A group of 11 female professional aerobic dancers (aged  $17.8 \pm 2.4$  years, height  $163.6 \pm 5.2$  cm, weight  $55.3 \pm 5.4$  kg) volunteered to participate in the study. All of them were informed of the procedures and of the main purpose of the study.

### Test protocol

Subjects underwent a 10-second test of maximal jumps with hands fixed on the hips. The mean of three max values of such a jumping series was considered as a max jump height (1MJ). For this purpose a diagnostic system FiTRO Jumper consisting of a special contact switch mattress connected by means of an interface to a computer was used. The system measures contact and flight times (with accuracy of 1 ms) during jumps and calculates basic biomechanical parameters (e.g., height of the jump).

After about 20 minutes subjects performed repeated

jumps with maximal effort until the jump height dropped to 75%, 50%, and 25% of 1 max jump (1MJ), respectively achieved in non-fatigued conditions. The same system FiTRO Jumper was used to measure height of jumps. Landings were performed barefoot with the trial duration (determined by % of 1MJ) order randomized for each subject.

Thirty seconds prior to and two minutes immediately after the exercises the COP velocity was registered at 100 Hz by means of posturography system FiTRO Sway Check based on dynamometric platform. Average values of 5-second intervals were used for the evaluation. Subjects were instructed to minimize postural sway by standing as still as possible.

While exercising and standing on stabilographic platform a heart rate was continuously monitored using SportTester.

A subjective level of exertion was estimated immediately after cessation of each exercise using Borg's 6 to 20 Rating of Perceived Exertion Scale [18].

### Statistical analysis

Ordinary statistical methods, including average and standard deviation, were used. A Wilcoxon test was employed to determine the statistical significance of differences between pre- and post-exercise parameters of balance,  $p \leq 0.05$  was considered significant.

## Results

It has been found (Fig. 1) that max height of the jump (MJ) decreased from  $27.7 \pm 2.8$  cm to  $20.1 \pm 2.6$  cm when subjects dropped to 75% of 1MJ, to  $13.8 \pm 1.6$  cm at 50% of 1MJ, and to  $6.9 \pm 0.8$  cm at 25% of 1MJ.

The COP velocity (Fig. 2) was significantly ( $p \leq 0.01$ ) higher after jumps matched 75% of 1MJ as compared

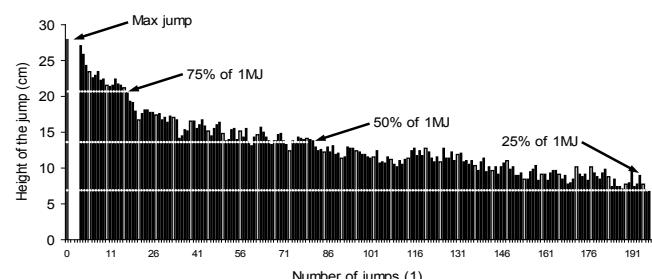


Figure 1. A schematic representation of the test execution: subjects performed three trials of repeated jumps with maximal effort until the jump height dropped to different percentages of 1MJ

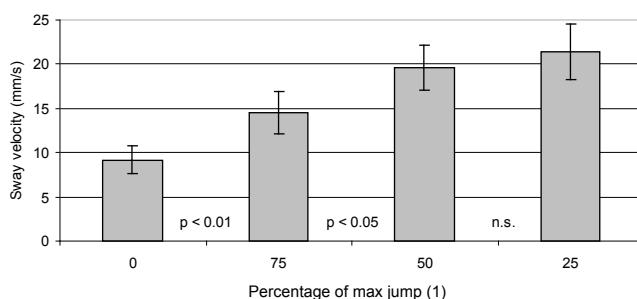


Figure 2. Sway velocity after jumps matched different percentages of 1MJ

to baseline (from  $9.2 \pm 1.6$  mm/s to  $14.5 \pm 2.4$  mm/s). Its further significant ( $p \leq 0.05$ ) increase was observed after jumps matched 50% of 1MJ (to  $19.6 \pm 2.6$  mm/s). However, there was only a slight increase in COP velocity after jumps matched 25% of 1MJ (to  $21.4 \pm 3.2$  mm/s).

In this case, its values remained temporarily elevated with slight tendency to increase and only after about 15–20 seconds a gradual decrease back to the resting level set in. However, COP velocity did not return to pre-exercise level within 2 minutes of recovery. On the other hand, after jumps matched 50% and 75% of 1MJ sway velocity started to decrease within 5 seconds of recovery.

According to Borg' scale [18] subjects perceived jumps matched 75% of 1MJ as light (11) to somewhat hard (12), those at 50% of 1MJ as hard (14), and those at 25% of 1MJ as very hard (18). Because a rating of 20 is rarely given by subjects, the RPEs above 18 are considered as a strenuous exercise [19].

## Discussion

Jumping performance of the subjects examined decreased to 75% of 1 max jump after about 17 jumps, to 50% of 1MJ after 81 jumps, and to 25% of 1MJ after 196 jumps. Such intensive proprioceptive stimulation during jumps seems to have an important influence on feedback mechanisms involved in control of balance, as indexed by an increase in sway velocity.

From biomechanical analyses it is known that ground reaction forces in aerobics may reach 3-, 4-, and even 5-times the body weight [1]. It may be assumed that stimulation of muscle spindles, tendon organs, joint receptors and cutaneous mechanoreceptors on the sole during jumping led to the impairment of their sensitivity. In particular, activity of muscle spindle can change under muscular fatigue [20, 21], possibly via modulation of reflex pathways originating from small-

diameter muscle afferents, namely group III and IV afferents [22]. Resulting partial reduction of afferent impulses leading to deterioration in proprioceptive feedback control of balance after jumps matched 75% of 1MJ contributed to about 36.6% increase in sway velocity relative to pre-exercise values. Further 26% increase was observed after jumps matched 50% of 1MJ.

However, despite more than double duration between jumps performed to drop at 50% and 25% of 1 max jump, sway velocity only slightly increased (on average 8.4%). This may be ascribed to an increase in excitability threshold. In this case, also compensatory mechanisms, e.g. increased reflex activity in muscle spindles [20] or increased muscle stiffness due to fatigue can be used for postural control.

Similarly, Vuillerme et al. [23] found that under muscle fatigue vibration does not induce a further increase in postural sway. They suggest that, to some extent, under the condition of fatigue, the central nervous system may decrease the reliance on proprioceptive information from the ankles and may use other sensory inputs providing a more reliable information for regulating postural sway. More specifically, in the context of ankle muscle fatigue, it would be appropriate for the CNS to rely less on proprioceptive information from the ankles. As a result, the multisensory integration made by the CNS would force the subjects to use other sensory inputs providing more reliable information for the regulation of postural sway (e.g., vestibular, neck, hip and knee proprioceptive inputs).

In addition, the control and perception of ankle movement results from the co-processing of both agonist and antagonist muscle spindles activity. In other words, the CNS would rely mainly on contrasting agonist and antagonist sources of information.

These findings indicate that besides the proprioceptive information generated by the ankle dorsiflexors, there are other mechanisms able to control efficiently postural stability in fatigue. This may, in part, explain only a slight increase in sway velocity after more than double duration of jumps performed to drop at 25% of 1MJ than those matching 50% of 1MJ.

Besides an acute balance impairment after exercise, also its readjustment to pre-exercise level is considered as an important ability in sports like aerobics or gymnastics, where impaired balance resulting from intensive jumping may adversely affects performance. Time course of postural sway after jumps matched 25% of 1MJ showed transient increase followed by 15 to 20 seconds of plateau and only then a gradual decrease back to the resting level set in. On the other hand, its values after jumps matched 50% and 75% of 1MJ

started to decrease within 5 seconds of recovery. Thus, in order to obtain more precise information on postural sway response to exercise, both magnitude of balance impairment in an initial phase of recovery and speed of its readjustment should be analysed.

## Conclusions

Sway velocity is significantly higher after jumps performed to drop at 75% of 1 max jump when compared to pre-exercise level. Its further increase occurs after jumps matched 50% of 1MJ. This effect may be ascribed to the deterioration of proprioceptive feedback control of balance.

In spite of more than double duration of jumps matching 50% and 25% of 1MJ, there is only a slight increase in sway velocity. It means that there is no linear relationship between the post-exercise balance impairment and the level of proprioceptive stimulation.

However, further studies are needed to evaluate the effect of such a deterioration of balance after jumping on performance in aerobics.

## Acknowledgment

This project was supported by the Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences (No. 1/0611/08).

## References

1. Hamar D., Reactive forces during physical activities [in Slovak]. *Muscle & Fitness*, 1995, 12, 60–61.
2. Ozguven H.N., Berme N., An experimental and analytical study of impact forces during human jumping. *J Biomech*, 1988, 21 (12), 1061–1066. doi:10.1016/0021-9290(88)90252-7.
3. Devita P., Skelly W.A., Effects of landing stiffness on joint kinetics and energetics in the lower extremity. *Med Sci Sports Exerc*, 1992, 24, 108–115.
4. Sands W.A., Injury prevention in women's gymnastics. *Sports Med*, 2000, 30, 359–373.
5. Seegmiller J.G., McCaw S.T., Ground reaction forces among gymnasts and recreational athletes in drop landings. *J Athl Train*, 2003, 38 (4), 311–314.
6. Sands W.A., Schultz B.B., Newman A.P., Women's gymnastic injuries: a 5-year study. *Am J Sports Med*, 1993, 21, 271–276. doi:10.1177/036354659302100218.
7. Caine D., Cochrane B., Caine C., Zemper E., An epidemiologic investigation of injuries affecting young competitive female gymnasts. *Am J Sports Med*, 1989, 17, 811–820. doi:10.1177/036354658901700616.
8. Garrick J.G., Requa R.K., Epidemiology of women's gymnastics injuries. *Am J Sports Med*, 1980, 8, 261–264. doi:10.1177/036354658000800409.
9. Weiker G., Injuries in club gymnastics. *Physician Sportsmed*, 1985, 13 (4), 63–66.
10. Ryan L., Mechanical stability, muscle strength, and proprioception in the functionally unstable ankle. *Aust J Physiother*, 1994, 40, 41–47.
11. Caulfield B., Functional instability of the ankle. Features and underlying causes. *Physiotherapy*, 2000, 86, 401–411.
12. Freeman M.A.R., Dean M.R.E., Henham I.W.F., The etiology and prevention of functional instability of the foot. *J Bone Joint Surg*, 1965, 47B, 678–685.
13. Konradsen L., Voigt M., Hojsgaard C., Ankle inversion injuries. The role of the dynamic defense mechanism. *Am J Sports Med*, 1997, 25, 54–58. doi:10.1177/036354659702500110.
14. Caulfield B., Garrett M., Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. *Clin Biomechanics*, 2004, 19, 617–621. doi:10.1016/j.clinbiomech.2004.03.001.
15. Le Pellec A., Maton B., Initiation of a vertical jump: the human body's upward propulsion depends on control of forward equilibrium. *Neurosci Lett*, 2002, 323, 183–186. doi:10.1016/S0304-3940(02)00129-5.
16. Zemková E., Hamar D., Dzurenková D., Postural sway response to resistance exercises with different intensity of proprioceptive stimulation. 10<sup>th</sup> Annual Congress of the European College of Sport Science, Belgrade 2005, 79.
17. Kyselovičová O., Zemková E., Modified aerobic gymnastics routines in comparison with laboratory testing of maximal jumps. *Sport SPA*, 2010, 7 (1), 37–40.
18. Borg G.A.V., Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med*, 1970, 2, 92–98.
19. Borg G.A.V., Borg's Perceived Exertion and Pain Scales. Human Kinetics, Champaign 1998.
20. Nelson D.L., Hutton R.S., Dynamic and static stretch responses in muscle spindle receptors in fatigued muscle. *Med Sci Sports Exerc*, 1985, 17, 445–450.
21. Pedersen J., Ljubislavlevic M., Bergenheim M., Johansson H., Alterations in information transmission in ensemble of primary muscle spindle afferents after muscle fatigue in heteronymous muscle. *Neuroscience*, 1998, 84, 953–959. doi:10.1016/S0306-4522(97)00403-X.
22. Bigland-Ritchie B., Dawson N.J., Awson R.S., Johansson O.C., Lippold O.C., Reflex origin for the slowing of motoneurone firing rates in fatigue of human voluntary contractions. *J Physiol*, 1986, 379, 451–459.
23. Vuillerme N., Danion F., Forestier N., Nougier V., Postural sway under muscle vibration and muscle fatigue in humans. *Neurosci Lett*, 2002, 333 (2), 131–135. doi:10.1016/S0304-3940(02)00999-0.

Paper received by the Editors: December 15, 2008.

Paper accepted for publication: April 21, 2010.

## Address for correspondence

Erika Zemková, Ph.D.  
Faculty of Physical Education and Sport  
Comenius University  
Svobodovo nábrežie 9  
814 69 Bratislava, Slovakia  
e-mail: zemkova@yahoo.com



## ACUTE CARDIOVASCULAR ALTERATIONS IN HYPERTENSIVE RENAL PATIENTS DURING EXERCISE WITH CONSTANT LOAD IN THE INTERDIALYTIC PERIOD

doi:10.2478/v10038-010-0011-5

**CARLOS RICARDO MANECK MALFATTI<sup>1, 2 \*</sup>, SIVOLNEI FERREIRA<sup>3</sup>**

<sup>1</sup> State University of Center-West (UNICENTRO), Irati, PR, Brazil

<sup>2</sup> Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil

<sup>3</sup> University of Santa Cruz do Sul (UNISC), Santa Cruz do Sul, RS, Brazil

### ABSTRACT

**Purpose.** The study investigated acute cardiovascular alterations during aerobic exercise in interdialytic phase. **Basic procedures.** Seven hypertensive men with chronic renal disease (CRD) and seven healthy men (C) were matched according to the age (CRD:  $48.5 \pm 8.5$ ; C:  $45.28 \pm 9.3$ ) and body mass index (CRD:  $24.2 \pm 2.8 \text{ kgm}^{-2}$ ; C:  $26.7 \pm 2.7 \text{ kgm}^{-2}$ ). The exercise was executed on a cycloergometer during 6 minutes at 75% of  $\text{HR}_{\text{max}}$  and 3 minutes of recovery without load at 55–60 rpm. The patients came twice and were controlled only on an occasion at the hospital at 9.00 am. The exercise was performed before and 24 hours after haemodialysis (HD). The blood samples were drawn immediately before and 24 hours after HD for hematocrit and hemoglobin analysis. The statistical difference was verified by the ANOVA and two-tailed unpaired Student's t-test only for  $p < 0.05$ . **Main findings.** After HD, the systolic blood pressure (SBP) shows reduction in the first stage ( $\sim 14\%$ ;  $p < 0.05$ ) and in the recovery period of exercise ( $\sim 18\%$ ;  $p < 0.05$ ). A hypotension effect of HD was better observed in the diastolic blood pressure (DBP) from the 5<sup>th</sup> to 9<sup>th</sup> min of exercise ( $\sim 20\%$ ;  $p < 0.05$ ). The HD did not modify biochemical (hematocrit and hemoglobin), physiological (Rest  $\text{SpO}_2$ ; rest SBP; rest DBP and  $\text{VO}_{2\text{max}}$ ) and body weight parameters. **Conclusions.** The study showed a significant reduction in blood pressure levels during the exercise, principally in DBP 24 hours after HD, suggesting that exercise executed during this period can induce better tolerance to exercise in dialyzed patients.

**Key words:** haemodialysis, hypertension, blood pressure, physical test

### Introduction

The regular physical activity is related to beneficial effects to renal patients, such as a reduced risk of cardiovascular mortality, improvement in blood pressure (BP), control among hypertensive individuals and improvement in health-related quality of life as a result of enhanced psychological well-being and improved physical functioning [1, 2]. Given that cardiovascular mortality is the number-one cause of death among patients with end-stage renal disease (ESRD) in the United States and approximately 80% of incident ESRD patients have a history of hypertension [3], there is great potential to reduce the death rate as a result of exercise participation in this population. Despite the myriad potential benefits of exercise, dialysis patients are extremely inactive [4], and nephrologists rarely assess patients' physical activity levels or counsel patients to increase activity [5]. The lack of exercise assessment and counseling is almost certainly multifactorial, re-

lated to such factors as competing medical issues that lead to limited time available for exercise counseling, lack of training in exercise prescription, and fear of adverse events related to exercise in this population. For example, it is possible that, although exercise participation could lead to greater benefits among patients with renal disease than in the general population, dialysis patients may also incur greater risk because of underlying heart or musculoskeletal disease.

The rationale for prescribing exercise in this patient population is extremely strong. However, barriers to regular exercise participation are many, which may explain the persistent sedentary behavior of this cohort. Motivation to exercise has been problematic, particularly when training is performed on non-dialysis days [6].

In addition, pre-dialysis and interdialytic (44 h) ambulatory systolic and diastolic BP decreased after the 4<sup>th</sup> month of training, a finding that persisted after the 6<sup>th</sup> month of training. Previous studies with dialyzed patients showed a chronic beneficial effect in BP control during haemodialysis after training [7, 8]. Intradialytic exercise also can induce positive psychological adaptations in this cohort by reducing symptoms of anxiety, depression, and fatigue and enhancing various compo-

\* Corresponding author.

nents of QOL, including general health, vitality, and perceptions of physical functioning.

Mechanisms underlying this enhancement of dialysis adequacy likely include increased blood perfusion between the working muscle and bloodstream, thereby enabling more thorough removal of the damaging solutes through haemodialysis (HD) treatment [9]. These benefits also may translate into the long term enhancement of dialysis adequacy (Kt/V) [10], although this hypothesis has not been rigorously investigated in a randomized controlled trial involving exercise training.

Miller et al. [11] demonstrated that hypertensive patients could significantly reduce pre-dialysis and post-dialysis systolic blood pressure after 3 months of intra-dialytic cycling. The reduction in BP was accompanied by a reduction in antihypertensive medications ( $-36\%$ ,  $p < 0.018$ ) resulting in cost savings of USD \$ 885 per patient annually. Additional trials have observed reduced resting BP [12, 13], and BP during maximal exercise [13] with 1–3 months of aerobic, or combined training. However, little importance has been given to acute cardiovascular alterations during exercise executed in interdialytic phase. This study focuses on the available data regarding tolerance exercise among renal patients before and one day after HD.

## Material and methods

### Subjects

The present study involved seven hypertensive men with chronic renal disease (CRD) that underwent periodic haemodialysis and seven healthy men (controls [C]) who were matched for age, body mass index (BMI) (Tab. 1). The patients were recruited randomly from a Renal Therapy Unit of University Hospital. Informed consent was obtained for the study in accordance with Resolution 196/96 of the National Council of Health in Brazil, which was approved by local Ethics Committee. All had been treated by three-week maintenance haemodialysis for at least one year. Dialysis access was by arterio-venous fistula. None had recirculation demonstrable on ultrasound dilution (Transonics). None had current angina or any other clinically apparent condition likely to impair their capacity to perform stationary cycling. All patients took regular antihypertensive medicaments, with diagnostic of hypertension in the Renal Therapy Unit of University Hospital in accordance with the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7).

Table 1. Clinical characteristics of the study population (means  $\pm$  SEM)

	Renal (n = 7)	Control (n = 7)
Age (years)	48.5 $\pm$ 8.5	45.28 $\pm$ 9.3
Height (m)	1.7 $\pm$ 0.06	1.73 $\pm$ 0.07
Weight (kg)	70.61 $\pm$ 11.7	79.8 $\pm$ 4.2
BMI (kg m $^{-2}$ )	24.2 $\pm$ 2.8	26.7 $\pm$ 2.7
Rest systolic blood pressure (mm Hg)	169.5 $\pm$ 6.4*	129.5 $\pm$ 7.8
Rest diastolic blood pressure (mm Hg)	105.7 $\pm$ 6.8*	82.8 $\pm$ 7.1
VO <sub>2max</sub> (mL/kg/min)	15.1 $\pm$ 1.6*	23.1 $\pm$ 1.7

Values are means  $\pm$  SE

\* Significant difference compared to control group at  $p < 0.05$  (two-tailed unpaired Student's t-test)

### Dialysis technique

Dialysis was carried out using a Fresenius Medical Care 4008H machine. All patients were treated exclusively using high-flux synthetic membranes, predominantly polysulfone. Dialysers were reused with peracetic acid (Renalin, Minntec Inc., USA) as the main processing agent. Bicarbonate was used as buffer. Ultra-pure water was used for all dialysis-related processes. Stringent bacteriological standards were maintained. Dialysis was prescribed and monitored using a two-pool kinetic model to ensure a Kt/V of 1.2. This was a composite of Kt/V (renal) and Kt/V (dialysis). Mean dialysis time was 180 min (range 140–225 min). The midweek dialysis session was chosen for the studies. Blood flow rates and dialysate flow rates were kept constant over the study period. Dialysis fluid temperature was maintained at 36°C throughout the procedures. No ultrafiltration was performed during the study period.

### Protocol of exercise

The indirect VO<sub>2max</sub> was determined using equation [14]. The protocol of exercise was performed using a cycloergometer (Bicycle Technology-BM 2800 PRO) with lower-limb use, pedaling in a sitting position according to the indirect protocol of Astrand and Rodahl [14]. The patients were asked to exercise for 9 minutes (6 minutes at 75% of HR<sub>max</sub> and 3 minutes of recovery without load) 75% of their theoretical maximum heart rate (HR<sub>max</sub>) for age (using tables from the American Heart Association). The load was adjusted for individuals to find intensity (75% of HR<sub>max</sub>) and with pedal cadency at 55–60 rpm.

The measurements taken were blood pressure (BP; mercury column), heart rate (HR; Polar – T-61), and peripheral oxygen saturation ( $\text{SpO}_2$ ; pulse oximeter – Nonimim) immediately before, at different moments and after exercise session. The subjective perceived exertion was rated by Borg scale used during exercise session [15].

The patients came twice, in random order, to hospital at 9.00 am after an overnight without medicament use (antihypertensive). For the first time, the patients performed exercise before HD session. For the second time, the exercise was performed 24 hours after HD procedure. The controls visited the hospital at 9.00 am for exercise procedure only once.

#### Laboratory measurements

The blood samples (5 mL) were drawn in random order, to hospital at 9.00 am, immediately before and 24 hours after HD procedure for hematocrit (Hct) and hemoglobin (Hgb) analysis. Hematocrit measurement was carried out according to Goldenfarb et al. [16] and the values found were expressed as a percentage of the total blood volume. Hemoglobin rate was determined by the cyanometahemoglobin method according to Collier [17], and its values were expressed in g/dL of blood.

#### Statistical analysis

All data are expressed as means  $\pm$  SEM. The statistical analyses of clinical characteristics of the study population data were carried out by two-tailed unpaired Student's t-test. The one-way analysis of variance (ANOVA) was performed to verify the difference between pre, post-haemodialysis and the control groups. A  $p < 0.05$  was considered significant. Post-hoc analysis was carried out, when appropriate, by the Student-Newman-Keuls test.

#### Results

The HD did not modify biochemical (hematocrit and hemoglobin), Physiological (Rest  $\text{SpO}_2$ ; rest SBP; rest DBP;  $\text{VO}_{2\text{max}}$  and rest heart rate) and body weight parameters quantified immediately before exercise realization. Regardless of HD realization (Pre-haemodialysis or post-haemodialysis), the CRD patients had a lower value for hematocrit ( $-20\%$ ;  $p < 0.05$ ), hemoglobin ( $-19\%$ ;  $p < 0.05$ ),  $\text{VO}_{2\text{max}}$  ( $-35\%$ ;  $p < 0.05$ ) and higher values for rest SBP ( $+24\%$ ;  $p < 0.05$ ) only in relation to the control group (Tab. 2). However, the rest systolic

blood pressure (SBP) has a little reduction ( $-11.5\%$ ;  $p < 0.05$ ) after HD procedure (no significant) between CRD patients, but have higher values ( $+16\%$ ;  $p < 0.05$ ) and significant difference when compared to the control group.

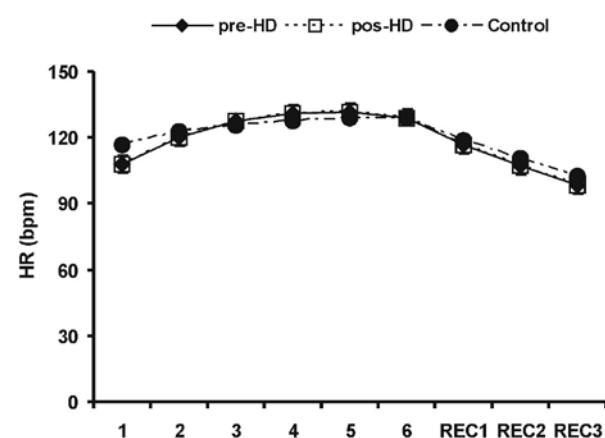
Table 2. Physiological and biochemical parameters in hypertensive renal patients before and 24 hours after dialysis procedure compared with healthy control non-dialyzed

	Pre-haemo-dialysis (n = 7)	Post-haemo-dialysis (n = 7)	Control (n = 7)
Hematocrit (%)	$34.9 \pm 4.1^*$	$36.5 \pm 3.0^*$	$43.2 \pm 2.2$
Hemoglobin (g/dL)	$11.8 \pm 1.1^*$	$12.2 \pm 1.4^*$	$14.6 \pm 0.8$
Rest heart rate (bpm)	$81.2 \pm 6.1$	$76.3 \pm 5.4$	$78.7 \pm 6.1$
Rest $\text{SpO}_2$ (%)	$99.0 \pm 0.3$	$99.5 \pm 0.4$	$98.8 \pm 0.5$
Rest systolic blood pressure (mmHg)	$169.5 \pm 6.4^*$	$150.0 \pm 9.0^*$	$129.5 \pm 7.8$
Rest diastolic blood pressure (mmHg)	$105.7 \pm 6.8$	$95.4 \pm 7.1$	$75.7 \pm 3.7$
Body weight (kg)	$70.6 \pm 11.7$	$71.2 \pm 9.0$	$79.8 \pm 4.2$
$\text{VO}_{2\text{max}}$ (mL/kg/min)	$15.1 \pm 1.6^*$	$14.9 \pm 1.5^*$	$23.1 \pm 1.7$

Values are means  $\pm$  SE

\* Significant difference compared to control group at  $p < 0.05$  (one-way analysis of variance)

A protocol of physical test was realized before and after 24 hours of HD with objective to verify the effects of dialysis in the cardiovascular parameters during exercise at 75% of  $\text{HR}_{\text{max}}$ . The HR and  $\text{SpO}_2$  were not different in the different phases of physical test between pre, pos-HD and the control group (Fig. 1).

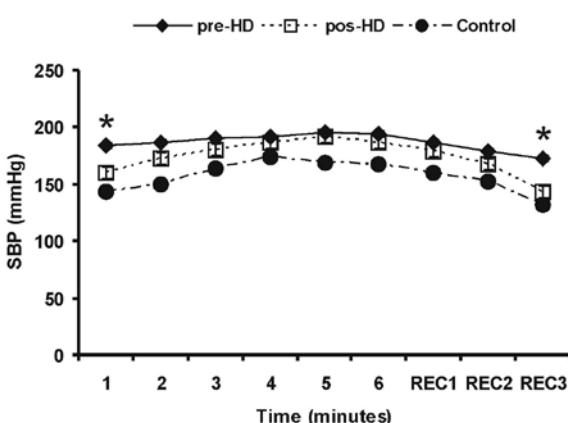


Values are means  $\pm$  SE; \*Significant difference compared to dialyzed and control group at  $p < 0.05$  (one-way analysis of variance)

Figure 1. Heart (beat) rate during protocol of exercise and recovery period (REC) before (pre-HD) and after 24 hours of haemodialysis (pos-HD) in hypertensive CRD patients (n = 7) compared to healthy control non-dialyzed (n = 7)

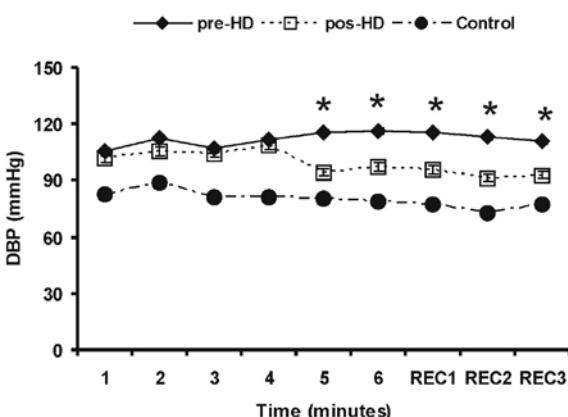
After dialysis, the SBP procedure has a reduction only at the first stage (Pre-HD vs Post-HD:  $-14\%$ ;  $p < 0.05$ ) and at the end of recovery period of physical test (Pre-HD vs Post-HD:  $-18\%$ ;  $p < 0.05$ ; Fig. 2).

A hypotension effect of HD in the patients was more evident in the diastolic blood pressure, where there was a reduction from the 5<sup>th</sup> to 9<sup>th</sup> min of physical test (Pre-HD vs Post-HD:  $-20\%$ ;  $p < 0.05$ ; Fig. 3). The peripheral oxygen saturation was not different between CRD patients (pre and post-HD) and control ones in the different phases of physical test, having a variation of approximately 97–99% (data is not shown here).



Values are means  $\pm$  SE; \*Significant difference compared to dialyzed and control group at  $p < 0.05$  (one-way analysis of variance)

Figure 2. Systolic blood pressure (SBP) during a protocol of exercise and recovery period (REC) before (pre-HD) and 24 hours after haemodialysis (post-HD) in hypertensive CRD patients ( $n = 7$ ) compared to healthy control non-dialyzed ( $n = 7$ )



Values are means  $\pm$  SE; \*Significant difference compared to dialyzed and control group at  $p < 0.05$  (one-way analysis of variance)

Figure 3. Diastolic blood pressure during a protocol of exercise and recovery period (REC) before (pre-HD) and 24 hours after haemodialysis (post-HD) in hypertensive CRD patients ( $n = 7$ ) compared to healthy control non-dialyzed ( $n = 7$ )

## Discussion

The investigators showed that training on non-dialysis days yielded significantly greater cardiorespiratory adaptations [8, 18]. In addition, patients engaged in the intradialytic training program significantly improved cardiorespiratory outcomes compared with non-exercising controls [18]. Mechanisms underlying this enhancement of dialysis adequacy likely include increased blood perfusion between the working muscle and bloodstream, thereby enabling more thorough removal of the damaging solutes through HD treatment [10].

The investigators concluded that it is difficult to persuade patients to maintain exercise programs on non-dialysis days [8, 18]. Therefore, exercising during HD is often recommended as a more feasible, convenient, and time-effective solution to promote exercise adherence [3, 8, 18].

Hypertension commonly occurs in the chronic renal patients. At the beginning of the haemodialysis treatment, approximately 80 to 90% of the patients are hypertensive and, after this initial period, around 60% still remain with elevated values of SBP and DBP [19]. In the hypertensive patients, the aerobic exercise has been utilized as complementary to the treatment of hypertensive status, aimed at (treatment for a disease, which is not the case, we presume) reduction in tensioinal levels. However, so far the chronic [6, 13] or acute effect of exercise 24 hours after dialysis on blood pressure levels have been studied a little.

Anderson et al. [6] investigated the effect of an exercise program on blood pressure in renal patients during the third and sixth month of HD. The results showed a significant reduction in SBP ( $138.4 \pm 19.6$  mm Hg to  $125.7 \pm 20$  mm Hg;  $p < 0.05$ ) and DBP ( $83.2 \pm 10.2$  mm Hg to  $74.7 \pm 9$  mm Hg;  $p < 0.05$ ).

In previous studies, it was recommended to do exercise only in the first two hours after the HD procedure, in order to avoid cardiovascular instability with fall in blood pressure after this phase [20]. On the other hand, in present study, we investigated the acute cardiovascular alterations in hypertensive renal patients during exercise with constant load (75% of HR<sub>max</sub>) for 24 h after HD. In this period of 24 h after HD there was observed a reduction in systolic ( $-14\%$ ;  $p < 0.05$ ) and principally in diastolic blood pressure ( $-20\%$  stages;  $p < 0.05$ ) only during exercise execution, but not at rest. Other studies have shown a blood pressure reduction only in rest situation after an exercise program [6, 13]. The DBP reduction during predominant aerobic exercise (constant load) executed after HD occurs probably as a function of enhancement in blood perfusion

or lower in sympathetic tonus in this interdialytic period. The hypotension effect observed 24 hours after HD in our study did not induce significant alterations in health markers (HR; SpO<sub>2</sub> and VO<sub>2max</sub>) and perceived exertion ratings (Borg scale) during exercise.

## Conclusions

In summary, the present study showed a significant hypotension effect during the exercise realization observed principally in DBP 24 hours after HD treatment in chronic renal patients. These patients have been recommended to do the exercise during HD and only for the first two hours after HD in order to avoid cardiovascular complications and enhanced clinical indicators. In the present study, we showed a little reduction in DBP 24 hours after HD only during exercise, which did not represent deleterious effect on health in the period of 24 hours after HD and can enhance performance indicators and better tolerance to exercise in the hypertensive and renal patients.

## References

- Office of the US Surgeon General: Physical Activity and Health: A Report of the Surgeon General, Washington, DC, US Department of Health and Human Services, National Center for Chronic Disease Prevention and Health Promotion, 1996.
- Willey K.A., Singh M.A., Battling insulin resistance in elderly obese people with type 2 diabetes: Bring on the heavy weights. *Diabetes Care*, 2003, 26, 1580–1588. doi:10.2337/diacare.26.5.1580.
- US Renal Data System: USRDS 2006 Annual Data Report: Atlas of End-Stage Renal Disease in the United States, Bethesda, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2006.
- Johansen K.L., Chertow G.M., Ng A.V., Mulligan K., Carey S., Schoenfeld P.Y., Kent-Braun J.A., Physical activity levels in patients on hemodialysis and healthy sedentary controls. *Kidney Int*, 2000, 57, 2564–2570. doi:10.1046/j.1523-1755.2000.00116.x.
- Johansen K.L., Sakkas G.K., Doyle J., Shubert T., Dudley R.A.: Exercise counseling practices among nephrologists caring for patients on dialysis. *Am J Kidney Dis*, 2003, 41, 171–178. doi:10.1053/ajkd.2003.50001.
- Anderson J.E., Boivin Jr. M.R., Hatchett L., Effect of exercise training on interdialytic ambulatory and treatment-related blood pressure in hemodialysis patients. *Ren Fail*, 2004, 26, 539–544. doi:10.1081/JDI-200031735.
- Daul A., Schafers R., Daul K., Philipp T., Exercise during hemodialysis. *Clin Nephrol*, 2004, 61 (suppl. 1), S26–S30.
- Kouidi E., Grekas D., Deligiannis A., Tourkantonis A., Outcomes of long-term exercise training in dialysis patients: Comparison of two training programs. *Clin Nephrol*, 2004, 61 (suppl. 1), S31–S38.
- Vaithilingham I., Polkinghorne K., Atkins R., Kerr P., Time and exercise improve phosphate removal in hemodialysis patients. *Am J Kidney Dis*, 2004, 43, 85–89. doi:10.1053/j.ajkd.2003.09.016.
- Kong C., Tattersall J., Greenwood R., Farrington K., The effect of exercise during hemodialysis on solute removal. *Nephrol Dial Transplant*, 1999, 14, 2927–2931.
- Miller B., Cress C., Johnson M., Nichols D., Schnitzler M., Exercise during hemodialysis decreases the use of antihypertensive medications. *Am J Kidney Dis*, 2002, 39, 828–833. doi:10.1053/ajkd.2002.32004.
- Mustata S., Chan C., Lai L., Miller J., Impact of an exercise program on arterial stiffness and insulin resistance in hemodialysis patients. *J Am Soc Nephrol*, 2004, 15, 2713–2718. doi:10.1097/01 ASN.0000140256.21892.89.
- Deligiannis A., Kouidi E., Tassoulas E., Gigis P., Tourkantonis A., Coats A., Cardiac effects of exercise rehabilitation in hemodialysis patients. *Int J Cardiol*, 1999, 70, 253–266. doi:10.1016/S0167-5273(99)00090-X.
- Astrand P.O., Rodahl K., Evaluation of physical performance on the basis of tests. In: Provenzano M.D. (ed.), Textbook of work physiology. Physiological basis of exercise. McGraw-Hill, New York 1986, 354–390.
- Borg G., Noble B.J., Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*, 1982, 14 (5), 377–381.
- Goldenfarb P.B., Bowyer F.P., Hall E., Brosious E., Reproducibility in the hematology laboratory: the microhematocrit determination. *Amer J Clin Path*, 1971, 56, 35–39.
- Collier H.B., The standardization of blood haemoglobin determinations. *Can Med Ass J*, 1944, 50, 550–552.
- Konstantinidou E., Koukovou G., Kouidi E., Deligiannis A., Tourkantonis A., Exercise training in patients with end-stage renal disease on hemodialysis: Comparison of three rehabilitation programs. *J Rehabil Med*, 2002, 34, 40–45. doi:10.1080/165019702317242695.
- Mailloux L.U., Haley W.E., Hypertension in the ESRD patient: pathophysiology, therapy, outcomes, and future directions. *Am J Kidney Dis*, 1998, 32, 705–719.
- Moore G.E., Painter P., Brinker K.R., Stray-Gundersen J., Mitchell J.H., Cardiovascular response to submaximal stationary cycling during hemodialysis. *Am J Kidney Dis*, 1998, 31, 631–637. doi:10.1053/ajkd.1998.v31.pm9531179.

Paper received by the Editors: June 1, 2009.

Paper accepted for publication: February 3, 2010.

### *Address for correspondence*

Carlos Ricardo Maneck Malfatti, PhD  
Department of Physical Education  
State University of Center-West  
Riozinho, 153; Km 7, 84500-000; Irati, PR, Brazil  
e-mail: crmalfatti@gmail.com



# EFFECTS OF DIFFERENT INTENSITIES OF FLEXIBILITY TRAINING ON EXPLOSIVE FORCE

doi:10.2478/v10038-010-0015-1

**LEONARDO ANTÔNIO DOS SANTOS GALDINO<sup>1\*</sup>, CARLOS JOSÉ NOGUEIRA<sup>1</sup>,  
ELOÍSA COSTA E SILVA GALDINO<sup>2</sup>, JORGE ROBERTO PERROUT DE LIMA<sup>3</sup>,  
RODRIGO GOMES DE SOUZA VALE<sup>1</sup>, ESTÉLIO HENRIQUE MARTIN DANTAS<sup>1,4</sup>**

<sup>1</sup> Human Motricity Biosciences Laboratory (LABIMH), Federal University of Rio de Janeiro (UNIRIO), Brazil

<sup>2</sup> Salgado de Oliveira University (UNIVERSO), MG, Brazil

<sup>3</sup> Faculty of Physical Education and Sports (UFJF), MG, Brazil

<sup>4</sup> Invited Research of Laboratory of Physical Activity and Health, University of Valencia, Spain

## ABSTRACT

**Purpose.** To verify whether there are changes in the performance levels of the explosive force when the same muscle group previously underwent different intensities of flexibility training (stretch & flex). **Basic procedures.** The tests were performed with 25 females on three consecutive days and were preceded by a 10-minute warm-up period. First, each participant performed a maximum vertical jump on a contact platform. The jump was repeated after 10 minutes, and the first day was considered the control (C). On the second day, a routine of stretching exercises (S) was included, and on the third day, the same routine, but intensified with a maximum static stretching exercises (flexibilizing – F), was used. **Main findings.** The height reached in the control jump decreased by 0.17%, showing no influence on the performance when the jump happened on the same day, with a time-interval of only 10 minutes ( $p = 0.903$ ). On the day of the stretching routine, there was a reduction of 3.6% ( $p = 0.001$ ), and on the third day with flexibilizing, there was a 6.8% reduction ( $p = 0.001$ ). A comparison of the groups showed no significant differences between them. **Conclusions.** The jumps after the two stretching routines were significantly lower. Submaximal or maximal (flexibilizing) stretching exercises reduced the explosive force of vertical jumps, although the differences between the training intensities were not significant.

**Key words:** flexibility, stretching, warm-up, vertical jump

## Introduction

Flexibility is an element of physical fitness, which particularly determines an individual's wholesomeness and independence [1]. Like other physical features, flexibility may be trained at submaximal intensity (stretching), performed within the normal range of motion and slightly forcing for 4 to 6 seconds, or at the maximal intensity (flexibilizing), performed with discomfort on the pain threshold for at least 10 to 15 seconds. In flexibility training, ballistic, proprioceptive neuromuscular facilitation (PNF), and static methods are traditionally used, with the latter having greater applicability [2].

Flexibility training has been used by athletes to prevent lesions and enhance athletic performance [2–4]. Nevertheless, its use in isolation as preparation for exercise is unlikely to prevent lesions and may even hamper performance in sports involving strength and power [5].

Static flexion prior to physical activity has been

shown to reduce force production and power output [6–9], inhibit dislocation speed [10]. Likewise, Bezerra et al. [11] have demonstrated that PNF exerts a negative acute influence on force resistance. On the other hand, there are investigations pointing to a favorable influence of stretching exercises on performance [3, 12, 13]. On the other hand, the results with constant training in sports without stretching also decrease maximal power output of lower extremities [14].

These results may be conflicting due to the lack of intensity standardization of flexibility training. Therefore, the aim of this study was to investigate changes in the performance levels of explosive force in young adult women when the same muscle group previously underwent flexibility exercises (stretch & flex) of different intensities.

## Material and methods

### Subjects

Twenty-five active in strength training adult women (aged  $28.2 \pm 3.5$  years; height  $162.2 \pm 1.4$  cm; body

\* Corresponding author.

mass  $56.9 \pm 1.1$  kg) volunteered for the study. The inclusion criteria were the absence of lesions and the ability to perform vertical jumps and flexibility exercises. All the participants had in their physical exercises programs, besides those for strength and cardiorespiratory resistance, one section that dealt with stretching, being performed at least three times a week. The participants were instructed to avoid intense physical activity 48 hours before each training session. Their flexibilities were assessed with a  $360^\circ$  steel goniometer (Cardiomod, Brazil) to ensure they had a healthy range of motion for hip joint extension (HE) and flexion (HF).

The volunteers signed an informed consent form according to both the 196/96 resolution of the Brazilian National Health Council and the 1975 Helsinki Declaration. The study was approved by the Ethics Committee of the Castelo Branco University (UCB/RJ), under the 0004/2008 protocol.

#### Procedure

The tests, preceded by a 10-minute warm-up in a stationary cycloergometer (Movement Summer G2, Brazil), were intended to make the subjects reach a heart rate which was 60% of the age-adjusted maximal heart rate (MHR) [15]; these tests were performed on three consecutive days. On the first day, the participants performed a maximum vertical jump (start jump), with the highest three results recorded. This was repeated after a 10-minute interval, without any training routine. This was the control (C). On the second day, a routine of submaximal stretching exercises (S) for 10 minutes was added. The same routine was repeated on the third day, but this time with intensity variation and the use of maximum static force (flexibilizing – F); this was performed with the same duration as in the previous two days. Figure 1 shows the procedures performed on the three days.

Jump heights were measured on a contact platform (Jump Test Pro, Ergojump, Brazil), and the counter-movement jump (CMJ) technique was used. According to this technique, the preparatory movement for the jump is one in which the start position is standing with the hands fixed on the waist and the feet as wide apart as the shoulders and parallel to each other. The hip, knee, and ankle joints are then flexed before the actual jump is performed.

During the stretching routine (S), the movements were slowly performed until the normal limit of the range of motion was reached, and then this position was sustained for 10 seconds. A manual tonometer

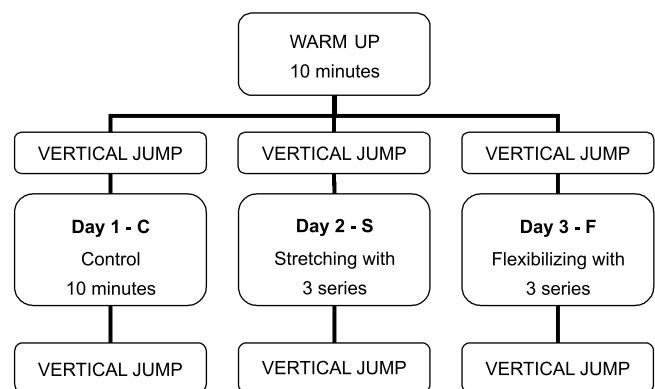


Figure 1. Diagram of test routines

(muscle test system – model 01163, Lafayette, LA, USA) was used to measure the pressure over the flexed body segment, with the device placed on the distal end of the limb being assessed and the reading obtained in the 10<sup>th</sup> second of posture adoption.

The movements performed were supine hip flexion with extended knee (HF); supine ankle dorsiflexion (DF); and prone knee flexion.

For the flexibilizing routine (F), the same movements were performed with greater pressure, i.e., greater intensity. Table 1 illustrates the pressures recorded for the two routines, along with the differences between them in percentages.

Table 1. Force used in the flexibility exercises routine

Flexion movements	Stretching (kgf)		Flexibilizing (kgf)		Delta %
	Mean	SD	Mean	SD	
Hip	4.28	1.33	7.25	1.24	69
Ankle	7.01	3.17	14.77	4.56	110
Knee	9.56	3.94	15.19	4.34	59

#### Statistical analysis

The SPSS 14.0 for Windows and Statistica packages were used for the calculation of the means and standard deviations. For data normality verification, the Shapiro-Wilk and Levene tests were used, with the following *p* values showing homogeneity of the collected data: C1 = 0.986; C2 = 0.442; S1 = 0.303; S2 = 0.552; F1 = 0.849; and F2 = 0.448.

For inferential statistics, a paired t-test for intra-group comparison was used. A 3x2 ANOVA and repeated measures ANOVA with two factors (routine × pre-post) were applied, followed by Tukey's post hoc test for inter-group comparison. To compare the per-

centage and absolute differences and the ratio index\*, a one-way ANOVA was used. Statistical significance was considered at  $p < 0.05$ .

## Results

Goniometry results ( $102.5 \pm 15.4^\circ$  for hip flexion, and  $44 \pm 11.4^\circ$  for hip extension) indicated that the participants were within the standard mean range according to the Academy of Orthopedic Surgeons, Kendall & McCreary, Hoppenfeld, and the American Medical Association.

The exercise intensity was significantly different between the stretching and the flexibilizing, which raises the possibility of an intensity change in the case of flexibility training.

The height reached in the control jump was  $23.4 \pm 4.3$  cm for C1 and  $23.3 \pm 3.5$  cm for C2; this indicates an absence of influence on the performance when the jumps were performed on the same day with a 10-minute interval only ( $p = 0.903$ ). On the day of the stretching routine, the results were:  $24.3 \pm 3.7$  cm for S1 and  $23.4 \pm 3.8$  cm for S2 ( $p = 0.001$ ). On the third day, which was reserved for greater intensity of the flexibility exercise (flexibilizing), the results were:  $24.3 \pm 4.1$  cm for F1 and  $22.6 \pm 3.8$  cm for F2 ( $p = 0.001$ ). Figure 2 shows these results. The jumps performed after the two flexibility routines were significantly lower. In comparison between the groups, there were no significant differences.

The relative difference ( $p = 0.001$ ), the absolute difference ( $p = 0.003$ ), and the ratio index (0.002) were all statistically significant according to the one-way ANOVA. Tukey's post hoc analysis showed that the percentage difference was only significant when the control (C) and flexibilizing (F) groups were compared ( $p = 0.001$ ). The same was found for the absolute difference ( $p = 0.002$ ) and for the ratio index ( $p = 0.001$ ).

## Discussion

This study was undertaken to compare the effect of two routines of flexibility exercises on the performance of the vertical jump, with the application of two distinct intensities. The differences were verified and a  $p < 0.05$

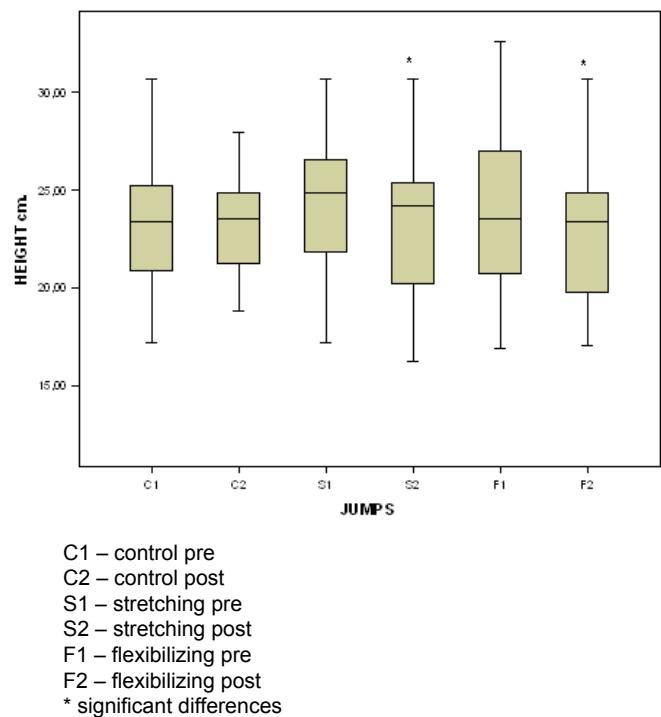


Figure 2. Comparison between the height reached in the vertical jumps, before and after control jumps, and the two routines of flexibility exercises

was found for the three movements applied. Because quantification of the intensity of flexibility exercises was feasible, the method may be useful for standardization in future experiments.

The reductions found in the performance of vertical jumps after the two flexibility routines were not significant. This is in agreement with other studies, which also indicated a non-significant fall in the heights of vertical jumps as a result of lower limb stretching [16, 17].

Cramer et al. [18] investigated the effects of static stretching at the peak of concentric and isokinetic torque, with leg extension at  $60^\circ$  and  $240^\circ/\text{s}$ , in the stretching limb (dominant) and relaxing limb (non-dominant) of 14 recreationally active women. These authors also noticed a non-significant reduction of the peak torque in both limbs and at both speeds ( $60^\circ$  and  $240^\circ/\text{s}$ ) using 4 series and with the posture sustained for 30 seconds. Although there was force reduction, this was not significant, even with the intensity increase. In our experiments the posture was sustained for 10 seconds only; maybe this fact has made the difference in results.

Likewise, Giordano et al. [19] investigated the difference between a Proprioceptive Neuromuscular Facilitation (PNF) routine and a warm-up that did not involve flexibility in eight American football players (age range 18–20 years); they did not find any significant

\* It is a mathematical form of normalization in which the value of the post-test is divided into the pre-test value, and when this value is superior to 1 it means that the post-test was greater than the pre-test, and vice-versa.

difference between the performance of vertical jumps. The motor action was the same as in the present study. Likewise, Little and Williams [16] did not find any significant reduction in the countermovement vertical jump when they investigated the acute effects of static and dynamic stretching as a warm-up prior to power and agility activities in 18 soccer players, with the posture sustained for 30 seconds for each flexion.

Our results are in agreement with those of Young and Elliot [20], who compared the acute effects of static stretching, PNF, and maximum isometric contraction on the production of explosive force and vertical jump in 14 men. These authors noticed a significant reduction of the jump with a fall after static stretching compared with the other conditions, even involving athletes who were accustomed to sports involving jumps. These findings may be due to a more intense training method, the PNF. Conversely, Bradley et al. [21] compared the acute effects of static stretching, ballistic stretching and PNF on the vertical jump performance of 18 male undergraduates and determined that the duration of this effect was up to 60 minutes, using 5 exercises in 4 series with the posture maintained for 30 seconds; they found only a 5% reduction after static stretching and PNF.

It is noteworthy that studies like ours have involved moderate routines of static stretching prior to the performance of vertical jumps, and no significant changes in the values of the vertical jumps were found [6, 22].

The method used in this study showed that stretching exercises may be applied at different intensities, thus being amenable to individualization according to each training type and even having the potential of being used (in a modified way) on competition days. The force applied on the stretched limb does not seem to be the most important factor in intensity change. Thus, a limitation of this study, the variation in the number of series or the time the limb is sustained in each position, may also be of interest.

## Conclusions

Stretching exercises at submaximal and maximum (flexibilizing) levels reduced the explosive force of vertical jumps, although the difference between the intensities was not significant when the intensities were compared. However, the difference was significant when flexibilizing (F) in isolation was considered. In comparison between the groups, there were no significant differences. Professional coaches involved in flexibility training should be cautious when applying a maximum or submaximal stretching routine for their athletes or students.

It was noted that the influence of the methods of flexibility training conducted immediately before the commencement of physical activities and competitions are controversial in relation to its effects. With a need for research into different methods and different volumes and intensities and studies with biochemical interventions, as well as longer sustaining times in each position, are warranted.

## References

- Nowak P.F., Ignasiak Z., The state of health of women aged 20–59 at different levels of physical activity. *Hum Mov*, 2008, 9 (1), 27–33. doi:10.2478/v10038-008-0005-8.
- Gremion G., The effect of stretching on sports performance and the risk of sports injury: A review of the literature. *Schweiz Z Med Traumatol*, 2005, 53 (1), 6–10.
- Andersen J.C., Stretching before and after exercise: effect on muscle soreness and injury risk. *J Athl Train*, 2005, 40 (3), 218–220.
- Yamaguchi T., Ishii K., Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. *J Strength Cond Res*, 2005, 19 (3), 677–683.
- Shrier I., When and whom to stretch? Gauging the benefits and drawbacks for individual patients. *Phys Sportsmed*, 2005, 33 (3), 22–26. doi:10.3810/psm.2005.03.61.
- Power K., Behm D., Cahill F., Carroll M., Young W., An acute bout of static stretching: Effects on force and jumping performance. *Med Sci Sports Exerc*, 2004, 36 (8), 1389–1396.
- Marek S.M., Cramer J.T., Fincher A.L., Massey L.L., Dangelmaier S.M., Purkayastha S. et al., Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *J Athl Train*, 2005, 40 (2), 94–103.
- Nelson A.G., Driscoll N.M., Landim D.K., Young M.A., Schexnayder I.C., Acute effects of passive muscle stretching on sprint performance. *J Sports Sci*, 2005, 23 (5), 449–454. doi: 10.1080/02640410410001730205.
- Galdino L.A.S., Nogueira C.J., César E.P., Fortes M.E.P., Perrout J.R., Dantas E.H.M., Comparison between lower limbs power strength levels before and after passive flexibilizing. *Fit Perf J*, 2005, 4 (1), 11–15.
- Siatras T., Papadopoulos D.M., Gerodimos V., Kellis S., Static and dynamic acute stretching effect on gymnast speed in vaulting. *Pediatr Exerc Sci*, 2003, 15, 383–391.
- Bezerra J.A., Castro A.N.S., Jácome J.G., Castro A.C.M., e Dantas E.H.M., Acute effect of flexibilizing by proprioceptive neuromuscular facilitation on strength endurance. *Fiep Bulletin*, 2008, 78, Special Edition. Available form [http://www.fiepbulletin.net/index.asp?a=trabalho\\_1er.asp&id=79&ido=e&full=s#ler](http://www.fiepbulletin.net/index.asp?a=trabalho_1er.asp&id=79&ido=e&full=s#ler) in 22/06/09.
- Church J.B., Wiggins M.S., Moode F.M., Crist R., Effect of warm-up and flexibility treatments on vertical jump performance. *J Strength Cond Res*, 2001, 15, 332–336.
- Behm D.G., Bamby A., Cahill F., Power K., Effect of acute static stretching on force, balance, reaction time, and movement time. *Med Sci Sports Exerc*, 2004, 36 (8), 1397–1402.
- Buško K., Nowak A., Changes of maximal muscle torque and maximal power output of lower extremities in male judoists during training. *Hum Mov*, 2008, 9 (2), 111–115. doi:10.2478/v10038-008-0013-8.
- Tanaka H., Monahan K.D., Seals D.R., Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*, 2001, 371 (1), 153–156.

16. Little T., Williams A.G., Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *J Strength Cond Res*, 2006, 21, 203–207.
17. Unick J., Kieffer H.S., Cheesman W., Feeney A., The acute effects of static and ballistic stretching on vertical jump performance in trained women. *J Strength Cond Res*, 2005, 19 (1), 206–212.
18. Cramer J.T., Housh T.J., Coburn J.W., Beck T.W., Johnson G.O., Acute effects of static stretching on maximal eccentric torque production in women. *J Strength Cond Res*, 2006, 20, 354–358.
19. Giordano N.C., Sikora D., Jones A., PNF Stretching and its effects on maximal exertion exercises. *J Undergrad Kinesiol Res*, 2005, 1 (1), 16–22.
20. Young W., Elliot S., Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jumping performance. *Res Q Exerc Sport*, 2001, 72 (3), 273–279.
21. Bradley P.S., Olsen P.D., Portas M.D., The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *J Strength Cond Res*, 2007, 21, 223–226.
22. Woolstenhulme M.T., Griffiths C.M., Woolstenhulme E.M., Parcell A.C., Ballistic stretching increases flexibility and acute vertical jump height combined with basketball activity. *J Strength Cond Res*, 2006, 20, 799–803.

Paper received by the Editors: September 21, 2009.  
Paper accepted for publication: April 12, 2010.

*Address for correspondence*

Leonardo Antônio dos Santos Galdino  
Rua Geraldo Galdino Vitalino, 40  
Graminha, Cep 36240-000  
Santos Dumont, Minas Gerais, Brazil

e-mail: [lasgaldino@yahoo.com.br](mailto:lasgaldino@yahoo.com.br)



# THE EFFECTS OF 12-WEEK AEROBIC EXERCISES ON RATE OF MENTAL HEALTH IN MALE STUDENTS OF AHVAZ PAYAM NOOR UNIVERSITY

doi:10.2478/v10038-010-0021-3

**MOHAMMAD HASSAN FERDOWSI<sup>1\*</sup>, FATEME MARASHIAN<sup>2</sup>, SEYED HUSSEIN MARASHIAN<sup>3</sup>**

<sup>1</sup> Payam Noor University (PNU), Iran

<sup>2</sup> Islamic Azad University of Iran, Ahvaz, Iran

<sup>3</sup> Shahid Chamran University, Ahvaz, Iran

## ABSTRACT

**Purpose.** The purpose of this study was to investigate the effects of 12-week aerobic exercises on self-esteem, social desirability and rate of mental health in male students of Payam Noor University (PNU). **Basic procedures.** For this reason we used male college students ( $n = 80$ , age =  $22 \pm 2.1$ ) who did not do any sport. They were randomly assigned to experimental ( $n = 40$ ) and control ( $n = 40$ ) groups, after having been selected via stratified random sampling among students of Ahvaz Payam Noor University. Also, to collect data there were implemented the *Cooper test* and the general health questionnaire of Goldberg (GHQ) and social desirability questionnaire of *Crowne-Marlowe*. **Main findings.** Statistical analysis showed that training like aerobic exercises is related to a significant improvement in mental health, self-esteem and social desirability because of favorable changes in some of physiological and psychological parameters. **Conclusions.** This study was of a semi-experimental type (pre-test, post-test). Data analyzed by Multivariate Analysis Of Variance (MANOVA) at  $p$  value ( $p = 0.05$ ) revealed that there were significant differences between experimental group and control group, in mental health, self-esteem and social desirability.

**Key words:** aerobic exercises, self-esteem, social desirability, mental health

## Introduction

Human is a social being and he/she knows his/her value in society but sometimes his/her life and social problems can endanger his/her mental health [1]. Though medical treatments are useful in curing these disorders, also sports activities can be one of the main elements of the treatment. The physiological effect of major exercises (aerobic and non-aerobic) is improving the body form and enhancing the breathing efficiency [2]. Aerobic exercise, which belongs to the long term sport activities, needs oxygen for performance [3]. This kind of exercise activates the systems which provide oxygen to all the cells in the organism, and in this way active muscles receive the oxygen through blood circulation. To establish this kind of aerobic metabolism, the intensity of training should be low, while duration of training should be long [4].

People having a good mental health, have good social relations and relatively healthy lives. Mental health is necessary for happiness and for a quiet life, away from disorders; it helps persons to mix socially with others more easily. However, these social interactions usually

breed some conflicts, in many cases these conflicts will threaten the person's mental health so sometimes will produce disorders in the person, such as depression, anxiety and a feeling of social insufficiency [5].

Sports activities, such as aerobic exercises, not only improve the person's physical health, but will affect the mental one. Since physical and mental states are generally related to each other, physical abilities reduction causes a fall in self-esteem sense, which means the person believes in the set of abilities, competence and characteristics of his/her own [6]. With regard to sports activities, they increase self-confidence, efficiency, competence and self-esteem, so they will have considerable influence on optimal performance, educational health, social and psychological health. Therefore, one of the research hypotheses is that a 12-week aerobic training leads to enhancement of the self-esteem in male students. Moreover, sports activities evoke enhancement of the lust for life, improvement in personal and social lives and mental hygiene [7].

Since the person's body determines his appearance and this influence can cause changes in the way one is understood and treated by others, it also has an effect on the person's image of himself. This effect, either of negative or positive direction, causes acceptance, more or less, of himself when his welfare, social desirability and mental health change. Therefore, another research

\* Corresponding author.

hypothesis is that a 12-week aerobic training leads to enhancement of the social desirability and mental health in male students. Social desirability refers to the capacity and ability to accept and bear polarities (bias), conflict opinions and then coordinate your opinions with others'. Social desirability is the resultant of several factors in social psychology such as social influence, social judgment, concerting with others and people's standpoint.

Social desirability forced people to change their behavior according to the society's requirements (conditions) until they were accepted by the society, even if they do not agree with these changes.

Since going in for sport is one of the best and most effective methods to decrease the psychological problems, and it is also closely related to psychological characteristics of an individual, in this study we investigated whether a 12-week aerobic training affects the rates of self-esteem, social desirability and mental health in male students of Payam Noor University (PNU).

## Material and methods

All participants in this research were students of Payam Noor University in Ahvaz city in the year 2008. 80 male students who had no regular exercise for at least 2 months were selected to this study. The subjects were selected as random sampling, then divided into two groups (experimental group  $n = 40$ ; and control group  $n = 40$ ). Having been familiarized with the exercise procedure, all subjects (control and experimental groups) were asked to do a performance test (pre-test), and then the experimental group followed the aerobic exercise program for 12 weeks – 3 sessions in a week and each session lasted 40 minutes.

After four weeks and having establishing a relative adaptation of the subjects to physical activity, the exercise intensity was increased. The protocol of an aerobic practice session was as follows:

1. Warm-up (7 minutes).

2. Original (initial) activity.

A: The subjects run for 10 minutes with 65% of maximal heart rate.

B: Rest (5 minutes) while walking and jogging.

C: The subjects run for 8 to 12 minutes with 65% of maximal heart rate, again.

D: Active rest (3 minutes).

3. Cool-down (5 minutes).

In this study we used the Cooper Smith scale of self-esteem to measure the rate of self-esteem. This scale, contains 58 questions and it is as self-report pencil-paper where question numbers: 6, 20, 13, 27, 34, 41, 48

and 55 are a polygraph test. The reliability coefficient was obtained by associating the scores with the criterion questions, whereas the gained validity coefficient was 39%, which was significant ( $p < 0.05$ ). Also the calculated reliability coefficients by Cronbach's alpha and split-half methods were respectively 0.87 and 0.77.

To evaluate the social desirability we used the Crowne-Marlowe scale. In this scale subjects had to answer: true or false (Ratus scale). To calculate the validity of this scale we used Cronbach's alpha and split-half methods; the coefficients were 0/83 and 0/64, respectively, and were acceptable. To measure the level of mental health we used general questionnaire (GHQ) – a 28-question form. This questionnaire designed by Goldberg and Hiller has been translated into different languages so far.

In the current study, the validity coefficient of this questionnaire which was found by associating Cronbach's alpha method with SCL-90 test was 0.84 and also the reliability coefficients were 0.97 and 0.93.

## Results

Descriptive findings in this study included the statistics indexes such as average, standard deviation, minimum and maximum score. All of them are shown in Tables 1, 2 and 3.

As the data in Tables 1 and 2 show, the averages of self-esteem and social desirability increased after exposure to the independent variable (aerobic exercise).

We need to explain that a small difference in the experimental group compared to the control group indicates an increase in self-esteem and social desirability. **The lower the score, the higher the value of the test variable.**

Table 3 shows average, standard deviation, minimum and maximum scores (experimental and control groups) before and after aerobic exercises. As Table 3

Table 1. Scores of self-esteem in experimental and control groups

Variable	Stage	Group	Statistical indexes				
			Mean	SD	Min	Max	n
Self-esteem	Pre-test	Experimental	31.25	13.41	10	48	40
		Control	23.12	13.97	5	48	40
Post-test	Experimental		42.30	16.97	0	48	40
		Control	22.68	13.54	5	46	40
Difference	Experimental		-11.05	18.61	0	36	40
		Control	0.44	9.01	-16	20	40

Table 2. Scores of social-desirability in experimental and control groups

Variable	Stage	Group	Statistical indexes				
			Mean	SD	Min	Max	n
Social-desirability	Pre-test	Experimental	19.12	4.45	9	29	40
		Control	16.10	3.96	5	10	40
Post-test		Experimental	20.88	6.71	13	28	40
		Control	15.61	3.49	5	10	40
Difference		Experimental	-1.76	7.61	0	8	40
		Control	0.49	4.01	-14	2	40

Table 3. Scores of mental health in experimental and control groups

Variable	Stage	Group	Statistical indexes				
			Mean	SD	Min	Max	n
Mental health	Pre-test	Experimental	36.30	11.44	10	56	40
		Control	23.12	11.96	5	56	40
Post-test		Experimental	16.82	18.93	0	54	40
		Control	26.68	11.49	5	52	40
Difference		Experimental	19.48	16.61	0	46	40
		Control	-3.56	6.01	-17	20	40

shows, the value of the mental health in experimental group decreased, which indicates an improvement in mental health. We need to explain that high score in the experimental group compared to the control group indicates that some problems of mental health have decreased. **The higher the score, the lower the value of the test variable**

Statistical analysis was conducted using SPSS version 12.0 for Windows. The data were analyzed by multiple comparison tests (MANOVA) and the results are shown in Tables 4 to 6.

As Table 4 indicates there is a significant difference between the experimental and control groups in self-esteem ( $F = 122.80, p = 0.0001$ ), mental health ( $F = 94.82, p = 0.0001$ ) and social desirability ( $F = 122.80, p = 0.0001$ ).

In other words, aerobic exercises in both groups lead to an improvement in self-esteem, social desirability and mental health.

As Tables 6 and 7 indicate there is a significant difference between the experimental and control groups in mental health variables (including physical syndromes, anxiety, depression and disorder in social performance). In other words, aerobic exercises will cause a decrease in physical syndromes, anxiety, depression and also in disorders of social performance.

Table 4. MANOVA on difference in self-esteem, social desirability and mental health

Test name	Value	Approx. F	Significance
Pillai	0.982	74.25	0.0001
Walk's lam	0.347	74.25	0.0001
Hotelling	2.59	74.25	0.0001
Roy's	3.28	74.25	0.0001

Table 5. The results of effects between subjects

Variables	Sum of squares	Mean square	F	Significance
Self-esteem	1426.03	1426.03	93.86	0.0001
Social desirability	1298.26	1298.26	122.80	0.0001
Mental health	1327.04	1327.04	94.82	0.0001

Table 6. MANOVA on difference in variables of mental health

Test name	Value	Approx. F	Significance
Pillai	0.483	25.48	0.0001
Walk's lam	0.517	25.48	0.0001
Hotelling	0.934	25.48	0.0001
Roy's	0.934	25.48	0.0001

Table 7. The results of effects between subjects

Group	Mean	Variables	Sum of squares	Mean square	F	Significance
Exper	5.44	Physical syndrome	734.57	734.57	74.42	0.0001
Con	-1.18					
Exper	4.98	Anxiety	810.83	810.83	70.41	0.0001
Con	-0.82					
Exper	4.10	Disorder in social performance	951.92	951.92	86.03	0.0001
Con	-1.23					
Exper	6.02	Depression	698.16	698.16	61.15	0.0001
Con	-0.71					

## Discussion

The investigation studied the effect of 12-week aerobic and resistance exercises on the improvement of mental health. The results showed that in comparison with the control group, after 12 weeks the control group showed a significant improvement in mental health, vitality, public health (general health), the level of physical pain, general body function, depression, physical stress and social desirability [8].

Dehart et al. [9] in their study found some relations between the self-esteem and sports performance. As was predicted there is a relationship between a higher

self-esteem and a better sports performance. Higher self-esteem, social desirability and the better sport performance are related with the higher positions as well as more money (wealth) and a lower level of job stress, also an athlete with high self-esteem used a little bit information for negative performances in the past.

In the research done by Dishman et al. [10], the issue analyzed was whether there is a relationship between physical activities, imaging of oneself and self-esteem and signs of depression or even its permanent state in the population of 1250 girls in the 12<sup>th</sup> grade school (average age 15.6 years). The results showed a strong and positive relationship between self-imaging, physical activities and self-esteem: moreover, they showed a significantly negative relationship between self-esteem and signs of depression.

In the research done by Jago et al. [11], it was shown that social desirability was related to the physical activity and aerobic exercises positively. Also there was significant and positive relation between sedentary lifestyle and negative self-conception.

Klein and his colleagues [12] in their research, investigated 74 depressed patients for 12 weeks who were divided into three groups: track and field group, the medical treatment group and medicine group. The findings showed that physical exercises improved rates of mental health more efficiently than medical treatment and medicine. The researchers continued this study for at least 1 year.

Knechtle [13] in a research in mental patients reached the conclusion that endurance training like resistance training has an effect on improving public health (general health) and psychological comfort. In athletes and in patients with psychological problems, especially in depressed patients, the physical activity decreases symptoms of syndrome [13].

Atlantis et al. [8] in their work concluded that 12-week aerobic and weight trainings are useful to improve the mental health.

Guszkowska in her research [14], analyzed the effect of aerobic trainings on the above factors and concluded that aerobic trainings including jogging, swimming and running with the medium or high intensity for 15 to 30 minutes and 3 sessions in a week will lead to a decrease in depression, anxiety and an increase in self-esteem.

O'Connor et al. [15] found in one of their studies that physical activity, including aerobic exercises, is the best way to reduce depression and increase the social desirability. Van den Berg et al. [16] dealt with two groups, control and experimental, of respectively 16 and 18 men. They came to the conclusion that a three-month aerobic training led to better quality of social

life and more active life in experimental group. Moreover, this group had more social desirability and more self-esteem.

## Conclusions

Based on the findings of this study, 12-week aerobic exercises will increase the self-esteem in male students. This result is consistent with the findings of Dishman et al. [10] Guszkowska [14], Van den Berg et al. [16].

To explain the findings of the present theory we can state that performing exercise such as aerobic exercises has an effect on a series of physical and psychological factors, and thus, results in an increase in people's self-satisfaction. Certainly, many of these variables, like the improvement in physical and psychological health, have a direct relation with self-esteem.

It seems that there is more self-consciousness along with the increasing self-esteem. Sport exercises give a sense of skill, ability and control that leads to an increase in the self-esteem in people. On the other hand, in the current study it was seen that 12-week aerobic exercises have increased the social desirability of male students. The results of this theory are consistent with the findings of Atlantis et al. [8], Jago et al. [11], O'Connor et al. [15], Van den Berg et al. [16].

Along with the increasing self-esteem, the person can express his thoughts and feelings straightforwardly and earn respect for himself, and on the other hand, he will respect desires and needs of others. Physical health as a result of exercises, following the mental health, gives a sense of self-efficiency and internal control to human (self-control) and also these feelings will strengthen the self-esteem and self-confidence in the mutual relations with others. As a result, the person will find really satisfactory interpersonal relations. When the person finds people who can satisfy his needs he will not close to others with fear of being hurt or controlled by others. Therefore, the person can find the ability to accept and to endure contrariness, unfavorable opinions, and consequently, will learn how to cope with others.

Also according to the findings of this research, it was clear that 12-week aerobic exercises lead to an improvement in the mental health and a decrease in all the values of its variables in male students. This result is consistent with Atlantis et al. [8], Klein et al. [12], Knechtle [13], Guszkowska [14].

Since positive mood is created by some of neurotransmitters such as dopamine and serotonin, it implies that the main reason for positive effects of sport training on mood is probably releasing endorphins through the

continuous efforts that produce a kind of elation, which is known as the “runner’s elation”. Para morphine and endorphin materials make athletes not feel the pain caused by injuries and fatigues, which occur while doing sport and who get confidence due to physical exercises. In fact, athletes will give wage from chemical created state. Another reason for positive mood in athletes is that there are social pleasant interactions in an environment of uniformity where people do physical activities and sport either individually or in a team.

Generally, we explained that sport and physical activity including aerobic exercises lead to higher self-confidence and more positive one’s body imaging. Probably, the main reason for the effect of physical exercises on mental health is the undeniable influence of attitudes and positions of people on the positive mood that is created by endorphins, social achievements and reduction in tension and depression.

## References

- Bellamy J.L., Behavioral problems following reunification of children in long term foster care. *Child Youth Serv Rev*, 2008, 30 (2), 216–228. doi:10.1016/j.childyouth.2007.09.008.
- Pelegrino N.R., Lucheta P.A., Sanchez F.F., Faganello M.M., Ferrari R., Godoy I., Influence of lean body mass on cardiopulmonary repercussions during the six-minute walk test in patients with COPD. *J Bras Pneumol*, 2009, 35 (1), 20–26. doi:10.1590/S1806-37132009000100004.
- Brosnahan J., Steffen L.M., Lytle L., Patterson J., Boostrom A., The relation between physical activity and mental health among Hispanic and non-Hispanic white adolescents. *Arch Pediatr Adolesc Med*, 2004, 158 (8), 818–823.
- Paluska S.A., Schwenk T.L., Physical activity and mental health current concepts. *Sport Med*, 2000, 29 (3), 167–180.
- McArdle W.D., Katch F.I., Katch V.L., Exercise physiology: energy, nutrition, and human performance. Lippincott Williams & Wilkins, USA 2006.
- Wilmore J.H., Costill D.L., Physiology of sport and exercise. 2<sup>nd</sup> ed. Human Kinetics, USA 1994.
- Hills P., Argyle M., Happiness, introversion-extraversion and happy introverts. *J Personality and Individual Differences*, 2001, 30 (4), 595–608. doi:10.1016/S0022-3651(00)00058-1.
- Atlantis E., Chow C.M., Kirby A., Fiatarone M., An effective exercise-based intervention for improving mental health and quality of life measures: a randomized controlled trial. *Prev Med*, 2004, 39 (2), 424–434. doi:10.1016/j.ypmed.2004.02.007.
- DeHart T., Pelham B.W., Fluctuations in state implicit self-esteem in response to daily negative events. *J Exp Soc Psychol*, 2006, 43 (1), 157–165. doi:10.1016/j.jesp.2006.01.002.
- Dishman R.K., Hales D.P., Pfeiffer K.A., Felton G., Saunders R., Physical self-concept and self-esteem mediate cross-sectional relations of physical activity and sport participation with depression symptoms among adolescent girls. *Health Psychol*, 2006, 25, 396–407.
- Jago R., Barnowski J.C., Barnowski T., Cullen K.W., Thompson D.I., Social desirability is associated with some physical activity, psychosocial variables and sedentary behavior but not self-reported physical activity among adolescent males. *Health Educ Res*, 2007, 22 (3), 438–449. doi:10.1093/her/cyl107.
- Klein M.H., Greist I.H., Gurtman A.S., A comparative outcome study of group psychotherapy vs exercise treatments for depression. *Int J Ment Health*, 1984–1985, 13 (3–4), 148–176.
- B. Knechtle, Influence of physical activity on mental well-being and psychiatric disorders [in German]. *Praxis*, 2004, 93 (35), 1403–1411. doi:10.1024/0369-8394.93.35.1403.
- Guszkowska M., Effect of exercise on anxiety, depression and mood [in Polish]. *Psychiatr Pol*, 2004, 38 (4), 611–620.
- O’Connor P.J., Raglin J.S., Martinsen E.W., Physical activity, anxiety and anxiety disorders. *Int J Sport Psychol*, 2000, 31, 136–155.
- Van den Berg E.R., Balk A., Bussmann H., Stam H., Does aerobic training lead to a more active lifestyle and improved quality of life in patients with chronic heart failure? *Eur J Heart Fail*, 2004, 6 (1), 95–100. doi:10.1016/j.ejheart.2003.10.005.

Paper received by the Editors: August 27, 2009.

Paper accepted for publication: May 19, 2010.

### Address for correspondence

Mohammad Hassan Ferdowsi  
Payam Noor University (PNU)  
Pardiss Boulevard, Ahvaz, Iran  
e-mail: mferdowsi1359@gmail.com



## BIOLOGICAL SYMPTOMS OF AGING IN WOMEN REGARDING PHYSICAL ACTIVITY AND LIFESTYLE

doi:10.2478/v10038-010-0023-1

**ALEKSANDRA STACHÓŃ\*, ANNA BURDUKIEWICZ, JADWIGA PIETRASZEWSKA,  
JUSTYNA ANDRZEJEWSKA, KRYSTYNA CHROMIK**

The Unit of Physical Anthropology, University School of Physical Education, Wrocław, Poland

### ABSTRACT

**Purpose.** Menopause in many women is related to worse health conditions, increased diseases incidence and body mass. The purpose of this research was to investigate whether the differentiation of the involutorial changes related to the climacteric period depends on women's physical activity and selected aspects of lifestyle. The following aging indices were analyzed: age of menopause, value of blood parameters, disease incidence, BMI. **Basic procedures.** The research, conducted in the health care units, was based on the survey approved by the Bioethical Committee at the Jagiellonian University. The data of 896 women above the age of 40 were used in the research. Basic statistics were calculated and tests of significance of differences and correlation were applied. **Main findings.** There is no significant relationship between the level of physical activity, the type of work performed and the age of menopause. However, women performing white-collar work and practicing sports enter menopause last. In smokers the age of menopause lowered. Women using vegetarian diets and women with high BMI values go through menopause later. High BMI values and nicotine addiction are significantly related to the increased level of blood sugar, diabetes incidence and high blood pressure. The cholesterol level is significantly related to the age of the subjects. The percentage of increased cholesterol level is smaller in women practicing sports who have also significantly lower BMI values than those who do not go in for any sports. **Conclusions.** The analysis of health and aging indices confirms the highest correlation between BMI and the external factors. Moreover, regarding the specificity of hormonal changes during climacterium, overweight and obese women go through menopause later.

**Key words:** aging, menopause, physical activity, lifestyle

### Introduction

Aging is a natural result of development and reached maturity. In recent years, due to the observed increase in life expectancy in modern societies the interest in the subject of late adulthood has increased. Many publications on aging indicate genetical and physiological conditioning of this phenomenon, yet they do not exclude the influence of general lifestyle frequently resulting from the educational level [1–3]. In various research on different aspects of aging, including the influence of external factors on the involutorial changes, ambiguities which raise questions can be observed. It means that the level of knowledge on aging processes is still insufficient.

Different assessment methods of the involutorial processes and the human's biological age can be distinguished (e.g. based on the osteological changes, the biochemical composition of cells, intensity of metabolism and many others). In women's case also age at menopause is thought to be a symptom of aging and health.

This research reveals that entering the menopause period is related to worse health conditions, increased incidence of vascular diseases, osteoporosis and body mass increment. Mondul et al. [4] report that menopause in older age is related to the increased risk of breast and uterine cervix cancer. On the other hand, it has been implied that women going through menopause earlier live shorter than those going through it later [5].

The purpose of this research was to investigate whether the differentiation of the involutorial changes related to the climacteric period depends on women's physical activity and selected aspects of lifestyle (type of work, nicotine addiction, diets). The analyzed aging and health indices were: age at menopause, values of physiological and biochemical parameters (blood glucose and total cholesterol, blood pressure), incidence of cardiovascular diseases and osteoporosis, body mass index (BMI) values.

The obtained results may be useful to create health oriented programs for women. The increased health care of mature women is more noticeable now, since a vast majority of Polish female population born in the post-war baby boom is currently passing this ontogenesis period. Moreover, due to the fast lifestyle and

\* Corresponding author.

women's prolonged social activity, this type of care is required.

## Material and methods

The research was based on the author's survey approved by the Jagiellonian University Bioethical Committee. Anonymous questionnaire was to be completed due to the personal specificity of some questions. The research carried out in the years 2005–2007 was conducted among women living in the southern provinces of Poland. Data was collected in the health care units during prophylactic cytological and mammographic screening. Women answered more than 40 questions concerning their social status, life style, reproductive period and health. The data of 896 women above the age of 40 were used in the analysis.

The age distribution in the sample varies from the Polish women's age structure based on demographic data of General Statistical Office [6]. Due to the research specificity and selected method most women in the course of the survey were 45–55. The numbers of women born in a big city, small town and in the country were approximately equal. However, while the research was being done, most women lived in big cities in the south of Poland – Wrocław, Katowice, Kraków, and Rzeszów. The subjects' education level and marital status were varied, but a vast majority of women were married.

In order to compare the results with those obtained in the national and international research, terminology related to the climacteric period was based on that commonly used and suggested by The World Health Organization [7, 8]. The categories of BMI were taken from the WHO guidelines [9], while glycemia and cholesterol threshold values and blood pressure derive from the national data [10].

Basic statistics were calculated. Tests of significance of differences and tests of correlation were applied. Statistica PL 7.0 and 8.0 were used for statistical calculations.

To confirm the hypothesis that climacteric period is related to the health deterioration, the results of two groups of women (before and after menopause) were compared. Mean values of menopausal age were computed on the basis of declared birth and last menstruation dates. Declared body mass and body height were used to calculate the mean BMI values.

The diversity of menopausal age and BMI values were examined by t-Student test (for the groups of equal and unequal variances), ANOVA, Scheffe's test and also multivariate tests.

Chi-squared test was applied to determine the correlation between the level of physiological and biochemical blood parameters and physical activity and other elements of lifestyle. Values of physiological parameters were categorized since few subjects knew the exact results of their research. However, most of them were able to determine whether their results were correct or not.

Due to the survey specificity, the reliability of the research was evaluated by the *test-retest* method [11]. This method is based on the research repetition with the time interval. Hence, the selected group of women filled in the questionnaire again. Its aim was to estimate the consistency of the given answers and their reliability. Based on the collected data the difference between the answers was determined. The significance of differences was examined by the usage of suitable statistical tests.

Due to women's reliable answers, it was observed that the first and second surveys tallied considerably with each other. The rate of memory mistake is not high and does not decrease the cognitive value of the research.

## Results

### A comparison of menstruating women with post-menopause women

To assess changes of women's body during climacterium, two groups of women: before and after menopause were compared. The difference in the mean age between the groups was obvious – post-menopause women were nearly 10 years older than menstruating women (Tab. 1).

In post-menopause women a greater number suffered from high blood pressure, elevated level of blood glucose and total cholesterol than in pre-menopause women (Tab. 1). Increased values of blood physiological

Table 1. Comparison of two groups of women:  
pre- and post-menopause

Characteristic	Percentages of women	
	pre-menopause	post-menopause
Hypertension	9.8%	29.3%
Increased blood cholesterol	27.6%	51.3%
Increased blood glucose	4.1%	10.6%
Cardiovascular diseases	17.7%	21.2%
Diabetes	2.5%	4.8%
Overweight/obesity	50.6%	61.8%
Osteoporosis	2.8%	13%
Bad self-rating of health	1.1%	4.8%
Mean		
Age of women	47.37 years	58.92 years
BMI	25.12 kg/m <sup>2</sup>	26.75 kg/m <sup>2</sup>

parameters in the post-menopause group of women, in comparison to those still menstruating, were connected with higher incidence of heart diseases, diabetes, osteoporosis, and occurrence of overweight and obesity among women (Tab. 1). As a consequence of deteriorating health conditions after menopause a greater number of women considering their health conditions as poor was observed among non-menstruating women (Tab. 1).

#### Age at menopause

Only women going through natural menopause were considered in the analysis of diversification of menopausal age (women undergoing supplementary hormonal therapy and those who went through artificial menopause were excluded), since the manner of retaining of ovarian function causes significant differences in the age of menopause [8, 12]. Mean age of natural menopause was approximately 50 years (Tab. 2).

The level of physical activity and the type of performed work were not significantly related to the age at menopause. However, it is worth indicating that women who are white-collar or freelance workers and those going in for sports enter menopause later (Tab. 3). After the analysis of all physical activities resulting from the type of job and sports done it was stated that women doing both white-collar work and sports went through menopause last.

Smoking cigarettes lowered the age of menopause in the subjects, while a vegetarian diet delayed climacterium (Tab. 3). In this case, the conclusions ought to be formed carefully since only few women admitted they were vegetarian. Women smoking over 20 cigarettes per day go through menopause first (48.4 years).

Table 2. Characteristics of menopausal age

Natural menopause	N	$\bar{x}$	SD	min	max
Basic statistics	247	50.2	3.44	40.20	58.94

It is surprising that women smoking for the longest period of time went through menopause later than those who smoked shorter (50.3 in comparison to 49.5 years).

Women's relative body mass is influenced by the lifestyle, diets and the level of physical activity. The higher body mass is related to the greater content of fat tissue, responsible for aromatization of sex hormones in the climacteric period and after menopause. The women examined showed a tendency to the increase of menopausal age with the growth of BMI values before menopause (Tab. 4).

Canonical analysis confirmed that none of the analyzed variables is significantly related to age at menopause ( $p = 0.940$ ).

#### Blood sugar level

High body mass index values of the subjects significantly increase the risk of hyperglycemia and diabetes (Tab. 5). Statistically significant relationship was observed between smoking cigarettes and blood sugar level ( $p = 0.0281$ ). A percentage of women with diabetes was lower among smoking than non-smoking women (2.6% and 5.2%, respectively). A low percentage of women with hyperglycemia and diabetes practised sport (8.3% in comparison to 16.8% among healthy women). No relationship between glycemia level and following low fat or vegetarian diets was observed (respectively  $p = 0.6003$ ;  $p = 0.7939$ ).

Table 3. Characteristics of menopausal age in relation to social features

Features	Menopausal age					
	N	$\bar{x}$	SD	min	max	Significance*
Type of job	manual	55	49.93	3.79	41.74	57.98
	white-collar	179	50.21	3.37	40.20	58.94
	self-employed	10	50.26	1.94	47.96	53.89
Sport	professional	8	50.82	1.99	48.41	54.00
	amateurish	35	50.68	3.49	40.36	58.94
	no	204	50.07	3.48	40.20	57.98
Smoking	yes	129	49.83	3.22	40.20	57.29
	no	118	50.57	3.64	40.45	58.94
Vegetarian diet	yes	8	51.58	2.88	48.41	56.50
	no	239	50.14	3.45	40.20	58.94
Slimming diet	yes	41	50.25	2.82	40.45	53.89
	no	198	50.18	3.49	40.20	57.98

\* t-Student test/ANOVA

Table 4. Characteristics of menopausal age in relation to BMI values ( $\text{kg}/\text{m}^2$ )

BMI	Menopausal age					
	N	$\bar{x}$	SD	min	max	ANOVA
18.50–24.99	52	49.7	3.15	43.16	58.94	
25.00–29.99	176	50.2	3.49	40.20	57.98	$p = 0.1450$
> 29.99	6	51.1	3.09	47.72	54.68	

Table 5. Characteristics of BMI ( $\text{kg}/\text{m}^2$ ) in relation to values of blood parameters

Blood parameters	BMI					
	N	$\bar{x}$	SD	min	max	Significance*
Glycemia	normal	405	26.3	4.43	17.99	44.95
	above normal	42	30.0	5.43	20.45	63.95
Cholesterolemia	below normal	13	26.8	3.11	20.43	30.85
	normal	246	26.7	4.93	19.00	63.95
Blood pressure	above normal	180	26.5	3.59	17.99	36.86
	normal	579	26.0	3.88	17.99	42.44
	hypertension	111	28.2	5.79	19.05	63.95

\* t-Student test/ANOVA

Table 6. Characteristic of women's age (years) in relation to values of blood cholesterol

Cholesterolemia	Women's age					
	N	$\bar{x}$	SD	min	max	Significance
Below normal	13	54.6	8.44	44.71	73.56	$p^* = 0.0048$
Normal	251	53.2	7.47	35.62	78.80	
Above normal	183	55.5	7.26	42.78	88.90	$p^{**} = 0.0049$

\* ANOVA, \*\* Scheffe's test (significant difference between normal and increased cholesterolemia)

### Blood cholesterol level

No relationship between the blood cholesterol, low-fat ( $p = 0.1902$ ) and vegetarian diets ( $p = 0.6137$ ), smoking cigarettes ( $p = 0.6834$ ) and physical activity ( $p = 0.2365$ ) and BMI values (Tab. 5) was observed. Still, the percentage of increased cholesterol level is lower in women practicing sports than in those who do not go in for any sports (31.8% and 42.9%, respectively). The cholesterol level is significantly related to the age of the subjects (Tab. 6).

### BMI

Women practicing sports as amateurs have significantly lower BMI values than those who do not practise any sports ( $24.8 \text{ kg}/\text{m}^2$  in comparison to  $26.4 \text{ kg}/\text{m}^2$ ;  $p = 0.0004$ ). The similar tendency was observed by Suchomel et al. [13]. While following low-fat diets is significantly related to the higher BMI values ( $27.7 \text{ kg}/\text{m}^2$  in women following diets and  $25.6 \text{ kg}/\text{m}^2$  in the other

women;  $p = 0.0000$ ). Body mass index was not related to nicotine addiction; however, it significantly influenced the value of blood pressure. Women with high blood pressure as a rule had higher BMI values (Tab. 5).

### High blood pressure

High blood pressure in women was not related to their physical activity ( $p = 0.3976$ ), nicotynism ( $p = 0.9159$ ) and use of low fat or vegetarian diets ( $p = 0.3615$ ).

### Osteoporosis

Osteoporosis incidence was not significantly related to any of the analyzed factors.

### Discussion

Correct functioning of the organism is controlled by the neurohormonal system which coordinates all the systems and organs and maintains homeostasis. The

organism's homeostasis ability weakens with age, thus many illnesses and incorrectness in organs' functioning can be observed. The period of time when health condition is worsening is more visible in women than in men. This period (climacterium) is strictly related to worsening of ovarian function. What characterizes it are changes in the physiological parameters values and in women's body build (fatness).

The characteristic feature of the female menopause hormon profile is the lower level of estrogen with increased level of FSH secretion. Disturbances in lipid metabolism are caused by hipoestrogenism. The increasing content of certain lipids fraction in plasma increases the risk of cardiovascular diseases development. An increase in fatness in post-menopausal women is also related to the change of hormone profile. Estradiol (the main estrogen of the reproductive period) is replaced by estrone, a hormone secreted by adrenal cortex and aromatized in the fat tissue cells.

Blood pressure, blood sugar and total blood cholesterol levels increase with age and change of menopausal status [14]. The results of this research are consistent with the above observations. The increased blood pressure values, total cholesterol and glucose were observed more frequently in post-menopausal women. That was related to the overweightness and obesity, cardiovascular diseases as well as diabetes and osteoporosis in post-menopausal women. Skrzypczak and Szwed noticed that the number of overweight and obese women increases with their age and after menopause [15].

Involutional processes influence the change of women's body shape; menopausal changes are mainly related to the way of fat tissue distribution. The BMI values change due to the alternations in body height and mass with age [16]. In post-menopausal women body proportions change due to fat tissue concentration in the waist area, unlike in younger women – on tights and hips [17].

Considering all this, the age of ovarians' function termination comes into prominence. Kaczmarek [18], applying Kaplan-Meier's method, assessed the age of early (below 46.6 years) and late menopause (over 55.0 years) in Polish women population. Based on the comparison conducted by the author, menopause in women from different countries of the world occurs approximately between 48 and 52. The difference between industrial regions, where women pass menopause after 51, and poor regions, where women stop menstruating approximately 5 years earlier, is also important [8]. It is supposed that in poor countries, due to the common malnutrition, the lower amount of oocytes is created in the foetal period.

Based on the analyses conducted, the computed mean menopausal age in the examined subjects was 50.2 years. The obtained results are similar to those published in the literature [19, 20]. Other authors obtained lower or higher mean age of menopause [12, 21, 22]. Those differences may result from different methodology of the survey and data analysis and from the diverse socio-economic conditions. Data of women after natural menopause, artificial menopause and those after hormonal treatment obtained in the earlier research were examined concurrently. That might have disturbed the average climacteric age. The menopausal age is a quantitative feature, whose final value depends on genetic predispositions and influence of the environment. The environmental factors influence, directly or indirectly, different biological properties of women's organism related to the climacterium.

Many published data indicate that inveterate smokers go through menopause earlier than non-smoking women [2, 23]. This is due to the toxic effect of cigarette smoke compounds on the ovarian follicle which causes oocytes degradation. Moreover, nicotine decreases the estrogen's level and accelerates tissues and organs aging, including ovaries, by oxidizing cell membranes. Despite the fact that smoking cigarettes and the number of cigarettes smoked per day did not significantly differentiate mean age of menopause in subjects, it is significant that non-smoking women go through menopause two years later than women who are habitual smokers. The period of smoking addiction was not significantly related to the age of menopause. However, it is surprising that in the sample analyzed the women smoking for the longest period go through menopause later (women smoking for less than 20 years did not significantly differ in their age from those smoking for over 20 years). In many women the nicotynism period was shorter since they gave up smoking due to their poor health conditions. It is likely that women who have been smoking for 20 years but in good health were not forced to quit smoking. Their genetical predispositions were related to the later menopausal age.

No relationship between menopausal age and use of vegetarian diets was proven (however, it is worth mentioning that in the sample, women following a vegetarian diet entered menopause 1 year later). A diligent comparison of these two groups is difficult since the groups were not equal in number. Baird et al. [24] observed earlier menopausal age in vegetarians, while Torgerson et al. [25] revealed the relationship between the amount of meat eaten and age at menopause.

The level of physical activity did not significantly influence the mean age of menopause among the sub-

jects, which was consistent with Parazzini et al.'s results [26]. It was observed that the mean menopausal age increases with the level of declared physical activity (described as: no sports practice, frequent sports training as amateur, professional sports training). Waszak et al. [27] noticed that moderate physical activity eases symptoms of menopause.

It was suspected that constitutional indicators, whose value is frequently connected to the lifestyle, may be related to the menopausal age. Despite that, the statistical significance was not proven, an increase of menopausal age can be observed with increasing BMI in women. The results of the research conducted on different populations are varied. The age at menopause increases with women's BMI [28]. In overweight women it may be related to the higher estrogen level. However, Beşer et al. [29] report that the risk of earlier menopause is increased by too high a BMI level. Kirchengast et al. [30] imply the lack of relationship between BMI and climacteric age.

High values of the body mass index significantly increase the risk of hyperglycemia and diabetes. It was proven that doing sport lowers BMI and protects against hyperglycemia and high blood pressure. Still, the percentage of increased cholesterol level is lower in women practicing sports. It is interesting to note that the use of low fat diets was related to the higher BMI values. The diets were probably used by the overweight women.

The results obtained during the analysis of smoking factor, commonly perceived as aging accelerator (damaged cells), were surprising. A percentage of women with diabetes was lower among smoking than non-smoking women (2.6% and 5.2%, respectively). Perhaps, smoking affects diet selection and consumption of carbohydrate. Nicotynism does not influence the BMI values, total blood cholesterol level and blood pressure.

Using low-fat diets was not related to the glycemia level, cholesterolemia and osteoporosis incidence in the subjects. The cholesterol level is significantly related to the age of the subjects. In comparison with younger women, older women have higher cholesterolemia values. This may be related to the higher percentage of overweight women and postmenopausal obesity.

Although osteoporosis incidence was not significantly related to any of the factors analyzed, it is commonly known that due to changes in the hormon profile, osteoporosis incidence is higher in older and in postmenopausal women [31], whereas bone mineral density is higher in physically active women [32].

As to the factors related to the climacterium and women's biological condition, the conclusions concerning the factors responsible for involutionary chan-

ges in acceleration are to be formulated cautiously. Moreover, no factor acts independently so the influences of many modicators are aggregated. Their actions are either reinforced or weakened, hence it makes the assessment more difficult.

## Conclusions

Summing up, the analysis of health and aging indices confirms a very high correlation between the relative body mass index and the external factors.

BMI diversification is significantly related to the intensity of the physical activity, diets used, high blood pressure and blood sugar level. Due to the specificity of hormone changes during climacterium, overweight and obese women go through menopause later.

The research was financed by the grant no. BW/IZ/29/2005.

## References

1. Leung W.C., Harvey I., Is skin ageing in the elderly caused by sun exposure or smoking? *Br J Dermatol*, 2002, 147 (6), 1187–1191. doi:10.1046/j.1365-2133.2002.04991.x.
2. Chmara-Pawlńska R., Szwed A., How the age at menopause is related to cigarette smoking in Polish women? *Acta Medica Lituanica*, 2005, 12 (4), 43–47.
3. Paillard-Borg S., Fratiglioni L., Winblad B., Wang H.X., Leisure activities in late life in relation to dementia risk: Principal component analysis. *Dement Geriatr Cogn Disord*, 2009, 28 (2), 136–144. doi:10.1159/000235576.
4. Mondul A.M., Rodriguez C., Jacobs E.J., Calle E.E., Age at natural menopause and cause-specific mortality. *Am J Epidemiol*, 2005, 162 (11), 1089–1097. doi:10.1093/aje/kwi324.
5. Snowdon D.A., Early natural menopause and the duration of postmenopausal life. Findings from a mathematical model of life expectancy. *J Am Geriatr Soc*, 1990, 38 (4), 402–408.
6. [http://www.stat.gov.pl/cps/rde/xbr/gus/PUBL\\_rocznik\\_demograficzny\\_2008.pdf](http://www.stat.gov.pl/cps/rde/xbr/gus/PUBL_rocznik_demograficzny_2008.pdf).
7. World Health Organization, Report of a WHO Scientific Group: Research on the menopause. *WHO Technical Report Series*, 1981, 670.
8. World Health Organization, Report of a WHO Scientific Group: Research on the menopause in the 1990s. *WHO Technical Report Series*, 1996, 866.
9. World Health Organization, Report of a WHO Consultation: Obesity: preventing and managing the global epidemic. *WHO Technical Report Series*, 2000, 894.
10. [http://www.cukrzyca.info.pl/UserAttachments/File/DDiK%20zalecenia%20PTD%202009\\_calosc.pdf](http://www.cukrzyca.info.pl/UserAttachments/File/DDiK%20zalecenia%20PTD%202009_calosc.pdf).
11. Ferguson G.A., Tekane Y., Statistical analysis in psychology and pedagogy [in Polish]. PWN, Warszawa 1999.
12. Kaczmarek M., Szwed A., Age at menopause and reproductive determinants in Polish women. *Przegl Antropol – Anthropol Rev*, 2001, 64, 57–72.
13. Suchomel A., Sigmundová D., Frömel K., The role of physical activity in the lifestyle of the inhabitants of the Liberec region. *Hum Mov*, 2008, 9 (1), 19–26. doi:10.2478/v10038-008-0003-x.

14. Meyerfreund D., Goncalves C., Cunha R., Pereira A.C., Krieger J.E., Mill J.G., Age-dependent increase in blood pressure in two different Native American communities in Brazil. *J Hypertens*, 2009, 27 (9), 1753–1760.
15. Skrzypczak M., Szwed A., Assessment of the body mass index and selected physiological parameters in pre- and post-menopausal women. *HOMO – J Comp Hum Biol*, 2005, 56, 141–152. doi:10.1016/j.jchb.2005.05.002.
16. Stachoń A.J., Involutional changes in somatic features among geriatric wards' female patients [in Polish]. *Ann Univ Mariae Curie-Skłodowska*, 2007, 62 (18/7), 419–423.
17. Sternfeld B., Bhat A.K., Wang H., Sharp T., Quesenberry C.P., Menopause, physical activity, and body composition/fat distribution in midlife women. *Med Sci Sports Exerc*, 2005, 37 (7), 1195–1202.
18. Kaczmarek M., Estimation of the age at natural menopause in a population-based study of Polish women [in Polish]. *Prz Menopauz*, 2007, 2, 77–82.
19. Koniarek J., Źukowski W., Age at menopause in LGOM region [in Polish]. Człowiek, Populacja, Środowisko. Prace Dolnośląskiego Centrum Diagnostyki Medycznej DOLMED we Wrocławiu, 1987, 4 (20/21), 252–253.
20. Rodziewicz-Gruhn J., Genetic and environmental determinants of the age of menopause and length of the reproductive period [in Polish]. *Studies in Human Ecology*, 1998, 2, 201–210.
21. Jaszmann L., van Lith D., Zaaij J.C.A., The perimenopausal symptoms: A statistical analysis of a survey. *Med Gynaecol Sociol*, 1969, 4, 268–277.
22. Szemik M., Changeability of adolescence and climacterium in environmental and generational differences [in Polish]. In: Bocheńska Z. (ed.), The child's physical development in industrial environment. *Zeszyty Naukowe AWF w Krakowie*, 1984, 31, 141–166.
23. Cramer D.W., Huijuan X., Harlow B.L., Does “incessant” ovulation increase risk for early menopause? *Am J Obst Gynecol*, 1995, 172, 2 (1), 568–573.
24. Baird D.D., Tylawsky F.A., Anderson J.J.B., Do vegetarians have earlier menopause? Proceedings of Society for Epidemiologic Research. *Am J Epidemiol*, 1988, 128 (4), 907–908.
25. Torgerson D.J., Avenell A., Russell I.T., Reid D.M., Factors associated with onset of menopause in women aged 45–49. *Maturitas*, 1994, 19 (2), 83–92.
26. Parazzini F., Negri E., la Vecchia C., Reproductive and general lifestyle determinants of age at menopause. *Maturitas*, 1992, 15 (2), 141–149.
27. Waszak M., Cieślik K., Grabowska M., Physical activity as a modifier of the course of menopause. *Studies in Physical Culture and Tourism*, 2007, 14 (2), 137–146.
28. Carda S.N., Bilge S.A., Öztürk T.N., Oya G., Ece O., Hamiyet B., The menopausal age, related factors and climacteric symptoms in Turkish women. *Maturitas*, 1998, 30 (1), 37–40.
29. Beşer E., Aydemir V., Bozkaya H., Body mass index and age at natural menopause. *Gynecol Obst Invest*, 1994, 37 (1), 40–42.
30. Kirchengast S., Gruber D., Sator M., Huber J., The individual age at menopause – An appropriate indicator of postmenopausal body composition? *Int J Anthr*, 1999, 14 (4), 243–253.
31. Wang S., Lin S., Zhou Y., Wang Z., Social and behavior factors related to aged Chinese women with osteoporosis. *Gynecol Endocrinol*, 2008, 24 (10), 538–545. doi:10.1080/09513590802309196.
32. Ignasiak Z., Skrzek A., Dąbrowska G., Bone mineral density and body composition of senior female students of the University of the Third Age in view of their diverse physical activity. *Hum Mov*, 2009, 10 (2), 109–115. doi:10.2478/v10038-009-0015-1.

Paper received by the Editors: January 21, 2010.

Paper accepted for publication: May 27, 2010.

#### *Address for correspondence*

Aleksandra Stachoń  
 Zakład Antropologii Fizycznej  
 Akademia Wychowania Fizycznego  
 al. I.J. Paderewskiego 35, budynek P2  
 51-612 Wrocław, Poland  
 e-mail: orchis@o2.pl



# THE EFFECTS OF DYNAMIC SURYA NAMASKAR ON DIFFERENTIAL CHEST CIRCUMFERENCE OF PHYSICAL EDUCATION STUDENTS

doi:10.2478/v10038-010-0024-0

**KRZYSZTOF STEC<sup>1</sup>, RAJEEV CHOUDHARY<sup>1</sup>, LESŁAW KULMATYCKI<sup>2\*</sup>**

<sup>1</sup> Department of Physical Education, Banaras Hindu University, Varanasi, India

<sup>2</sup> Department of Physical Education, University School of Physical Education, Wrocław, Poland

## ABSTRACT

**Purpose.** The objective of the study was to determine the effects of dynamic Surya Namaskar (sun salutations) on the differential chest circumference of selected physical education students at Banaras Hindu University, Varanasi. **Basic procedures.** The subjects for this study were selected from the Department of Physical Education at Banaras Hindu University. A total of 20 male subjects were selected and used as one practicing group. Dynamic Surya Namaskar was considered the independent variable and differential chest circumference was considered the dependent variable. The test was for differential chest circumference. The Repeated Measures Design was used for this study. Only one group of 20 participants was created. Tests were administered at regular intervals of two weeks. The tests started four weeks prior to the dynamic Surya Namaskar (DSN) treatment and took place every two weeks, three times. Thereafter, tests took place every two weeks during the treatment and after the completion of the treatment, they were continued for the following four-week period. **Main findings.** To determine the effect of dynamic Surya Namaskar on physiological and anthropometric variables of selected physical education students at Banaras Hindu University, Varanasi, one way ANOVA was used at .05 level of significance. **Conclusions.** In relation to differential chest circumference, a significant ( $p < 0.05$ ) effect of dynamic Surya Namaskar was found.

**Key words:** dynamic Surya Namaskar, differential chest circumference, physical education

## Introduction

Surya Namaskar practice is a very powerful practice and affects the whole body. It especially remains the preferred cardiovascular exercise [1, 2]. This makes it open to people of all ages and levels. The number of rounds should be decided on the basis of physical condition, whereas maximum benefit is obtained by performing a sequence of yoga-poses regularly [3–5]. After the session, the practitioners usually rest in the yoga resting posture – Shavasana.

The practice of Surya Namaskar as a complete and perfect compound blend of body movement, breathing and concentration is used in many Indian schools and ashrams since it was considered by the ancients of India to be a form of *kriya* (purification), or body oblation, which would give an abundance of health, vitality and spiritual upliftment [6–10]. The fact that some authors call it *kriya* indicates its strong purification qualities. Historically, it is widely believed that in the state of Maharashtra, the national freedom fighter of the 17<sup>th</sup> century, King Shivaji Maharaj, sage Samarth

Ramdas and the Marathas performed Surya Namaskar as a physical exercise to develop strong and able bodies. This is not surprising since *vyayama* (physical exercise) traditionally has been influenced by spirituality. Many physical practices have an ingrained spiritual value in them [11–13]. In addition, spiritual training has been considered a part of physical training in India since ancient times [14, 15]. The routine differs greatly with regards to the recommended pace of movement, number of repetitions, sequence of asanas and the emotional approach (whether ritual or physical exercise). In ritual form, the movements are accomplished very slowly with devotion and mantra repetition and the central pose is the Ashtanga Namaskar. The exercise version requires a high number of repetitions, often more than 200, to be performed quickly, i.e. less than 20 seconds per round.

Some sources mention as many as forty various Surya Namaskar-like routines. Over the years, especially when they were performed as a part of ritual, these routines were renamed and now one can find such names as Chandra Namaskar, Guru Namaskar, Hanuman Namaskar, etc. There are some differences with regard to the body movements, yet the main idea of the original Surya Namaskar remains intact.

Surya Namaskar (SN) is a yogic practice generally

\* Corresponding author.

done at sunrise and usually consists of twelve *asanas* (postures) which are performed in a pre-established sequence. Each and every movement of the body should be coordinated with respiration [4, 16, 17]. The mind should be focused on the breathing process. The sequence of postures used for the experiment was the traditional style popularly called the Rishikesh series which is based on the work of the Kaivalyadhama Institute (Lonavla) [7] and the Bihar School of Yoga (Munger) [3].

In addition to the above definition, dynamic Surya Namaskar (DSN) requires that the speed of one round of Surya Namaskar is performed in 7.5 to 8 seconds, making approximately 40 rounds of Surya Namaskar per five minutes. Usually during one session, several hundred rounds are performed.

## Material and methods

### Objective of the study

The objective of the study was to determine the effects of dynamic Surya Namaskar (sun salutations) on differential chest circumference of selected physical education students at Banaras Hindu University, Varanasi.

### Hypothesis

It was hypothesized that there shall be a significant effect of dynamic Surya Namaskar on differential chest circumference on the group following the regime of the daily dynamic Surya Namaskar practice in comparison to the period when such regular practice was not followed.

Flexibility is an important characteristic of physical fitness. Most sports and exercise systems are rarely applied directly to maintain the rib cage flexibility and its range of motion, while Surya Namaskar uniquely addresses such shortcoming.

### Participants

The subjects for this study were selected from the Department of Physical Education at Banaras Hindu University. A total of 20 male subjects were selected and used as one practicing group.

### Variables

Dynamic Surya Namaskar (sun salutations) was considered the independent variable and differential chest circumference was considered the dependent variable.

### Test for differential chest circumference

Chest circumference was measured with the help of a meter tape during the maximum inhalation and maximum exhalation and was recorded in centimeters. The measurement was taken as soon as the subject took inhalation or exhalation holding it steady for a few seconds and the tape was adjusted at the subject's back to the horizontal level marked *mesosternale*.

The differential chest circumference was calculated by using the following formula:

$$\text{Differential Chest Circumference (cm)} = \text{Chest Circumference after Inhalation (cm)} - \text{Chest Circumference after Exhalation (cm)}.$$

### Experimental design

The Repeated Measures Design was used for this study. Only one group of 20 participants was created. Tests were administered at regular equal intervals of two weeks. The tests started four weeks prior to the dynamic Surya Namaskar (DSN) treatment and took place every two weeks, three times. Thereafter, tests took place every two weeks during the treatment and after the completion of the treatment, they were continued for the following four-week period.

Data set	1	2	3	4	5	6	7	8
	Pre-treatment		Treatment starts	Treatment period			Post-treatment	
Time (weeks)	-4	-2	0	+2	+4	+6	+8	+10

### Experimental treatment – dynamic Surya Namaskar (sun salutations) practice

All the subjects were assembled at Shivaji Hall (gymnasium and a weight training hall) at Banaras Hindu University, Varanasi and were briefed on the general objectives and requirements of Surya Namaskar practice (SN), as well as on the specific objectives and requirements of the dynamic Surya Namaskar practice (DSN).

Subjects were administered the dynamic Surya Namaskar practice in addition to regular participation in all other activities as scheduled by the Department of Physical Education at Banaras Hindu University, Varanasi.

Dynamic Surya Namaskar training was carried out for a period of six weeks, six times per week (excluding university holidays) between December 15, 2008 and January 24, 2009. The scheduled time of the practice lasted for 45 minutes between 6:30 a.m. and 7:15 a.m.

and was conducted instead of the students' regular conditioning period. Each and every practice period was concluded with five minutes of Shavasana (relaxation posture).

Each day of the first week, Surya Namaskar practice was demonstrated to the group by the research scholar and the most important points were reviewed several times. Afterwards, a review of the most important points and common mistakes was conducted once per week. Individual correction of Surya Namaskar practice was conducted every day on an ongoing basis. Additionally, a number of stretching exercises were taught in order to facilitate better and more accurate execution of the individual asanas which are a part of the Surya Namaskar cycle.

## Results

### Statistical analysis

To determine the effect of dynamic Surya Namaskar on differential chest circumference variable of selected physical education students at Banaras Hindu University, Varanasi, one way ANOVA was used at .05 level of significance (Table 1, Table 2).

It appears from Table 2 that the computed value of F in relation to the differential chest circumference is greater than the required F (7,152) to be significant at the 0.05 level of significance. Since the F-value was found to be significant, the least significant difference (L.S.D.) post hoc test was applied for inter-group comparison.

Table 1. Mean and standard deviation of eight different trials in differential chest circumference

Trials	Mean	Standard deviation
1	5.2500	2.07428
2	5.6500	2.10950
3	5.3500	1.89945
4	7.0000	2.49209
5	7.7450	2.25843
6	8.3750	2.42180
7	6.8500	2.05900
8	6.4500	2.32775

Table 2. Analysis of variance of differential chest circumference in eight different trials

	Sum of squares	df	Mean square	F	Sig.
Between groups	179.841	7	25.692	5.244	.000
Within groups	744.697	152	4.899		

Table 3. Least significant difference (L.S.D.) post hoc test for comparison of the means of the trials of the effect of dynamic Surya Namaskar on differential chest circumference

	Paired means (I) (J)	Mean difference (I-J)	Sig.
Trial 1	Trial 2	-.40000	.569
	Trial 3	-.10000	.887
	Trial 4	-1.75000(*)	.013
	Trial 5	-2.49500(*)	.000
	Trial 6	-3.12500(*)	.000
	Trial 7	-1.60000(*)	.024
	Trial 8	-1.20000	.088
Trial 2	Trial 3	.30000	.669
	Trial 4	-1.35000	.056
	Trial 5	-2.09500(*)	.003
	Trial 6	-2.72500(*)	.000
	Trial 7	-1.20000	.088
	Trial 8	-.80000	.255
Trial 3	Trial 4	-1.65000(*)	.020
	Trial 5	-2.39500(*)	.001
	Trial 6	-3.02500(*)	.000
	Trial 7	-1.50000(*)	.034
	Trial 8	-1.10000	.118
Trial 4	Trial 5	-.74500	.289
	Trial 6	-1.37500	.051
	Trial 7	.15000	.831
	Trial 8	.55000	.433
Trial 5	Trial 6	-.63000	.370
	Trial 7	.89500	.203
	Trial 8	1.29500	.066
Trial 6	Trial 7	1.52500(*)	.031
	Trial 8	1.92500(*)	.007
Trial 7	Trial 8	.40000	.569

\* The mean difference is significant at the .05 level

- There is no significant difference between Trial 1 & Trial 2, Trial 1 & Trial 3, and Trial 2 & Trial 3. (Table 3) This shows that no improvement took place in differential chest circumference before the start of the treatment.
- There is significant difference between Trial 3 & Trial 4, Trial 3 & Trial 5 and Trial 3 & Trial 6. (Table 3). This shows that the treatment proved to be effective in the improvement of differential chest circumference especially in the early phase of its application.
- There is no significant difference between Trial 4 & Trial 5 and Trial 5 & Trial 6. (Table 3). This indicates that the treatment does not result in any differential

chest circumference effect in the later phase of its application.

- There is no significant difference between Trial 7 & Trial 8. On the other hand, there is significant difference between Trial 6 & Trial 7 and Trial 6 & Trial 8. (Table 3). This shows that the effect of dynamic Surya Namaskar remains for two weeks even after a pause in treatment but the achieved performance decreases significantly after four weeks of rest (Fig. 1).

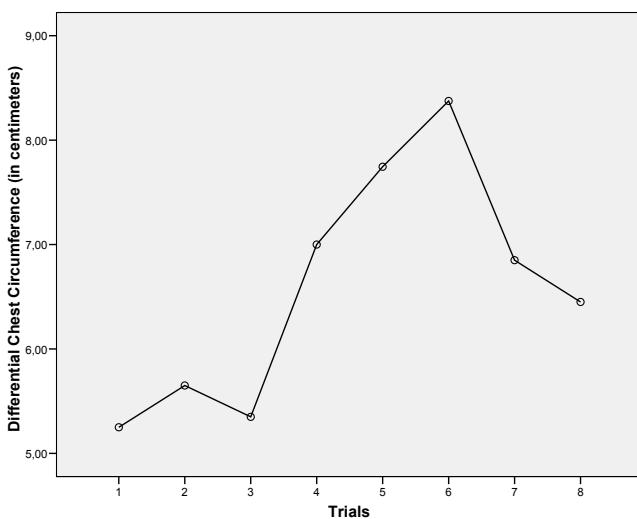


Figure 1. Graphical representation of the comparison of the means of the trials of the effect of dynamic Surya Namaskar on differential chest circumference

#### Descriptive statistics of the subjects

Table 4. Descriptive statistics of the subjects in relation to calendar age

N	Valid	20
	Missing	0
Mean	22.09	
Std. error of mean	.36417	
Median	21.78	
Mode	21.28	
Std. deviation	1.63	
Variance	2.65	
Range	6.16	
Minimum	19.21	
Maximum	25.37	
Sum	441.80	

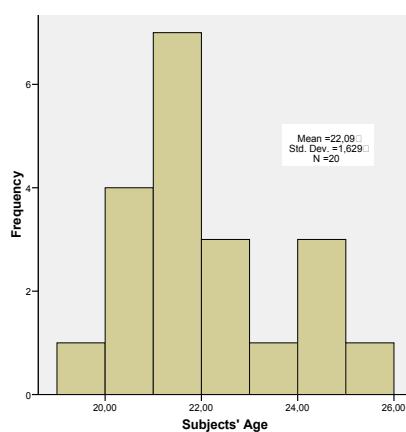


Figure 1. Graphical representation of the subjects' age

Table 5. Descriptive statistics of the subjects in relation to active participation in various sports

N	Valid	20
	Missing	0
Mean	7.10	
Std. error of mean	.721	
Median	7.50	
Mode	10.00	
Std. deviation	3.23	
Variance	10.41	
Range	11.00	
Minimum	1.00	
Maximum	12.00	
Sum	142.00	

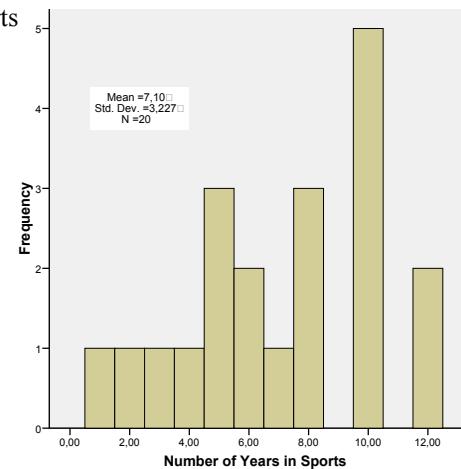


Figure 2. Graphical representation of the frequency of the subjects' active participation in various sports

#### Discussion

##### Findings in the light of the literature

Bhattacharya et al. [18] have confirmed that yoga practice improved oxidative status. Vaze et al. [19] have confirmed that yogasanas and pranayamas followed by 20 minutes of relaxation techniques considerably improved chest flexibility. However, no statistics were used in their report. In this study, it was found that the differential between the in-breath and the out-breath chest circumference increased in a statistically significant manner. Therefore, this earlier study has been confirmed by statistics here which show that yoga, and in particular dynamic Surya Namaskar, increases chest flexibility. The post hoc least significant difference test in relation to differential of chest circumference shows that the duration of the first two weeks of the treatment was sufficient to bring about significant difference (mean difference = -1.65). The following two intervals were not effective enough to bring about any significant difference though there was an observable small improvement. According to Sinha et al. [2] after three months of yoga training dynamic Surya Namaskar as aerobic exercise seemed to be ideal as it involves static stretching and slow dynamic component of exercise with optimal stress on the cardiorespiratory system. Ray et al. [1] tested 28 of yoga trainees who were administered yogic practices for ten months (Table 4, Table 5, Fig. 2, Fig. 3). There was improvement in body flexibility and at submaximal level of exercise and in anaerobic

threshold. Also Christensen [20], Ornish [21], Cowen and Adams [22] and Sanjay [23] have mentioned the influence of heart rate in yoga practice.

### Limitations

Moreover, the present study of dynamic Surya Namaskar practice does not allow determining whether the level of skills of the students, their personality profile or some kind of external motivation influence the final result. Questions such as these need to be addressed in future research.

### Conclusions

To conclude, the study shows that the effect of dynamic Surya Namaskar remains for two weeks even after a pause in treatment but the achieved performance decreases significantly after four weeks of rest (mean difference = 1.525).

### References

1. Ray U.S., Sinha B., Tomer O.S., Pathak A., Dasgupta T., Selvamurthy W., Aerobic capacity & perceived exertion after practice of Hatha yogic exercises. *Indian J Med Res*, 2001, 114, 215–221.
2. Sinha B., Ray U.S., Pathak A., Selvamurthy W., Energy cost and cardiorespiratory changes during the practice of Surya Namaskar. *Indian J Physiol Pharmacol*, 2004, 48 (2), 184–190.
3. Satyananda S., Surya Namaskara – A Technique of Solar Visualization. Munger Yoga Publication Trust, Munger 2006, 97.
4. Gore M.M., Physiology of Yoga Practice. Yoga Mimamsa, Mudranalaya, Lonavla 1980, 200.
5. Jois P., Sri K., Surya Namaskara. Ashtanga Yoga, New York 2005, 60.
6. Gharote M.L., Ganguly S.K., Teaching Methods for Yogic Practices. Yoga Mimamsa Mudranalaya, Lonavla 2006, 120.
7. Gharote M.L., Guidelines for Yogic Practices. Lonavla Yoga Institute, Lonavla 1982, 106.
8. Patel S., Surya Namaskar – Teach yourself the Sun Salute. Srishti Publishers, New Delhi 2004, 83.
9. Bhattacharya P.B., Surya Namaskara. Sri Aurobindo Ashram Trust, Pondicherry, 2007, 9.
10. Stiles M., Ayurvedic Yoga Therapy. Lotus Press, Twin Lakes 2007, 253.
11. Mujumdar D.Ch., Encyclopedia of Indian physical culture. Good Companions, New Delhi 1950.
12. Pant A., Pratinidhi B., The Raja of Aundh. Surya Namaskara – an Ancient Indian Exercise. Orient Longman, Hyderabad 1989.
13. Michelis de E., A History of Modern Yoga. Continuum, London 2005, 250.
14. Bijlani R.L. (ed.), Understanding medical physiology, with a special chapter on yoga physiology. Jaypee Bros, New Delhi 1995, 950.
15. Gharote M.L., Devnath P., Jha V.K., Hathatativakamudi – a Treatise on Hatha-yoga by Sundaradeva. Lonavla Yoga Institute, Lonavla 2006, 800.
16. Douillard J., Body, Mind and Sport. Crown Trade Paperbacks, New York 198.
17. Kansal D.K., Test and Measurement in Sports and Physical Education. D.V.S., New Delhi 1996, 374.
18. Bhattacharya S., Pandey U.S., Verma N.S., Improvement in oxidative status with yogic breathing in young healthy males. *Indian J Physiol Pharmacol*, 2002, 46, 349–354.
19. Vaze S., Porwal N.K., Damodaran A., Yoga for women: Effect on weight, waist, hips and chest flexibility. In: Nagendra H.R., Ragurathna R., Telles S. (eds.), Yoga Research & Applications. Proceedings of the 5th International Conference on Frontiers in Yoga Research and Applications. Vivekananda Kendra Yoga Research Foundation, Bangalore 2000, 279–284.
20. Christensen A., Yoga for Sports. Contemporary Books, Chicago 2000, 250.
21. Ornish D., Dr. Dean Ornish's Programme for Reversing Heart Disease. Ivy Books, USA 1996, 631.
22. Cowen V., Adams T., Heart rate in yoga asana practice: A comparison of styles, *Journal of Bodywork and Movement Therapies*, 2007, 11 (1), 91–95.
23. Sanjay U., Basics, Benefits and Method of Surya Namaskar, Scientific Research Department, Kaivalyadham, Lonavla 2008.

Paper received by the Editors: September 1, 2009.

Paper accepted for publication: May 27, 2010.

#### *Address for correspondence*

Lesław Kulmatycki  
Katedra Promocji Zdrowia  
Akademia Wychowania Fizycznego  
ul. Rzeźbiarska 4  
51-629 Wrocław, Poland  
e-mail: leslaw.kulmatycki@awf.wroc.pl



# EFFECTIVENESS OF VISUAL INFORMATION IN THE PROCESS OF TEACHING SWIMMING MOTOR ACTIVITIES

doi:10.2478/v10038-010-0019-x

DOROTA BURZYCKA-WILK

Institute of Tourism and Recreation, Faculty of Physical Education and Physiotherapy, Opole Technical University, Opole, Poland

## ABSTRACT

**Purpose.** In the process of learning motor functions, it is important to avoid perpetuating the wrong movements. For this purpose, it is recommended to use a combination of various media: speech, demonstration and practical activity. However, in some cases the learning process can be disrupted by difficult conditions (e.g. buzz at a swimming pool), which cause significant disturbance in perception of verbal information. In this situation, the teacher may use visual communication (in the form of gestures). The aim of this study was to determine differences in the accuracy of learning swimming skills (in the experimental and control groups) after implementing visual information (in the form of gestures) in the experimental group. **Basic procedures.** The test method used was a pedagogical experiment conducted among 86 people (40 in the experimental group and 46 in the control group). The difference between the groups consisted in different ways of correcting errors in movements: in the experimental group, I introduced an independent variable – visual information communicated by gestures, while in the control group errors were eliminated by means of verbal information.

**Main findings.** Analysis of the results shows that the difference in the coefficients of swimming accuracy in the experimental and control groups is statistically significant and in favour of the experimental group. The result was significantly influenced by the precision of hip joint movements – bending and straightening – reached in the experimental group. Slightly less, but also important were differences in the precision of single movements like arm flexion, dorsal flexion in the talocrural joint and extension of the knee. **Conclusions.**

1. Visual information transmitted using “language of gestures” affects the accuracy of learning swimming motor activities. 2. In teaching of swimming motor activities, visual information is more effective than the information communicated verbally.

**Key words:** feedback, visual information, gesture, education of swimming

## Introduction

Researchers have been interested in the problem of learning for a long time. Some of them have dealt with the issue of mental learning, others with that of motor learning.

In new theories the difference between skill learning and mental learning is hardly visible. After having studied the process of acquiring motor skills, scientists state that it is very complex, as it involves creating both motor plans and programmes based on a thorough analysis, thinking, and cognitive processes [1].

Psychologists treat the terms “learning” and “memory” as equivalent, though memory is regarded as the organism’s ability to store the acquired experiences, whereas learning as a manifestation of this storing expressed in behaviour. A learning process starts from memorizing incoming information in the short-term memory (STM). However, its capacity is limited (~7 units), and duration is very short (15–30 seconds); in addition, it cannot be reconstructed, so the information encoded at this level is quickly forgotten. To remember it for a longer period of time, it must reach the long-term memory (LTM), which is a permanent memory store.

For physiologists, learning consists in increasing effectiveness of synapses and in reducing physiological cost needed to do an action. Therefore, it depends on plastic properties of the nervous system, which is involved in developing any changes in behaviour [2]. Every process of acquirement has its origin in retention of the incoming information at the fresh memory level. This level comprises the sensory memory, which is responsible for keeping a trace of a stimulus action in the analyzer, and the short-term memory, which lasts as long as there are nervous impulses circulating between sensory fields and associating ones of the cerebral cortex.

To store new contents in LTM, a neuron receiving information must reach a certain stimulation level. Multiple repetition of the same stimuli contributes to changes in sensibility of the neuron’s cell wall, which starts reacting to less quantity of neurotransmitter than before. This change, which is defined as a long-term synaptic reinforcement, reinforces considerably the synapses between the neurons sending and those receiving information [3–6].

The greatest influence on permanent retention of information has repetition, which enables the learned contents to be used more easily in the future. However,

during repetition, also some undesired information can reach the permanent memory; for example, errors occurring while learning motor activities. Errors repeated many times result in permanent retention in LTM. But not all imperfections need immediate correction [7, 8]. Defects, i.e. deflections, which result from individual differences between exercise doers, are normal and do not require a pedagogical intervention. They can be treated as superimposition of a technique on the student's individual characteristics. The teacher's intervention, in such a situation, consists in modification of the pattern and adjustment of the requirements to the learner's capacities.

In addition, an immediate correction is not required in the case of inadequacies, i.e. defects of certain movements whose images the learner has already in mind. Correction of inadequacies is limited to providing the learner with information (verbal, visual, sensory) about the occurrence of inadequacies, because the learner usually is not aware of his/her shortcomings. While learning, it may also turn out that an activity deviates from an intended goal, because some movements at variance with an anticipated activity plan (errors) occurred. Errors must be eliminated as soon as possible, because they hinder effectively a correct acquirement of a new activity. In order to prevent from perpetuating undesirable movements in the permanent memory, it is necessary to spare no effort so that the acquiring activity is executed properly. That is why, while performing an activity, the student should be constantly provided with detailed information about the movement structure and how to correct occurring errors [8].

The teacher, giving the learner information about a movement structure, can make use of different media: verbal information, i.e. speech, visual information, i.e. demonstration, and kinetic information, i.e. acting in practice [8–11].

In order to acquire properly a new activity, it is necessary to make use of all the information media at the same time. It means that verbal communication should be reinforced by a demonstration and complemented with sensory impressions; the lack of one of them may cause disturbances in effectiveness of the entire learning process [1].

In some situations learning is disrupted by difficult conditions (for example, buzz at the swimming pool during swimming lessons) which cause significant disturbances in receiving verbal information. As a result, the student cannot hear messages how to execute a movement and that it is possible to correct it, which contributes to the incorrect activity execution [7, 8]. In this situation, in order to compensate insufficiency of

verbal information (words), the teacher should make use of non-verbal information media, for example, visual information. Visual information can have a form of symbols, i.e. signs or gestures. Such an elementary sign in a process of transmitting information about human movements is a sensorimotor sequence [12]. Using the notion of a sequence, it is possible to distinguish the most important elements of a movement in an activity being taught and then, in a simplified way, change them into visual signs (gestures), and only in such a form communicate students indispensable information about the movement structure.

In order to make the communication through gestures (signs) possible, there must be a common repertoire, where signs mean the same both for the teacher and the learner. The point is that learners should recognise unequivocally the gestures made by the teacher and that their interpretation should be in accordance with the teacher's intention [9, 11]. Due to the information communicated in this way the learner can systematically verify his/her idea about the movement and correct the wrong movements in order to get closer to a previously intended goal. In learning, as Kotarbiński [13] claims, the most important is effectiveness. In the case of learning an activity, one can speak about an effective activity only when it leads to a previously intended goal. The achieved goal should be as close as possible to the pattern or possibly the least different from the pattern. The more the performance is close to the pattern, the more precisely the activity was performed.

The aim of the work was to establish differences in the accuracy of learning swimming motor activities (in the experimental and control groups) as a result of the application of visual information (in the form of gesture) in the experimental group.

### Hypothesis

Visual information communicated by means of a "gesture language" has an influence on the accuracy of learning swimming motor activities.

### Material and methods

#### Selection of learners for the experiment

74 pupils, aged 9 years, from Primary School No. 5 in Opole and 62 pupils, aged 9 years, from Primary School No. 12 in Kędzierzyn-Koźle took part in the experiment. In both schools there were similar teaching and school conditions.

The selected pupils participated in an obligatory swimming course, which consisted of eight 45-minute lessons held once a week. Since motor, somatic and intellectual differences between boys and girls at this age do not have significant importance in teaching physical education, the experiment was held in coeducational groups [14, 15].

The basic qualification criterion to take part in the experiment was the lack of ability to swim. However, before the experiment started all the subjects had undergone a preliminary adaptation to the water environment, which lasted four consecutive lessons. Its aim was to even out the starting level of all the participants. I recognized that children were accustomed to the water if they were able to do the following exercises: to jump to the water no matter in what way, to immerse the head under the water and exhale at the same time, to push themselves with both legs from the swimming pool wall in order to slide on the breast and on the back.

Out of 136 pupils who underwent the preliminary adaptation, 122 were qualified to take part in the experiment; they at most were able to remain afloat. Unfortunately, after having carried out the experiment, I could make a final diagnosis only on 86 persons' performances (40 in the experimental group and 46 in the control group), because the results of the other subjects could not be taken into consideration due to periodical absences from the lessons.

#### Selection of teachers to the research

Physical education teachers of different seniority (7, 11, 18, 26, 31 years of experience) participated in the experiment. They had a master degree (*magister*) in physical education and were qualified swimming instructors. Each of them conducted lessons in both groups and none of them was told about the main objective of the experiment.

The basic research method was a natural pedagogical experiment. The method of pedagogical experiment consisted in dividing the subjects into experimental and control groups. Swimming lessons were conducted by the same teachers. 45-minute lessons were held once a week for 7 consecutive weeks, during the 8<sup>th</sup> lesson a test of ability to do the backstroke using the standard technique was held. Lesson subjects and objectives were the same in both experimental and control groups.

For the experiment I chose an ability to do the backstroke, because it is characterised by natural (side-alternating) movements of lower and upper limbs, facilitated breathing (no difficulties to overcome) and a facilitated

pupil's contact with the teacher. In addition, the body lying on the back enables both parts, the teacher and the learner, visual communication (possibility of using gestures) and allows learners to correct occurring errors on their own.

The difference between the experimental group and the control one consisted in the fact that in the experimental group I introduced an independent variable, that is visual information communicated by a gesture whenever there was an incorrect movement. Correction regarded the errors, i.e. elements of movements, which should not appear during the executed movement.

#### The preparation procedure of the independent variable for the experimental group

In order to communicate by means of gestures, before starting the experiment, I established with pupils the common repertoire of gestures (code). In this way, different gestures were invented, some to correct a wrong position of the body in water, others to correct wrong movements of lower limbs and some others to correct errors in movements of upper limbs [16].

Additionally, before each lesson I reminded the participants the meaning of the gestures which could be used during the lesson and I instructed them to watch carefully my behaviour during the whole lesson and correct their swimming techniques adequately.

In the control group wrong movements were corrected verbally.

#### The procedure of the accuracy assessment of teaching the backstroke standard technique

After having completed the experiment all the pupils were filmed. The material obtained in this way was used to compare the subjects' swimming techniques with the model technique. To work out a model technique required dividing the taught motor activity into sensorimotor sequences [12]. For this purpose a complete swimmer's cycle of movements while doing the backstroke was filmed. The material recorded on the video tape was processed into digital information (I changed images into numbers) following the procedure adopted by Zatoń [9] in her research. Since movements in all the joints are performed at the same time, I regarded as an earlier movement the one in the joint placed closer to the head (so, first was the movement in the humeral joint, then in the hip, knee joints and finally in the talocrural joint) and the movement of the left side (a movement in a left joint came before a movement in the respective right joint). Such a procedure

Table 1. The significance of the differences between the control and experimental groups in the *U* Mann-Whitney's test

Variable	Rank sum	Rank sum	Value Z corrected	Level p probability	No. of subjects		Exact significance
	E	C			E	C	
<b>Coefficient of swimming accuracy</b>	<b>1998.500</b>	<b>1742.500</b>	2.24	0.0251	40	46	0.0247
Left humeral joint– abduction	1725.000	2016.000	-0.13	0.8963	40	46	0.9006
Right humeral joint– adduction	1740.500	2000.500	0.00	0.9961	40	46	0.9966
Left hip joint – extension	1761.500	1979.500	0.19	0.8499	40	46	0.8531
Right hip joint– flexion	1859.000	1882.000	1.04	0.2966	40	46	0.3066
Left knee joint – flexion	1651.000	2090.000	-0.84	0.4017	40	46	0.4455
Right knee joint – extension	1603.000	2138.000	-1.28	0.2017	40	46	0.2386
Left talocrural joint – sole flexion	1796.000	1945.000	0.66	0.5076	40	46	0.6325
Right talocrural joint – dorsal flexion	1876.000	1865.000	1.64	0.1013	40	46	0.2421
Left hip joint – flexion	<b>2109.500</b>	<b>1631.500</b>	3.23	0.0012	40	46	<b>0.0012</b>
Right hip joint – extension	<b>2139.000</b>	<b>1602.000</b>	3.50	0.0005	40	46	<b>0.0004</b>
Left knee joint – extension	1841.000	1900.000	0.97	0.3322	40	46	0.3861
Right hip joint – flexion	1842.500	1898.500	1.00	0.3181	40	46	0.3767
Left talocrural joint – dorsal flexion	1956.000	1785.000	2.85	0.0044	40	46	0.0618
Right talocrural joint – sole flexion	1910.000	1831.000	1.78	0.0746	40	46	0.1428
Left hip joint – extension	1930.500	1810.500	1.67	0.0956	40	46	0.0992
<b>Right hip joint – flexion</b>	<b>2095.000</b>	<b>1646.000</b>	3.10	0.0020	40	46	<b>0.0019</b>
Left knee joint – flexion	1628.000	2113.000	-1.00	0.3186	40	46	0.3361
Right knee joint – extension	1526.000	2215.000	-1.94	0.0522	40	46	0.0643
Left talocrural joint– sole flexion	1618.000	2123.000	-1.36	0.1740	40	46	0.2944
Right talocrural joint – dorsal flexion	1896.000	1845.000	1.92	0.0553	40	46	0.1791
Left humeral joint – adduction	1840.500	1900.500	0.88	0.3800	40	46	0.3861
<b>Right humeral joint – abduction</b>	<b>1499.000</b>	<b>2242.000</b>	-2.14	0.0324	40	46	<b>0.0369</b>
Left hip joint – flexion	1942.000	1799.000	2.36	0.0181	40	46	0.0810
<b>Rigt hip joint – extension</b>	<b>1992.000</b>	<b>1749.000</b>	2.85	0.0044	40	46	<b>0.0289</b>
Left knee joint – extension	1915.500	1825.500	1.95	0.0511	40	46	0.1291
Right knee joint – flexion	1890.000	1851.000	1.62	0.1053	40	46	0.1966
<b>Left talocrural joint – dorsal flexion</b>	<b>1970.000</b>	<b>1771.000</b>	3.59	0.0003	40	46	<b>0.0465</b>
Right talocrural joint – sole flexion	1954.000	1787.000	2.28	0.0225	40	46	0.0643
<b>Left hip joint – extension</b>	<b>2084.000</b>	<b>1657.000</b>	3.41	0.0007	40	46	<b>0.0026</b>
<b>Right hip joint – flexion</b>	<b>2081.000</b>	<b>1660.000</b>	3.38	0.0007	40	46	0.0029
Left knee joint – flexion	1801.500	1939.500	0.61	0.5387	40	46	0.5962
Right knee joint – extension	1757.500	1983.500	0.18	0.8598	40	46	0.8802
Left talocrural joint – sole flexion	1880.000	1861.000	1.42	0.1561	40	46	0.2284
Right talocrural joint – dorsal flexion	1778.000	1963.000	0.57	0.5696	40	46	0.7467
<b>Left hip joint – flexion</b>	<b>2026.000</b>	<b>1715.000</b>	3.09	0.0020	40	46	<b>0.0129</b>
Right hip joint – extension	1961.000	1780.000	2.39	0.0170	40	46	0.0560
<b>Left knee joint – extension</b>	<b>1980.000</b>	<b>1761.000</b>	2.59	0.0096	40	46	<b>0.0377</b>
Right knee joint – flexion	1942.000	1799.000	2.18	0.0291	40	46	0.0810
Left talocrural joint – dorsal flexion	1882.000	1859.000	2.21	0.0270	40	46	0.2218
Right talocrural joint – sole flexion	1944.000	1797.000	2.16	0.0304	40	46	0.0780

statistically significant values at the level  $p \leq 0.05$  are marked in bold type.

enabled me to work out a desired algorithm of movements. Knowing the succession of movement appearances, I established exactly a number of sequences occurring in each joint. Thus, the model backstroke technique consisted of 592 sequences. I repeated the same procedure for all the video records of the participants. Knowing the number of sequences in each joint in both experimental and control groups I was able to compare the performances in each of them. In order to do it I made use of the *U* Mann-Whitney's test [17] (Tab. 1).

In addition, the established number of the sequences made it possible to calculate the swimming accuracy coefficient worked out and empirically verified by Zatoń [9].

#### Swimming accuracy coefficient $W_{op}$

$$W_{op} = \frac{l_{pw}}{l_c} = \frac{l_c - l_o - l_p}{l_c}$$

where:

- $W_{op}$  – is a swimming accuracy coefficient, which takes into consideration the number of sequences omitted and presented,
- $l_{pw}$  – number of correctly occurred sequences in a given person,
- $l_c$  – number of total sequences (in the pattern),
- $l_o$  – number of omitted sequences,
- $l_p$  – number of presented sequences.

### Results

The analysis of the results shows that the difference in the values of swimming accuracy coefficient in the experimental and control group is statistically significant in favour of the experimental group. Due to this fact, the gestures eliminating errors in body positions in the water and the gesture indicating the place where the lower limbs should start their movement were essential. A bit less important, but still significant, were the differences in accuracy of single movements: abduction of the arm, flexion of the dorsal talocrural joint, extension of the knee joint.

### Discussion

The analysis of the results obtained in the present experiment shows that pupils who took advantage of non-verbal communication means, i.e. the visual information prepared in the form of gestures, demonstrated a more accurate technique. Those who mainly took ad-

vantage of verbal information during swimming lessons demonstrated a less accurate technique of movements. Since the differences between the experimental and control groups were already visible just after only seven lessons, it can be presumed that the gap will increase in the further learning process. Thus, the pupils from the control group will perpetuate their incorrect movements in the successive repetitions, which will cause structural changes around synapses and, consequently, lead to remembering errors in the permanent memory.

Later elimination of undesired movements will require additional time and effort. Claude Shannon, presently considered the father of the classical information theory, in his theory about the communication of information stated that information could be transmitted in an optimal way through an interference channel [18]. Shannon claimed that disturbances slow down the transmission speed, but do not make the information less accurate. Moreover, he maintained that there is always a coding and decoding method, due to which the probability of error occurrence can become deliberately small. This experiment confirms that gestures can be an effective method of coding and decoding information, provided a previous agreement as to their meanings between the teacher and the learner.

In the 1970s, Pyżow [19–21] dealt with application of gestures during swimming lessons. Since then, there has been a gap in research on this issue. In spite of that, the issue of using gestures in order to eliminate incorrect movements while learning swimming seems to me worth discussing, because (as the results of the experiment show) information communicated in this way influences considerably accuracy of acquirement of the swimming technique.

In the present experiment gestures turned out to be more efficient than verbal communication, because the eye receives a larger quantity of information per second than the ear; moreover, for children images are clearer and help understand better the whole movement structure [8]. In addition, gestures reach the pupil even in difficult conditions (considering a general buzz at the swimming pool), so they are an efficient substitute of words.

Contemporary psychology tends to attribute more and more importance to the communication processes [22]. While a new motor activity is being taught, the movement course is directed by the information which becomes the key to its successful acquirement. These pieces of information have been called by Bogen [23] "basic supporting points". According to him directing concentration of consciousness to the most important elements increases teaching effectiveness and shortens

the time of acquiring a new motor task. Also, in this experiment the most important pieces of information were encoded in a series of gestures and became the stimuli to which the pupil reacted in a proper way, correcting errors in movements, and as a result, he/she could swim technically better.

Domaradzki [24] dealt with application of gestures during swimming lessons. He observed teachers while they were working and distinguished the following groups of gestures: teaching, correcting, reinforcing and organizing. On the basis of his research he drew a conclusion that experienced teachers used visual communication more than novice ones. Moreover, he noticed that the most commonly used gestures regarded organization of a lesson and correction of wrong movements. Unfortunately, Domaradzki did not examine an influence of gestures on accuracy of acquirement of the swimming technique.

Also, Dybińska [25] studied visual communication. In her experiment she used visual information in the form of programme cards. By means of them, visual information was communicated to pupils before a motor task started, during its execution and after the lesson when the teacher and pupils were discussing their mistakes. In Dybińska's experiment, the visual information contained on the programme cards was an efficient method of communicating information about movements. In this work, as well, visual communications (in this case – gestures) appeared to be an efficient way to communicate information about movements and how to correct errors when they occur.

In other works on the visual communication of information in teaching swimming activities Dybińska [26] stated that implementation of techniques of effective communication of visual information can have a considerable impact on effects in teaching motor activities, which has been confirmed by this experiment. Making use of gestures while teaching motor activities is especially important in the conditions when verbal communication appears inefficient. In such a case, gesture becomes the only source of information how to correct an error when it occurs.

## Conclusions

Visual information, communicated by means of “the language of gestures”, has an influence on the accuracy of learning swimming motor activities.

1. In teaching swimming motor activities, visual information is more efficient than verbal information.

## Acknowledgements

I would like to express my gratitude to Prof. Kryszyna Zatoń from the University School of Physical Education in Wrocław, supervisor of my Ph.D. thesis, for numerous suggestions, consultations and inspiration to further research.

## References

1. Guła-Kubiszewska H., Didactic effects of self-regulatory motor learning [in Polish]. *Studia i Monografie AWF we Wrocławiu*, 86.
2. Brooks G.A., Fahey T.D., Exercise physiology: human bioenergetics and its applications. Macmillan Publishing, New York 1985.
3. Borroni A.M., Fichtenthaltz H., Woodside B.L., Teyler T.J., Role of voltage-dependent calcium channel long-term potentiation (LTP) and NMDA LTP in spatial memory. *J Neurosci*, 2000, 20, 9272–9276.
4. Geinisman Y., Structural synaptic modification, associated with hippocampal LTP and behavioral learning. *Cereb Cortex*, 2000, 10, 952–962.
5. Baudry M., Lynch G., Remembrance of arguments past: how well is the glutamate receptor hypothesis of LTP holding up after 20 years? *Neurobiol Learn Mem*, 2001, 76, 284–297. doi:10.1006/NLME.2001.4023.
6. Villarreal D.M., Do U., Haddad E., Derrich B.E., NMDA receptor antagonists sustain LTP and spatial memory: active processes mediate LTP decay. *Nat Neurosci*, 2002, 5, 48–52. doi:10.1038/Nn776.
7. Zatoń K., Verbal communication during Physical Education classes [in Polish]. *Studia i Monografie AWF we Wrocławiu*, 1995, 48.
8. Czabański B., Selected problems of learning and teaching sports techniques [in Polish]. AWF, Wrocław 1998.
9. Zatoń K., The effectiveness of verbal information while teaching motor functions in swimming [in Polish]. *Rozprawy Naukowe AWF we Wrocławiu*, 1981, 16, 242–253.
10. Zatoń K., The influence of quality and quantity of verbal information on the creation of plans and programs of motor activity [in Polish]. In: Bober T. (ed.) V Szkoła Biomechaniki i Nauczania Techniki Sportowej. *Zeszyty Naukowe AWF Wrocław*, 1986, 42, 237–250.
11. Zatoń K., Optimization of Verbal Method of Teaching the Breaststroke [in Polish]. *Kultura Fizyczna*, 1993, 7–8, 19–21.
12. Ungerer D., Zur Theorie des sensomotorischen Lernens. 3<sup>rd</sup> edition. Hofmann, Schorndorf 1977.
13. Kotarbiński T., The treatise of good work [in Polish]. Zakład Narodowy im. Ossolińskich, Wydawnictwo Polskiej Akademii Nauk, Wrocław–Warszawa–Kraków 2000.
14. Pietrusik K., Kałmuczak A., Kokoszko J., Dimorphic diversity of selected somatic and motor properties in young swimmers [in Polish]. In: Problems of Sexual Dysmorphisms in Sport: Post-Conference Materials of the 4<sup>th</sup> International Scientific Conference. AWF, Katowice 1997, 118–122.
15. Ignasiak Z., Conditioning of the development of school-age children's morphological and motor characteristics in the aspect of biological age [in Polish]. *Studia i Monografie AWF we Wrocławiu*, 1988, 19.
16. Burzycka-Wilk D., The effectiveness of immediate information in the process of teaching motor activities [in Polish]. PhD Thesis, AWF, Wrocław 2008.

17. Ferguson G.A., Takane Y., Statistic analysis in psychology and pedagogy [in Polish]. PWN, Warszawa 1997.
18. Shannon C.E., Weaver W., A mathematical theory of communication. The University Press, Illinois 1949.
19. Pyżow W.W., Correction of errors in swimming techniques of the self-taught [in Polish]. *Wychowanie Fizyczne i Higiena Szkolna*, 1966, 5, 15–18.
20. Pyżow W.W., Language of gestures [in Polish]. *Kultura Fizyczna*, 1968, 11, 518–520.
21. Pyżow W.W., Application of the immediate information method in the initial phase of learning swimming [in Polish]. *Kultura Fizyczna*, 1969, 10, 478–482.
22. Tomaszewski T., Main ideas of contemporary psychology [in Polish]. Wydawnictwo Akademickie Żak, Warszawa 1998.
23. Bogen M. M., Problems of increasing effectiveness of teaching motor activities. [in Polish], *Zeszyty Naukowe AWF we Wrocławiu*, 1989, 50, 150–154.
24. Domaradzki J., Experienced and novice teachers of swimming vs their language of gestures [in Polish]. Master Thesis, AWF, Wrocław 1995.
25. Dybińska E., Effectiveness in the learning and teaching of swimming skills to children at the younger school age in the light of the applied method. *Annales Universitatis Mariae Curie-Skłodowska, Sectio D Medicina*, 2004, 95, 14, 496–502.
26. Dybińska E., Communicating visual information in teaching swimming skills as the criterion of effectiveness of the didactic process [in Polish]. In: Bartoszewicz R., Koszczyc T., Nowak A. (eds.), Didactics of Physical Education vs. Educational Needs. WTN, Wrocław 2005, 407–416.

Paper received by the Editors: April 23, 2009.  
Paper accepted for publication: April 21, 2010.

*Address for correspondence*

Dorota Burzycka-Wilk  
Instytut Turystyki i Rekreacji  
Wydział Wychowania Fizycznego i Fizjoterapii  
Politechnika Opolska  
ul. Prószkowska 76  
45-758 Opole, Poland  
e-mail: d.burzycka-wilk@po.opole.pl



# LEARNING BY ANALOGIES: IMPLICATIONS FOR PERFORMANCE AND ATTENTIONAL PROCESSES UNDER PRESSURE

doi:10.2478/v10038-010-0025-z

LINDA SCHÜCKER<sup>1\*</sup>, LISA EBBING<sup>1</sup>, NORBERT HAGEMANN<sup>2</sup>

<sup>1</sup> Institute of Sports Science, University of Münster, Germany

<sup>2</sup> Institute of Sports and Sports Science, University of Kassel, Germany

## ABSTRACT

**Purpose.** According to the self-focus theory of choking under pressure, conscious control of automated processes leads to a disruption of movement execution and deterioration in performance. In this study we examined whether analogy learning is a method to prevent choking under pressure. **Basic procedures.** Novice golfers learned the full swing over a period of six weeks either in a traditional way with technical instructions or with analogy instructions. Their performances were assessed in an indoor golf simulator. Attentional processes were measured using a dual task paradigm. Different kinds of learning instructions are linked to measures of skill-focused attention under low and high pressure conditions. **Main findings.** Performance scores in the dual task show that pressure leads to an increase in skill-focused attention of the technical learning group, compared to a decrease in skill-focused attention of the analogy learning group. **Conclusions.** Attentional processes under pressure are related to the method (analogy vs. technical instructions) implemented in the learning phase.

**Key words:** motor learning, implicit learning, attentional processes

## Introduction

Scott Hoch, an American professional golfer was an excellent player for a long time but he had never won a major championship. In 1989 he should have won the Masters in Augusta (Georgia) but he did not. Hoch led Nick Faldo by one on Number 17 but missed a relatively short par putt and fell back. This missed putt, which every professional golf player, including Hoch, would have executed successfully in other circumstances led to a tie on Number 18 and to a sudden death play-off. On the first hole of the play-off Hoch had the possibility to two-putt and win the Masters. The first putt rolled about two feet past the cup so he could have quite easily putted the second to win. He took a long time to decide how to play and finally shot the ball five feet past the hole. For the second time in this tournament, a high level of performance pressure led to a breakdown of performance. In the end Hoch lost the Masters.<sup>1</sup>

Choking under pressure is defined as performing more poorly than expected given one's skill level in situations with increased performance pressure [1].

Pressure results from the individual desire to perform as well as possible in situations which demand high level performance [2]. Despite optimal motivation and individual striving to do one's best, performance drops to a suboptimal level. It is important to note that this less than optimal performance is not just a random fluctuation in performance, in contrast it results in response to a high pressure situation [3].

Two contrasting attentional theories have been proposed to account for skill failure in high pressure situations [e.g. 4]. Distraction theories suppose that pressure creates a distracting environment that shifts attention away from skill execution to task irrelevant cues, for example, worries about the situation [e.g. 5, 6–8]. On the contrary, self-focus theories (also termed explicit monitoring theories) suggest that performance pressure raises self-consciousness and causes the expert performer to pay attention to the process of performing and its step by step control [e.g. 1, 2, 8]. These contrasting predictions about the underlying processes of choking under pressure have been addressed in many studies. There is support for the distraction hypothesis in tasks that load heavily on working memory, for example, mathematical problem solving [e.g. 5]. However, for sensorimotor skills, the self-focus theories have received strong support in explaining performance decrements under pressure.

\* Corresponding author.

<sup>1</sup> Top 10 Worst Golf Chokes and Collapses by Brent Kelley ([http://golf.about.com/od/historyofgolf/a/worst\\_chokes\\_2.htm](http://golf.about.com/od/historyofgolf/a/worst_chokes_2.htm)).

### Self-focus explanations for choking in sensorimotor skills

Explicit monitoring theories have received support from studies directly manipulating the focus of attention as well as from training studies which provide indirect support for a self-focus explanation of choking. Results in various sensorimotor skill domains show that directing attention to the execution of well learned motor tasks leads to deterioration in performance. For example, Beilock et al. [9] studied this effect in golf putting and dribbling with a soccer ball. In both sports, they found that an internal focus of attention led to performance decrements for experienced players on behavioral measures (higher number of strokes per holes in golf and slower completion of a dribbling course in soccer). Similar effects were found in baseball [10], in soccer [11] and in field hockey [12]. These studies typically manipulate attention focus by the use of dual task paradigms. The secondary task either directs attention to external stimuli (subjects, for example, have to perform an auditory monitoring task) or to skill execution (subjects, for example, monitor the side of the foot that most recently contacted the ball in a dribbling task) [9]. For skilled performers, attention to the step-by-step control of proceduralized skills leads to poorer performance, whereas a focus on external stimuli does not harm performance. Beilock et al. [13] used a different kind of manipulation to investigate attentional focus effects. Novice and expert golfers were instructed to either emphasise accuracy or speed while executing a series of putts. Experts putted more accurately under speed instructions, whereas novices were more accurate under accuracy instructions. Speed instructions intended to reduce the time to explicitly monitored movement execution. Hence, the automated skill of an expert benefits from instructions that limit attention to performance execution. According to Masters and colleagues [14, 15] an inward focusing of attention leads to conscious processing of explicit knowledge with the result of an isolated concentration on specific components of the movement. As a consequence, the overall sequence of the movement is disturbed and not executed smoothly. Masters [14] terms this explanation the “reinvestment hypothesis”. Beilock and Carr [1] talk about deterioration in performance through explicit monitoring or execution focus theories. Attention on the step-by-step control of an automated movement leads to its breakdown. Wulf and colleagues [e.g. 16–18] have conducted a series of studies on the attentional focus effect. Their explanation is the “constraint action hypothesis” which is less cognitive in nature than Master’s [14] reinvest-

ment hypothesis. The constraint action hypothesis assumes that the conscious control of a movement leads to a constraint of the motor system by interfering with automatic “processes that would ‘normally’ regulate” movement coordination [17, p. 6]. Support for this explanation comes from studies using electromyographic (EMG) outcome measures [e.g. 16, 19]. Although these explanations (reinvestment, explicit monitoring or constraint action) propose different specific processes, they all have in common that an inward focus on movement execution disrupts automated processes, which leads to deterioration in performance.

The question is whether the previously described attentional focus effect applies to skilled performance when executed under high amounts of pressure. Training studies provide indirect evidence for an inward shift of attention on movement execution in pressure situations. Beilock and Carr [1, Experiment 4] examined whether practice in dealing with self-focused attention or training in a dual task environment would reduce choking under pressure. Participants practiced the golf putt under three different learning conditions and were then exposed to a pressure situation. The conditions were single task, dual task (auditory monitoring) or self-consciousness (participants were videotaped in order to direct attention to themselves and their performance). Beilock and Carr found that performance decrements in a pressure situation were eliminated by self-consciousness training [1]. They concluded that training under internal focus conditions helps performers to adapt to the type of attentional focus that occurs under pressure. Lewis and Linder [8] had used this study design before and also found that learning a skill in a self-consciousness environment prevents performers from choking.

Important insight into the underlying attentional processes of choking comes from a study conducted by Gray [20]. He directly investigated the effects of performance pressure in a baseball batting task. College baseball players batted under two different dual task conditions (judging tone frequency or direction of bat movement on tone presentation). When placed under pressure the level of skill-focused attention was significantly higher, indicated by better performance in the skill-focused dual task: Participants judged the direction of bat movement significantly more correctly in the pressure condition compared to a control group who performed the dual task without pressure. There was no difference in the tone judgement task. The increase in skill-focused attention was associated with degradation in batting performance as well as changes in batting kinematics. This finding provides the first direct evidence

that choking under pressure is caused by an inward shift of attentional focus as proposed by Baumeister [2].

Jackson and Willson [21] proposed a method to prevent the reinvestment of explicit rules under pressure. This method holds thinking of a global cue rather than thinking about detailed technical rules. Experienced golfers had to put under conditions of low and high state anxiety. A set of different attentional strategies was given, including a swing thought condition. Participants' putting performance was assessed. Choking under pressure was significantly reduced when participants verbalised a single global cue word (swing thought). In a recent study it was also shown that a swing thought condition reduced choking under pressure [4].

#### Implicit learning to prevent choking under pressure

Masters [14] relates an inward shift of attention to conscious processing of explicit knowledge of how the skill works. More specifically he talks about reinvestment of conscious knowledge under high amounts of stress. Explicit knowledge about movement execution includes technical know-how and rules about the movement processes. Beilock and Carr [1, Experiment 1] were able to demonstrate an effect of level of expertise on the amount and content of generic and episodic knowledge of golf putting. Reduced episodic memories of specific puts in golf among experts indicate that performance is controlled by automated procedural knowledge. According to explicit monitoring theories of choking, this proceduralization makes performance vulnerable to deterioration of performance under pressure.

An approach to prevent choking is the attempt to avoid the build-up of a conscious representation about the movement process during the learning phase. Two types of learning theories that operate without explicit knowledge have been reported in the literature: implicit learning and the related analogy learning. In the former type of learning a skill is acquired without knowledge of explicit rules, but rather learned along the way without necessarily intending to do so. In Masters' [14] experiment subjects learned a golf putting skill either explicitly or implicitly and their performances were assessed under stress in a post-test condition. The hypothesis that performers with a small amount of explicit knowledge were less prone to choking was supported by the results.

However, by implicit learning the learning progress will take a long way as no rules or other aids to acquire the skill are given. An alternative is provided by analogy learning. Analogy learning in sport operates with biomechanical metaphors or metaphors of motion instead

of explicit rules and technical know-how. Masters [22] states the following: "The aim is to get the pupil to perform the to-be-learned skill using one general analogical rule which acts as a biomechanical metaphor encompassing many of the technical rules necessary for successful execution of the skill. The learner follows this simple analogy and inadvertently employs these camouflaged rules" [22, p. 538].

Liao and Masters [23] examined the hypothesis that analogy learning is implicit in nature and will therefore show similar characteristics to implicit learning. They instructed table tennis novices to learn the topspin forehand either implicitly (no additional instructions but secondary task in the learning phase), explicitly (set of 12 basic techniques on how to hit topspin) or by analogy (instruction to pretend to draw a right-angled triangle with the bat). Their results confirmed that the implicit characteristics (a small number of explicable explicit rules, robustness under secondary task load and a lack of correlation between confidence and performance) also apply to analogy learning (Experiment 1). In a second experiment they were furthermore able to demonstrate that the performance of an analogy learning group was not affected by stress, suggesting that this method may be a possible means to prevent choking under pressure. Using the same approach as Liao and Masters [23] (learning the table tennis forehand by analogy), Law et al. [24] showed that supportive audiences induced performance decrements in the explicit learning group but not in the analogy learning group. It is assumed that the presence of supportive audiences leads to the same processes as stress, an inward shift of attention and in turn to a deterioration in performance. Analogy versus explicit learning has predominantly been studied in table tennis. Recently Lam et al. [25] investigated this subject in a modified basketball shooting task. In a dual task transfer test performance decrements were shown for explicit and control conditions, but not for the analogy learning group.

Contrasting results are shown in a recent study [26]. The table tennis forehand was performed 10,000 times by an analogy and explicit learning group. After 1,400 and 10,000 repetitions, performance under pressure was assessed but did not show any difference between the groups despite differences in rule formation. This result does not confirm that the amount of explicit knowledge is detrimental for performance under pressure.

#### The present study

The present experiment was designed to evaluate whether analogy learning can be used as a sound method

to prevent choking under pressure. For the full swing in golf a learning paradigm including two different learning conditions (one classic condition with technical instructions and one condition with analogy learning) was implemented. Different learning methods for the golf swing and their effectiveness are also of applied relevance for golf clubs as they teach the golf swing to novices on a daily basis. When put under pressure, it is assumed that the analogy learning group will focus less internally and show better performance than the technical learning group. This experiment combines studies that examine learning conditions with regard to choking under pressure and studies that directly measure attentional processes. We do not only want to show that the analogy group will show better performance under pressure, but we also want to show directly that different attentional processes apply to technical and analogy learning group in the pressure condition. This will be done by using a skill-focused dual task so that performance in the dual task can be used as an indicator of attention focus. Under high pressure we expect that the technical learning group will perform better in the dual task than under low pressure thus showing an increase in internal focus of attention. We assume, furthermore, that the analogy learning group will show similar dual task performance under low and high pressure as they are protected from focusing internally under pressure by learning by analogy.

## Material and methods

### Participants

Fifty-one participants (33 male, 18 female) aged 21–65 years ( $M = 32.7$ ,  $SD = 12.3$ ) volunteered for this study. They were randomly assigned to either an analogy learning group ( $n = 28$ ) or a technical learning group ( $n = 23$ ). 49 of the participants were right handed, two participants were left handed. All participants were inexperienced in golf playing and had no official permission to play golf in Germany (inclusion criteria to participate in this study). After completion of the learning experiment subjects took an assessment to get



Figure 1. ProTee Golf Simulator System  
(with permission from ProTee United)

this official permission. A questionnaire tapped the participants' experience in golf, 34 of them had taken a trial course but never played golf on a regular basis. The study was conducted according to the ethical guidelines of the American Psychological Association (APA).

### Apparatus

To measure swing performance an indoor golf simulator was used (ProTee Golf Simulator System, Zaltbommel, The Netherlands), see Figure 1. The player hits a ball and the system measures the swing characteristics with 94 optic high speed sensors. Two parameters were taken to evaluate the participant's swing performance: carry and off-line. These parameters mainly determine the overall quality of the swing. Carry is measured in meters (m) and is defined as the length of ball flight up to the point of impact on the ground. Off-line is given in degree (°) to assess deviance from straight ball flight. The best performance is given when the shot is preferably long and straight.

To assess attention focus a skill-focused dual task design similar to the one used in Gray's [20] experiments was used. A single auditory tone was presented while participants performed the swing. After completion of the swing they had to judge the swing phase (backswing, downswing and follow through) in which the tone appeared. Pictures of each phase were shown and the

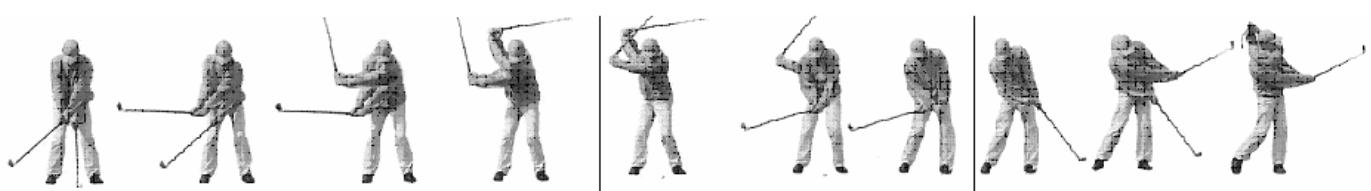


Figure 2. Pictures of the backswing, downswing and follow through phase according to Lehnertz, Heuler and Quirmbach [27] used for the skill-focused dual task (with permission from Deutscher Golf Verband e.V.)

participants were asked to indicate the picture that corresponded to the time interval the tone appeared during the swing, see Figure 2. The tone was linked to a light signal so the actual time interval in which the tone appeared could be identified by video analysis. An independent rater who had not been introduced to the aim of the study analysed the videos frame by frame with the program V1 Home 2.0 to determine in which movement phase the light was visible, meaning the tone was presented to the participants.

### Procedure

During a six-week learning phase a golf-professional instructed the participants to learn the full swing in golf. Each participant had a one-hour golf lesson together with 5–7 other participants once a week. After this one-hour lesson there was another hour of free practice. The participants were assigned to two different learning conditions. An instructional set for each condition was developed with the golf-professional and experienced coaches before the experiment. The instructional set included rules and metaphors for basic position and swing phases as well as instructions for error corrections as this is an important aspect when learning the golf swing. On the whole, there were nine technical instructions and associated metaphors for basic position, split into grip position (4), pressure on the grip (1) and posture (4). For the different phases of the swing there were 21 technical rules and related metaphors, separated into backswing (12), downswing (5) contact (2) and position of golf club head (2). Individual characteristics of the different learning groups and examples are presented in the following section.

*Technical learning group.* Technical instructions typically contain movement descriptions and include biomechanical and physiological processes. The movement of single body parts and their relative position are described in detail. Added to this are descriptions of how the muscles should be activated and where tension on muscles is necessary. Thus, these instructions include a high number of explicit rules of how the skill works. On the basis of a textbook on learning the golf swing [27] and with experience of the golf-professional and coaches, the specific technical instructions were developed. For example, the instruction for the right grip was as follows: “The pressure of both hands on the grip is equal. The wrists should move freely, hands should stay on the grip while swinging.” The technical instruction for the correct posture was the following: “From an upright position the core is bended slightly to the front. The knees are also bended so that the club touches

the ground. Body weight should be evenly distributed between heel and ball.”

*Analogy learning group.* In the learning process some teachers draw analogies to give the learner a better understanding of how the skill works. According to Liao and Masters [23] “the function of the analogy is to integrate the complex rule structure of the to-be-learned skill in a simple biomechanical metaphor that can be reproduced by the learner” [p. 308]. Thus, in one single analogical rule many of the technical rules that are necessary for successful execution of the skill are encompassed [22]. In contrast to Masters’ conception of analogy learning, we do not operate with a single analogy but with a whole set of analogies to learn the full swing in golf. We believe that for the new learning of a complex motor movement as the golf swing (unlike the usually studied table tennis forehand) a single metaphor cannot encompass all the necessary aspects of this movement. A textbook for learning golf operating with many analogies [28] helped to develop the instructional set for the analogy group. The golf professional and coaches provided further information for creating several analogies. The instruction for the correct grip was the following: “Imagine you have an open tube of toothpaste between your hands and the contents must not be pushed out.” The correct posture was taught with the following instruction: “The posture is comparable to a light lowering of the bottom on the rim of a bar stool.”

*Test intervals.* The first performance test was done after the first training session and used as a baseline measure. After the fifth session there was a second performance test to measure training progress. Each performance test included 10 full swings in the ProTee Golf Simulator System. After the sixth session a test under conditions of low pressure and a test under conditions of high pressure were performed. Subjects were told they had to perform two sets of 12 full swings in the ProTee Golf Simulator.

*Pressure conditions.* The second set of swings was introduced as a part of the test to get the official permission to play golf in Germany, whereas the first set was introduced as a preparation set. Without this official permission you are not allowed to play on a golf course in Germany, so the test for this permission is very important for everyone who wants to play golf in Germany. Subjects were told that the indoor learning conditions differ from the outdoor environment on the actual golf course. For this reason they would be able to show their indoor learned performance in an indoor test. For a good result (long and straight ball flight) bonus hits would be given for the outdoor permission test. The highest reward was a bonus of 2 hits on 3 holes of 9 to

be played in the test round. In this way a realistic pressure manipulation was obtained, showing the high relevance of the indoor test on the later official permission outdoor test. In each of the two sets the skill-focused dual task was conducted. As a comprehensible explanation for the tone judgement task, participants were told that correct judgement of the tone was used to determine the stability of the swing. After completion of the two tests subjects were debriefed and participants finally finished the experiment with the full test to get the official permission to play golf in Germany.

#### Statistical analysis

All data analyses were computed with SPSS 15. Repeated measure ANOVAs with between subject factors of learning condition and within subject factors for first and second test intervals and low and high pressure conditions were computed for the different parameters. For effect sizes  $\eta_p^2$  was calculated.

### Results

#### Learning progress

As not all the participants were present in the baseline test after session one and the learning progress test after session five the performance of only 46 participants (25 in the analogy learning group and 21 in the technical learning group) was analysed. Both groups showed a significant improvement from the first to the fifth training session on the parameter carry,  $F(1, 44) = 14.28, p < 0.05, \eta_p^2 = 0.25$ . The interaction effect of test interval and learning condition was not significant,  $F(1, 44) = 0.07, p = 0.79$ . For off-line there was neither a significant main effect,  $F(1, 44) = 0.01, p = 0.92$ , nor a significant interaction effect,  $F(1, 44) = 0.43, p = 0.51$ . The main effect for learning condition was neither significant for carry,  $F(1, 44) = 1.38, p = 0.25$ , nor for off-line  $F(1, 44) = 0.00, p = 0.98$ . Technical and analogy learning groups did not differ significantly with regard to learning progress. Descriptive values of the baseline test and the test after fifth session are presented in Table 1.

#### Low and high pressure test

Looking at the tone judgement task, there was a significant interaction of learning group and pressure condition,  $F(1, 49) = 14.36, p < 0.05, \eta_p^2 = 0.23$ , see Figure 3. The technical and the analogy learning groups showed similar performances in the tone judgement task when

Table 1. Descriptive values for analogy and technical learning groups in baseline test and after fifth learning session

		After first session (baseline)		After fifth session	
		M	SD	M	SD
Carry (m)	Analogy learning	70.35	25.30	81.86	27.37
	Technical learning	80.16	26.59	90.19	32.10
Off-line (°)	Analogy learning	12.90	5.52	12.23	4.99
	Technical learning	12.38	3.58	12.85	5.71

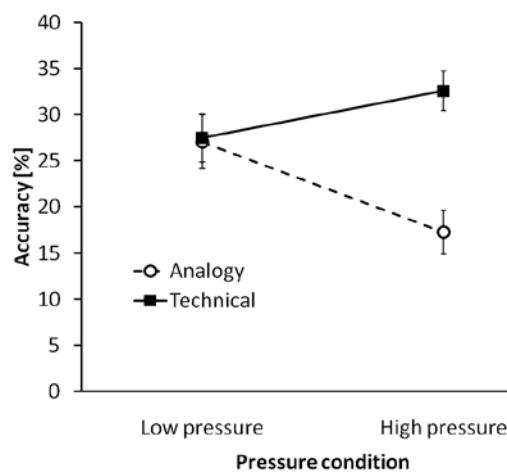


Figure 3. Mean accuracy of tone judgement (%). Performance of analogy and technical learning groups in low pressure and high pressure conditions

pressure level was low. However, at a high level of performance pressure the technical learning group showed better performance in judging the occurrence of the tone in relation to the swing phase ( $p < 0.001$ ) than the analogy learning group. Post hoc paired sampled t-tests showed a decrease in skill-focused performance for the analogy learning group  $t(27) = 4.32, p < 0.001$  and a trend to increase in dual task performance for the technical learning group,  $t(22) = 1.5, p = 0.07$ .

The analysis of the two performance parameters, carry and off-line, did not yield any significant effects, main effect pressure (carry),  $F(1, 49) = 1.13, p = 0.29$ , interaction effect pressure and learning condition (carry),  $F(1, 49) = 0.37, p = 0.37$ , main effect pressure (off-line)  $F(1, 49) = 1.28, p = 0.26$ , interaction effect pressure and learning condition (off-line)  $F(1, 49) = 1.66, p = 0.20$ . The main effect for learning condition was neither significant for carry,  $F(1, 49) = 0.88, p = 0.35$ , nor for off-line  $F(1, 49) = 0.16, p = 0.69$ . Although statistically not significant, the analogy learning group shot the ball 3 m further in the high pressure compared to the low pressure condition, whereas the technical learning group kept the same length, see Table 2 for descriptive values.

Table 2. Descriptive values for analogy and technical learning groups in low and high pressure conditions

		Low pressure		High pressure	
		M	SD	M	SD
Carry (m)	Analogy learning	80.82	23.26	83.80	26.87
	Technical learning	89.69	27.33	89.64	30.00
Off-line (°)	Analogy learning	16.14	7.48	14.33	8.94
	Technical learning	14.52	6.11	14.64	5.46

None of these results was statistically significant

## Discussion

In this study we examined whether different learning conditions (analogy learning and technical learning) lead to different performance and attentional processes under conditions of high pressure. Participants learned the full swing in golf in a six-week learning period. We determined performance parameters in an indoor golf simulator and attentional processes with a dual task paradigm.

One of the assumptions was that the analogy learning group and the technical learning group would not differ in learning progress. The results supported this assumption. Both groups showed parallel learning progress on the parameter carry. However, after four training sessions no progress was found on the parameter off-line. It follows that analogy learning as a form of implicit motor learning does not interfere with learning progress as compared to a classic learning situation with technical instructions. These findings support Masters' [22] view on the advantages of analogy learning. However, it has to be taken into account that the analogy learning method in this study differs from Master's view as in the present study we operate with a whole set of analogies.

A major finding of this study was the difference between the two learning groups in dual task performance under pressure. Attention focus was measured with a design similar to Gray [20]. Participants had to indicate in which phase of the golf swing a tone was presented during movement execution. The skill-focused attention measured with this dual task was comparable in the analogy and technical learning groups in a low pressure situation. This means that the presented tone was judged equally by the two groups in relation to the swing phase. This pattern changed when participants were put under performance pressure. Those who learned with explicit technical rules displayed a trend for an increased attention focus on movement execution as shown by better performance in the skill-focused dual task (a higher number of correct tone judgements).

Opposed to that, the analogy learning group displayed a decreased attention focus on skill execution which was a surprising result. There was no reason to believe that pressure would actually reduce skill-focused attention of the analogy learning group, we expected that dual task performance of this group would not be affected by pressure.

It seems that analogy learning and technical learning lead to different attentional processes in a high stress situation. Explicitly acquired knowledge is activated in a performance pressure situation [14]. In analogy learning knowledge seems to be processed differently as it is not activated under pressure. Even though using verbal instructions, the motion metaphors might be processed and stored in a visuospatial form rather than in the form of explicable verbal rules. However, we have to ask why the analogy learning group did not display a similar amount of internal focused attention under low and high pressure conditions but actually showed a decrease in internal focus of attention under pressure. At this point we cannot provide a sound explanation for this finding.

Looking at the performance parameters the expected picture is not as clear. We assumed that the analogy learning group would show better performance under pressure than the technical learning group. As reported, we did not find any significant main or interaction effects on the performance parameters (carry and off-line) for different pressure and learning conditions. This means we did not observe performance decrements under pressure for either of the learning groups. We would have expected to observe the phenomenon of choking under pressure for the technical learning group, however, the results did not support our assumption. We assumed that an increased attentional focus on movement execution would be related to worse performance. Despite differences in dual task performance (technical learning group showed an increase in skill focused attention under pressure compared to analogy learning group) we did not observe differences in performance. A reason for the findings not being significant could be the degree of automation of the golf swing. An internal attentional focus on movement execution does lead to performance decrements when the to-be-performed skill is already well automated [e.g. 9, 10]. As subjects in this study learned the skill over a six-week period, the level of proceduralization of the skill might not have been enough for performance decrements with an increased internal attentional focus. It would be interesting to look at the results of pressure after a longer learning interval as it was done in the table tennis study by Koedijker et al. [26].

A limiting factor of this study, which has to be taken into account, is that no objective measure of stress level was implemented. Assessing stress level after the low pressure pre-test might have disturbed participants with respect to the following high pressure post-test, that is why no questionnaire was distributed between the two performance sets. Still, the amount of actually felt performance pressure can only be assumed by the realistic implementation of the stress manipulation. Even though we do not have an objective manipulation check we prefer this lifelike pressure manipulation to the manipulation used in many laboratory settings. The test to get the official permission to play golf in Germany puts participants into a real performance situation. The studies that use monetary rewards or artificial social pressure seem to manipulate pressure successfully – but whether this pressure is comparable to real life pressure situations has to be questioned.

The fact that performance had not significantly improved on both performance parameters might also be explained by the length of the learning interval. Four weeks lay between the baseline and the performance test session for learning progress. However, carry has to be seen as one of the most important parameters and an improvement here shows that participants actually did learn and improve their full swing in golf. Furthermore, it has to be taken into account that the baseline measure took place after the first training. Participants had already acquired main parts of the golf swing during the first session. The considerable increase in learning progress that one has to expect when a new skill is learned might have already taken place during the first learning session before the baseline measurement. This could explain why there were no big differences between baseline and performance tests for learning progress.

As promising as the analogy learning approach may seem, it is a means against choking under pressure that can only apply to persons who have not yet acquired a skill over a long learning period. Experts who have already learned the skill in the traditional, explicit way will have already stored a large number of explicit rules. Learning by analogies might not be helpful to prevent choking under pressure as they do no longer have to learn the performance pattern of the skill. Nevertheless it would be interesting to let experts train with motion metaphors and assess performance under pressure later on. Yet, Jackson and Willson's [21] approach to prevent choking by using global cue words might better fit performances at an expert level.

## Conclusions

The aim of our study was to link two different kinds of learning strategies to performance and an assessment of attentional processes under pressure. Both learning strategies were equally effective in the learning process. We were able to show different attentional processes of analogy and technical learning groups under pressure using a skill-focused dual task. This provides evidence for the involvement of attentional processes in performing under pressure. However, we were not able to show that differences in attentional processes are linked to performance parameters. Showing differences in skill focused attention under pressure dependent on the strategy used during the learning phase is an important finding but we cannot claim that analogy learning is more effective than technical learning in preventing people from choking.

## References

1. Beilock S.L., Carr T.H., On the fragility of skilled performance: What governs choking under pressure? *J Exp Psychol Gen*, 2001, 130 (4), 701–725. doi:10.1037/0096-3445.130.4.701.
2. Baumeister R.F., Choking under pressure: self-consciousness and paradoxical effects of incentives on skillful performance. *J Person Soc Psychol*, 1984, 46 (3), 610–620.
3. Beilock S.L., Gray R., Why do athletes choke under pressure? In: Tenenbaum G., Eklund R.C. (eds.), *Handbook of Sport Psychology*. John Wiley & Sons, New Jersey 2007, 425–444.
4. Gucciardi D.F., Dimmock J.A., Choking under pressure in sensorimotor skills: Conscious processing or depleted attentional resources? *Psychol Sport Exerc*, 2008, 9 (1), 45–59. doi:10.1016/j.psychsport.2006.10.007.
5. Beilock S.L., Kulp C.A., Holt L.E., Carr T.H., More on the fragility of performance: Choking under pressure in mathematical problem solving. *J Exp Psychol Gen*, 2004, 133 (4), 584–600. doi:10.1037/0096-3445.133.4.584.
6. Wine J., Test anxiety and direction of attention. *Psychol Bull*, 1971, 76 (2), 92–104.
7. Eysenck M.W., Derakshan N., Santos R., Calvo M.G., Anxiety and cognitive performance: Attentional control theory. *Emotion*, 2007, 7 (2), 336–353. doi:10.1037/1528-3542.7.2.336.
8. Lewis B.P., Linder D.E., Thinking about choking? Attentional processes and paradoxical performance. *Pers Soc Psychol B*, 1997, 23 (9), 937–944.
9. Beilock S.L., Carr T.H., MacMahon C., Starkes J.L., When paying attention becomes counterproductive: Impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *J Exp Psychol Appl*, 2002, 8 (1), 6–16. doi:10.1037/1076-898X.8.1.6.
10. Castaneda B., Gray R., Effects of focus of attention on baseball batting performance in players of differing skill levels. *J Sport Exerc Psychol*, 2007, 29 (1), 60–77.
11. Ford P., Williams A.M., Hodges N.J., Online attentional-focus manipulations in a soccer-dribbling task: Implications for the proceduralization of motor skills. *J Motor Behav*, 2005, 37 (5), 386–394.
12. Jackson R.C., Ashford K.J., Norsworthy G., Attentional focus, dispositional reinvestment, and skilled motor performance under pressure. *J Sport Exerc Psychol*, 2006, 28 (1), 40–68.

13. Beilock S.L., Bertenthal B.I., McCoy A.M., Carr T.H., Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychon Bull Rev*, 2004, 11 (2), 373–379.
14. Masters R.S.W., Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *Br J Psychol*, 1992, 83, 343–358.
15. Masters R.S.W., Polman R.C.J., Hammond N.V., “Reinvestment”: A dimension of personality implicated in skill breakdown under pressure. *Pers Indiv Differ*, 1993, 14 (5), 655–666.
16. Vance J., Wulf G., Töllner T., McNevin N., Mercer J., EMG activity as a function of the performer’s focus of attention. *J Mot Behav*, 2004, 36 (4), 450–459. doi:10.3200/JMBR.36.4.450-459.
17. Wulf G., Attentional focus and motor learning: A review of 10 years of research. *Bewegung Training*, 2007, 1, 1–64.
18. Wulf G., McNevin N., Shea C.H., The automaticity of complex motor skill learning as a function of attentional focus. *Q J Exp Psychol*, 2001, 54A (4), 1143–1154.
19. Zachry T., Wulf G., Mercer J., Bezodis N., Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Res Bull*, 2005, 67, 304–309. doi:10.1016/j.brainresbull.2005.06.035.
20. Gray R., Attending to the execution of a complex sensorimotor skill: Expertise differences, choking, and slumps. *J Exp Psychol Appl*, 2004, 10 (1), 42–54. doi:10.1037/1076-898X.10.1.42.
21. Jackson R.C., Willson R.J., Using ‘swing thoughts’ to prevent paradoxical performance effects in golf putting. In: Farrally M.R., Cochran A.J. (eds.), *Science and golf III: Proceedings of the 1998 world scientific congress of golf*. Human Kinetics, Leeds 1999, 166–173.
22. Masters R.S.W., Theoretical aspects of implicit learning in sport. *Int J Sport Psychol*, 2000, 31, 530–541.
23. Liao C., Masters R.S.W., Analogy learning: A means to implicit motor learning. *J Sports Sci*, 2001, 19, 307–319.
24. Law J., Masters R.S.W., Bray S.R., Eves F., Bardswell I., Motor performance as a function of audience affability and metaknowledge. *J Sport Exerc Psychol*, 2003, 25 (4), 484–500.
25. Lam W.K., Maxwell J.P., Masters R.S.W., Analogy versus explicit learning of a modified basketball shooting task: Performance and kinematic outcomes. *J Sports Sci*, 2009, 27 (2), 179–191. doi:10.1080/02640410802448764.
26. Koedijker J.M., Oudejans R.R.D., Beek P.J., Table tennis performance following explicit and analogy learning over 10.000 repetitions. *Int J Sport Psychol*, 2008, 39, 237–256.
27. Lehnertz K., Heuler O., Quirmbach S., The technique of the golf swing [in German]. Deutscher Golf Verband e.V. Lehrbrief 4, Albrecht Golf Verlag GmbH, Gräfelfing 2002.
28. Spearman M., *Aim of golf. Visual-imagery lessons to improve every aspect of your game*. Rodale, USA 2004.

Paper received by the Editors: September 23, 2009.

Paper accepted for publication: June 11, 2010.

*Address for correspondence*

Linda Schücker  
 University of Münster  
 Institute of Sports Science  
 Department of Sport Psychology  
 Horstmarer Landweg 62b  
 48149 Münster, Germany  
 e-mail: lindaschuecker@uni-muenster.de



# THE ESTIMATION OF EDUCATIONAL NEEDS OF PHYSICAL EDUCATION TEACHERS IN THE LIGHT OF THE NEW EDUCATIONAL PROGRAM BASIS

doi:10.2478/v10038-010-0014-2

ALICJA KOSTENCKA\*, MIROSŁAWA SZARK-ECKARDT

Kazimierz Wielki University, Bydgoszcz, Poland

## ABSTRACT

**Purpose.** The study is aimed at showing the state of educational needs of physical education (PE) teachers in the light of the new educational program as well as presenting their opinions about the implementation of some elements of the up-to-date physical education didactics (on the example of teachers in the Kuyavian-Pomeranian Voivodeship). **Basic procedures.** The survey was conducted in March 2009 among 118 people (including 63 men and 55 women) – PE teachers of various working experience (1 to 36 years of work experience), from randomly chosen primary schools (PS) and secondary schools called gymnasium (G) in the Kuyavian-Pomeranian Voivodeship. **Main findings.** The analysed views of PE teachers of primary schools and gymnasias of the Kuyavian-Pomeranian Voivodeship allow us to state that the teachers notice a need to use basic elements of the up-to-date physical education didactics. They expect concrete materials on the educational program of physical education for 2009. The highest percentage of PE teachers (up to ca. 80%) would like to make use of information on proposals for up-to-date forms of exercises, health-giving training and lifelong sporting activities. Over 70% of them feel the need for materials on pupils' activation and individualisation in PE classes and descriptions of how to use activating methods (ca. 68%). A high percentage, amounting up to 62%, think that these materials should concern methods in health education, and 58.5% (including 66.7% of PS and 50.8% of SS) want to learn about proposals for activities which develop pupils' health. **Conclusions.** Physical education teachers employed at elementary schools and gymnasias in the Kuyavian-Pomeranian Voivodeship, regardless of sex and work experience, support the educational program of physical education. Regarding the usage of various diagnostic tools, it was found out that there are statistically significant differences between elementary school teachers and gymnasias ones. Physical education teachers, regardless of school type, sex and work experience, emphasize the need for training in the didactics of their subject and in health education.

**Key words:** physical education teachers, educational needs, new program basis, health education

## Introduction

The reform of the educational program has set new tasks to PE teachers. These tasks require from teachers high competence in the recent achievements in didactics, pedagogy, psychology and health promotion. The most important element of the changes is introduction of health education issues in physical education (PE) classes in the form of both theoretical lessons in the classroom and a practical part in the gym, where pupils can choose the form of physical activity. Health education (HE) – which, on the one hand, comprises any activity whose objective is to learn about health and illness [1], and on the other hand, is a pedagogical and social process making use of methods and techniques applied in social sciences (pedagogy, psychology, social economy, legislation, etc.) and directed to change people's and social groups' behaviours of pro-health character [2] – requires from teachers specialist knowledge and skills, but first of all, proper attitudes which constitute

a base for the other competences. Modern teachers – HE masters – must begin from themselves, from "studying the roots of their uniqueness" as professionals [3]. Evaluation of teachers' attitudes is very difficult. In some way, teachers' opinions on educational issues may reflect their attitudes.

While the reform of the educational program is being introduced, it is worth considering if and how physical education teachers perceive some competences necessary to give classes in accordance with the new guidelines and consequently their educational needs. A diagnosis of teachers' educational needs is a logical point of departure for actions whose objective is further effective modernization of physical education; additionally, asking teachers about their needs and bringing these needs to their attention should favour an increase in motivation and activeness [4].

The aim of this work is to present the state of PE teachers' educational needs in the light of the new educational program basis and to present teachers' opinions about an application of several elements of the up-to-date didactics in physical education (on the example of the Kuyavian-Pomeranian Voivodeship).

\* Corresponding author.

## Material and methods

The survey was carried out in March 2009 among 118 persons (63 men and 55 women) – physical education teachers of different work experience (from 1 to 36 years of seniority) employed in randomly chosen primary schools (pupils aged 6–12 years) and secondary schools (pupils aged 13–15 years) called *gymnasium* in the Kuyavian-Pomeranian Voivodeship. The questionnaire used in the research was prepared by the authors and its validity was confirmed in some pilot research. A vast majority of the subjects – 102 teachers (over 86%) have a degree of higher education, being graduates from university schools of physical education. The statistical analysis was done making use of Statistica 8.0.

The answers to the research questions were analysed by means of  $\chi^2$  test taking into consideration the demographic data of the subjects. The level of statistical significance was set at  $p < 0.05$ . The statistical characteristics of the subjects are presented in Tables 1 and 2.

Table 1. Statistical characteristics of the subjects – type of school

Sex	Type of school				
	Primary school		Secondary school		
	n	%	n	%	Total
Men	27	47.4	36	59.0	63
Women	30	52.6	25	41.0	55
Total	57	100.0	61	100.0	118

Table 2. Statistical characteristics of the subjects – work experience

Sex	Work experience						
	Under 10 years		10–19 years		Above 20 years		Total
	n	%	n	%	n	%	
Men	24	61.5	23	46.0	16	55.2	63
Women	15	38.5	27	54.0	13	44.8	55
Total	39	100.0	50	100.0	29	100.0	118

## Results

The obtained opinions of physical education teachers from primary schools (PS) and secondary schools (SS) about the necessity of applying some elements of the modern didactics of physical education are shown in Tables 3–5.

The research findings show that the application of the program basis is approved by 63.5% of physical education teachers, that is, 75.4% of primary school

teachers and by about one third less, i.e. 52.5% of secondary school teachers. Nearly 7% (over 8% secondary school teachers included) have not answered the question, whereas 7.6% of the subjects (7.0% in PS and 8.2% in SS) do not know the program basis at all. Almost 17% of the subjects (14.0% in SP and 19.7% in SS) do not approve of the new program basis (they think it causes organizational problems or it still needs polishing up). A vast majority of PE teachers, over 87% of the subjects (92.2% in PS and 82.0% in SS) understands the need to use a diagnosis in their work. Teachers indicate as diagnostic tools, among others, physical fitness tests – 61.9% of the subjects (primary school teachers – 73.7% are ahead by nearly 23 percentage points in comparison to secondary school teachers – 50.8%). Questionnaires as a diagnostic tool have been mentioned by ca. 17% (only 3.4% in PS and 26.2% in SS), while observations by over 16% of the subjects. Physical fitness tests as the only element of diagnosis have been indicated by 44.1%, that is almost 60% of primary school teachers and about 30% of secondary school ones. As many as 22.9% of the subjects (17.5% in PS and 27.9% in SS) have not answered the question, which may indicate that they neither apply, nor understand the need to use any kind of diagnosis. The differences between the teachers in primary schools and those in secondary schools in the aspect of applying various diagnostic tools are statistically significant at a level below 0.01 ( $p = 0.003918$ ).

Another important element of the modern didactics is evaluation. 80% of physical education teachers realise the necessity of its application in their work. The similar high percentage of the subjects (86.4%) understands the necessity of introducing innovative solutions in a teaching process (93.0% in PS and 80.3% in SS). Only 61.0% of the teachers notice the sense of planning their work in the form of devising plans in the result-focused aspect, whereas over 50% of the subjects claim that it is important to write synopses in the activity-focused aspect. The differences between the declarations of the primary school teachers and the secondary school ones are not statistically significant.

Table 4 shows physical education teachers' opinions on the issues discussed above, divided according to sex.

The results included in Table 4 show that the percentages of both men and women who consider it necessary to apply most of the above mentioned elements of modern didactics in physical education lessons are close to each other (differences of few percentage points). Only in the case of applying evaluation, there can be observed a difference of over 12 percentage points, but even this is not statistically significant.

# HUMAN MOVEMENT

A. Kostencka, M. Szark-Eckardt, Educational needs of physical education teachers

Table 3. Type of school vs. physical education teachers' opinions about the necessity of applying some elements of the up-to-date didactics of physical education

Elements of didactics and the level of significant differences between PE teachers' opinions in primary and secondary schools (test $\chi^2$ )	Techars' opinions	Primary school n = 57		Secondary school n = 61		Total n = 118	
		n	%	n	%	n	%
<i>Application of the educational program basis</i> <i>p = 0.4542</i>	Do not know it	4	7.0	5	8.2	9	7.6
	Approve	43	75.4	32	52.5	75	63.5
	Do not approve	2	3.5	4	6.6	6	5.1
	No opinion	8	14.0	12	19.7	20	16.9
	No answer	3	5.3	5	8.2	8	6.8
<i>Diagnosis</i> <i>p = 0.2389</i>	No	3	5.3	4	6.6	9	7.6
	Yes	53	92.9	50	82.0	103	87.3
	No answer	1	1.7	5	8.2	6	5.1
<i>Diagnostic tools</i> <i>p = 0.003918*</i>	Fitness tests as the only diagnostic tool	34	59.6	18	29.5	52	44.1
	Questionnaires	4	3.4	16	26.2	20	16.9
	Observations	9	15.8	10	16.4	19	16.1
	Fitness tests and other tools of diagnosis	42	73.7	31	50.8	73	61.9
	No answer	10	17.5	17	27.9	27	22.9
<i>Evaluation</i> <i>p = 0.988</i>	No	5	8.8	4	6.6	9	7.6
	Yes	45	78.9	48	78.7	93	78.8
	No answer	7	12.3	9	14.7	16	13.6
<i>Innovative solutions</i> <i>p = 0.3928</i>	No	3	5.3	8	13.1	11	9.3
	Yes	53	93.0	49	80.3	102	86.4
	No answer	1	1.7	4	6.6	5	8.8
<i>Devising plans in the result-focused aspect</i> <i>p = 0.39641</i>	No	22	38.6	20	32.8	42	35.6
	Yes	32	56.1	40	65.6	72	61.0
	No answer	3	5.3	1	1.6	4	3.4
<i>Writing synopses in the activity-focused aspect</i> <i>p = 0.342692</i>	No	29	50.9	24	39.3	53	44.9
	Yes	27	47.4	34	55.7	61	51.7
	No answer	1	1.7	3	4.9	4	3.4

\*  $p < 0.01$

Table 4. Teachers' sex vs. their opinions on the necessity of applying some elements of the up-to-date didactics of physical education

Elements of didactics and the level of significant differences between PE teachers' opinions divided according to sex (test $\chi^2$ )	Teachers' opinions	Men n = 63		Women n = 55		Total n = 118	
		n	%	n	%	n	%
<i>Application of the program basis</i> <i>p = 0.2851</i>	Do not know it	4	6.3	5	9.1	9	7.6
	Approve	39	61.9	36	65.4	75	63.5
	Do not approve	5	7.9	1	1.8	6	5.1
	No opinion	11	17.5	9	16.4	20	16.9
	No answer	4	6.3	4	7.3	8	6.8
<i>Diagnosis</i> <i>p = 0.2060</i>	No	7	11.1	2	3.6	9	7.6
	Yes	54	85.7	49	89.1	103	87.3
	No answer	2	3.2	4	7.3	6	5.1
<i>Diagnostic tools</i> <i>p = 0.6874</i>	Fitness tests	37	58.7	36	65.4	73	61.9
	Questionnaires	12	19.0	8	14.5	20	16.9
	Observations	9	14.3	10	18.2	19	16.1
	No answer	15	23.8	12	21.8	27	22.9
<i>Evaluation</i> <i>p = 0.1656</i>	No	5	7.9	4	7.3	9	7.6
	Yes	46	73.0	47	85.4	93	78.8
	No answer	12	19.0	4	7.3	16	13.6
<i>Innovative solutions</i> <i>p = 0.6934</i>	No	5	7.9	6	10.9	11	9.3
	Yes	56	88.9	46	83.6	102	86.4
	No answer	2	3.2	3	5.4	5	8.8
<i>Devising plans in the result-focused aspect</i> <i>p = 0.6381</i>	No	23	36.5	19	34.5	42	35.6
	Yes	37	58.7	35	63.6	72	61.0
	No answer	3	4.8	1	1.8	4	3.4
<i>Writing synopsis in the activity-focused aspect</i> <i>p = 0.3873</i>	No	32	50.8	21	38.2	53	44.9
	Yes	29	46.0	32	58.2	61	51.7
	No answer	2	3.2	2	3.6	4	3.4

The survey which concerned the opinions of teachers with different work experience about the application of some elements of the up-to-date didactics of physical education show that there is not statistically significant difference between teachers with long work experience (over 20 years), medium (10–19 years) and short (Tab. 5). The percentages of the subjects in each seniority category are similar. Only in the case of application of the right diagnostic tools, most teachers with short work experience declare they make use of fitness tests (over 60%). It is twice the percentage of the teachers with long work experience and even three times as many in comparison with the teachers with medium work experience. The category that has most often avoided answering this question is the one with long work experience. In comparison with the other categories, slightly more teachers with short work experience claim that it is necessary to make use of work plans in the result-focused aspect and synopses in the activity-focused aspect.

Tables 6–8 show the educational needs for more competence in the basic elements of didactics which physical education teachers claim to feel.

Table 6 shows that over 70% of the subjects (75.4% in PS and 67.2% in SS) expect contents concerning

active-learning teaching and individual teaching in physical education lessons, as well as descriptions of the active-learning methods (about 68%, 64.9% in PS and 70.5% in SS). A high percentage of PE teachers (57.6%) sees the need to use materials containing descriptions of how to apply diagnosis and monitoring (63.2% in PS and 54.1% in SS). Over 60% of the teachers expect contents about the ways of evaluation (64.9% in PS and 55.7% in SS), whereas 55.1% of the subjects (52.6% in PS and 57.4% in SS) expect contents which explain how to apply the evaluation. Examples of work plans in the result-focused aspect are expected by about 46%, but over 50% do not feel such a need. Around 44% of the subjects claim to feel the need to use materials with the information about how to draw up their own educational programs. Nowadays, when electronic communication is omnipresent, only less than 40% of the teachers feel the need to make use of computer technology in their work with pupils. On average, one subject in three is interested in new ways of recording their work, as well as synopses of utility-focused classes. 21.2% of the subjects claim it is necessary to broaden their knowledge in order to be promoted. The percentage of the teachers in primary schools is a little higher than in secondary schools who

Table 5. Teachers' seniority vs. their opinions on the necessity of applying some elements of the modern didactics of physical education

Elements of didactics and the level of significant differences between PE teachers' opinions divided according to work experience (test $\chi^2$ )	Teachers' opinions	Seniority up to 10 years n = 39		Seniority 10–19 years n = 50		Seniority 20 years and more n = 29		Total n = 118	
		n	%	n	%	n	%	n	%
Application of the program basis <i>p</i> = 0.2353	Do not know it	4	10.3	5	10.0	0	0	9	7.6
	Approve	24	61.5	31	62.0	20	69.0	75	63.5
	Do not approve	4	10.3	1	2.0	1	3.4	6	5.1
	No opinion	6	15.4	10	20.0	4	13.8	20	16.9
	No answer	1	2.6	3	6.0	4	13.8	8	6.8
Diagnosis <i>p</i> = 0.8576	No	3	7.7	3	6.0	3	10.3	9	7.6
	Yes	33	84.6	45	90.0	25	86.2	103	87.3
	No answer	3	7.7	2	4.0	1	3.4	6	5.1
Diagnostic tools <i>p</i> = 0.9759	Fitness tests	24	61.5	10	20.0	9	31.0	73	61.9
	Questionnaires	8	20.5	8	16.0	4	13.8	20	16.9
	Observations	7	17.9	8	16.0	4	13.8	19	16.1
	No answer	8	20.5	10	20.0	9	31.0	27	22.9
Evaluation <i>p</i> = 0.6217	No	4	10.3	4	8.0	1	3.4	9	7.6
	Yes	32	82.0	38	76.0	23	79.3	93	78.8
	No answer	3	7.7	8	16.0	5	17.2	16	13.6
Innovative solutions <i>p</i> = 0.4530	No	4	10.3	5	10.0	2	6.9	11	9.3
	Yes	34	87.2	41	82.0	27	93.1	102	86.4
	No answer	1	2.6	4	8.0	0	0.0	5	8.8
Devising plans in the result-focused aspect <i>p</i> = 0.1277	No	9	23.1	23	46.0	10	34.5	42	35.6
	Yes	28	71.8	26	52.0	18	62.1	72	61.0
	No answer	2	5.1	1	2.0	1	3.4	4	3.4
Writing synopses in the activity-focused aspect <i>p</i> = 0.6309	No	17	43.6	21	42.0	15	51.7	53	44.9
	Yes	21	53.8	26	52.0	14	48.3	61	51.7
	No answer	1	2.6	3	6.0	0	0.0	4	3.4

Table 6. Type of school vs. physical education teachers' educational needs for more competence in the basic elements of didactics

Educational needs and the level of significant differences between PE teachers' opinions in primary and secondary schools (test $\chi^2$ )	Teachers' opinions	Primary school <i>n</i> = 57		Secondary school <i>n</i> = 61		Total <i>n</i> = 118	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Teacher's promotion prospects <i>p</i> = 0.2113	No	47	82.5	42	68.8	89	75.4
	Yes	9	15.8	16	26.2	25	21.2
	No answer	1	1.7	3	4.9	4	3.4
Documentation of the teacher's work <i>p</i> = 0.6304	No	34	59.6	36	59	70	59.3
	Yes	22	38.6	22	36.1	44	37.3
	No answer	1	1.7	3	4.9	4	3.4
Active-learning and individualization of PE lessons <i>p</i> = 0.4850	No	13	22.8	17	27.7	30	25.4
	Yes	43	75.4	41	67.2	84	71.2
	No answer	1	1.7	3	4.9	4	3.4
Drawing up the teacher's own educational program <i>p</i> = 0.6281	No	30	52.6	32	52.5	62	52.5
	Yes	26	45.6	26	42.6	52	44.1
	No answer	1	1.7	3	4.9	4	3.4
PE work plan in the result-focused aspect <i>p</i> = 0.5409	No	31	54.4	29	47.5	60	50.8
	Yes	25	43.9	29	47.5	54	45.8
	No answer	1	1.7	3	4.9	4	3.4
Synopses of the utility-focused classes <i>p</i> = 0.5706	No	39	68.4	38	62.3	77	65.2
	Yes	17	29.8	20	32.8	37	31.4
	No answer	1	1.7	3	4.9	4	3.4
Description of how to use active-learning methods <i>p</i> = 0.5310	No	18	31.6	16	26.2	34	28.8
	Yes	37	64.9	43	70.5	80	67.8
	No answer	1	1.7	3	4.9	4	3.4
Description of how to use diagnosis and monitoring <i>p</i> = 0.4621	No	20	35.1	26	42.6	46	39
	Yes	36	63.2	34	54.1	68	57.6
	No answer	1	1.7	3	4.9	4	3.4
Description of how to use evaluation <i>p</i> = 0.4881	No	26	45.6	23	37.7	49	41.5
	Yes	30	52.6	35	57.4	65	55.1
	No answer	1	1.7	3	4.9	4	3.4
Description of evaluation methods <i>p</i> = 0.4551	No	19	33.3	24	39.3	43	36.4
	Yes	37	64.9	34	55.7	71	60.2
	No answer	1	1.7	3	4.9	4	3.4
Application of computer technology at work with pupils <i>p</i> = 0.6369	No	34	59.6	35	57.4	69	58.5
	Yes	22	38.6	23	37.7	45	38.1
	No answer	1	1.7	3	4.9	4	3.4

expect contents about teacher's work recording, active-learning teaching and individualization in PE lessons, as well as drawing up teacher's own educational program, descriptions of applications of diagnosis and monitoring as well as evaluation methods. However, the differences are not statistically significant.

A little higher percentage of women compared to men claim they need to improve their competence in active-learning teaching and individualization in PE lessons (by 10 percentage points), work planning in the result-focused aspect (by 16 percentage points), synopses of utility-focused classes (by 16 percentage points), and application of computer technology (by nearly 7 per-

centage points). However, the differences are not statistically significant (Tab. 7)

The survey of the teachers with different work experience which regarded their educational needs related to the basic elements of didactics has shown no statistically significant differences between the teachers with long work experience (over 20 years), those with medium work experience (10–19 years) and those with short work experience. The percentages of the subjects in each category are very close (Tab. 8).

Tables 9–11 show the educational needs related to health education mentioned by physical education teachers.

Table 7. Physical education teachers' sex vs. their educational needs related to the basic elements of didactics

Teachers' educational needs and the level of significant differences between PE teachers' opinions divided according to sex (test $\chi^2$ )	Techaers' opinions	Men <i>n</i> = 63		Women <i>n</i> = 55		Total <i>n</i> = 118	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Teacher's prospects for promotion <i>p</i> = 0.9517	No	47	74.6	42	76.4	89	75.4
	Yes	14	22.2	11	20.0	25	21.2
	No answer	2	3.2	2	3.6	4	3.4
Documentation of teacher's work <i>p</i> = 0.8459	No	36	57.1	34	61.8	70	59.3
	Yes	25	39.7	19	34.5	44	37.3
	No answer	2	3.2	2	3.6	4	3.4
Active-learning and individualization of PE classes <i>p</i> = 0.4497	No	19	30.2	11	20.0	30	25.4
	Yes	42	66.7	42	76.4	84	71.2
	No answer	2	3.2	2	3.6	4	3.4
Drawing up teacher's own syllabus <i>p</i> = 0.9983	No	33	52.4	29	52.7	62	52.5
	Yes	28	44.4	24	43.6	52	44.1
	No answer	2	3.2	2	3.6	4	3.4
PE work plan in the result-focused aspect <i>p</i> = 0.1820	No	37	58.7	23	41.8	60	50.8
	Yes	24	38.1	30	54.5	54	45.8
	No answer	2	3.2	2	3.6	4	3.4
Synopsis of utility-focused classes <i>p</i> = 0.1555	No	46	73.0	31	56.4	77	65.2
	Yes	15	23.8	22	40.0	37	31.4
	No answer	2	3.2	2	3.6	4	3.4
Description of how to use pupils' activating methods <i>p</i> = 0.9873	No	18	28.6	16	29.1	34	28.8
	Yes	43	78.2	37	67.3	80	67.8
	No answer	2	3.2	2	3.6	4	3.4
Description of how to use diagnosis and monitoring <i>p</i> = 0.8605	No	26	41.3	20	36.4	46	39.0
	Yes	35	55.5	33	60.0	68	57.6
	No answer	2	3.2	2	3.6	4	3.4
Description of how to use evaluation <i>p</i> = 0.9480	No	27	42.9	22	40.0	49	41.5
	Yes	34	54.0	31	56.4	65	55.1
	No answer	2	3.2	2	3.6	4	3.4
Description of evaluation methods <i>p</i> = 0.9201	No	24	38.1	19	34.5	43	36.4
	Yes	37	58.7	34	61.8	71	60.2
	No answer	2	3.2	2	3.6	4	3.4
Application of computer technology at work with pupils <i>p</i> = 0.7201	No	39	61.9	30	54.5	69	58.5
	Yes	22	34.9	23	41.8	45	38.1
	No answer	2	3.2	2	3.6	4	3.4

The data shown in Table 9 indicate that the highest percentage of physical education teachers, up to 79.7% (86.0% in PS and 73.8% in SS) expect descriptions of some up-to-date forms of movement, health-focused training and lifelong sports. 73.7% of the subjects, including 80.7% of primary school teachers and 67.2% of secondary school teachers, feel the need for a new handbook which will contain issues related to the new program basis. Over 77% of the teachers claim it is necessary to organize a teacher training conference focused on the new program basis. A high percentage of the subjects, i.e. about 62% (63.2% in PS and 60.6% in SS), think that the contents should regard health

education teacher training, whereas 58.5% (66.7% in PS and 50.8% in SS) would make use of suggestions how to develop pupils' health. On average, one subject in three is interested in synopses of pro-health classes. Primary school teachers are a little more concerned than those in secondary schools about health education teacher training, suggestions of activities regarding pupils' health development, as well as up-to-date forms of movement, health-focused training and lifelong sports, but the differences are not statistically significant.

More women than men claim they need to raise their competence in health education teaching techniques (by nearly 17 percentage points), to use synopses

Table 8. Physical education teachers' work experience vs. their educational needs related to the basic elements of didactics

Educational needs and the level of significant differences between PE teachers' opinions divided according to seniority (test $\chi^2$ )	Teachers' pinions	Seniority up to 10 years $n = 39$		Seniority 10–19 years $n = 50$		Seniority 20 years and more $n = 29$		Total $n = 118$	
		n	%	n	%	n	%	n	%
Teacher's promotion prospects $p = 0.2334$	No	26	66.7	40	80	23	79.3	89	75.4
	Yes	12	30.8	7	14.0	6	20.7	25	21.2
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Documentation of teacher's work $p = 0.5673$	No	25	64.1	29	58.0	16	55.2	70	59.3
	Yes	13	33.3	18	36.0	13	44.8	44	37.3
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Active-learning and individualization of PE classes $p = 0.5586$	No	8	20.5	14	28.0	8	27.6	30	25.4
	Yes	30	76.9	33	66	21	72.4	84	71.2
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Drawing up teacher's own educational program $p = 0.5356$	No	20	51.3	28	56.0	14	48.3	62	52.5
	Yes	18	46.1	19	38.0	15	51.7	52	44.1
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
PE work plan in the result-focus aspect $p = 0.2825$	No	16	41.0	26	52.0	18	62.1	60	50.8
	Yes	22	56.4	21	42.0	11	37.9	54	45.8
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Synopsis of utility-focused classes $p = 0.6072$	No	26	66.7	33	66.0	18	62.1	77	65.2
	Yes	12	30.8	14	28.0	11	37.9	37	31.4
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Description of how to use pupils' activating methods $p = 0.5191$	No	9	23.1	15	30.0	10	34.5	34	28.8
	Yes	29	74.4	32	64.0	19	65.5	80	67.8
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Description of how to use diagnosis and monitoring $p = 0.6554$	No	14	35.9	20	40.0	12	41.4	46	39
	Yes	24	61.5	27	54.0	17	58.6	68	57.6
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Description of how to use evaluation $p = 0.5506$	No	14	35.9	22	44.0	13	44.8	49	41.5
	Yes	24	61.5	25	50.0	16	55.2	65	55.1
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Description of evaluation methods $p = 0.6924$	No	15	38.5	17	34.0	11	37.9	43	36.4
	Yes	30	76.9	40	80.0	24	82.7	71	60.2
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Application of computer technology at work with pupils $p = 0.6784$	No	24	61.5	28	56.0	17	58.6	69	58.5
	Yes	14	35.9	19	38.0	12	41.4	45	38.1
	No answer	1	2.6	3	6.0	0	0.0	4	3.4

of pro-health classes (by over 22 percentage points), and to learn up-to-date forms of movement, health-focused training and lifelong sports (by over 7 percentage points). In most cases the differences are not statistically significant. It has been noticed only in the case of the synopses of pro-health classes at the level of significance below 0.05 ( $p = 0.041$ ) (Tab. 10)

The survey of the opinions of teachers with different work experience related to their educational needs indicate that there are no statistically significant differences (test  $\chi^2$ ) between teachers with a long work experience (over 20 years), those with medium work experience (10–19 years) and short work experience. The percentages in each category are similar (Tab. 11).

## Discussion

The concept of pro-health physical education formulated a few years ago where it became an element of the general education system provides for an inclusion of physical education both in the modern education system and in the health promotion process [2]. The new generation theory does not guarantee its good application in practice, which in the Polish school is still far from the expected standards. The problem of lagging behind and not following modern tendencies in the education theory was noticed already in the 1980s [5] and is still valid for the 21<sup>st</sup> century physical education. Does the contemporary PE teacher still underline a gap

Table 9. Type of school vs. physical education teachers' educational needs related to health education

Educational needs and the level of significant differences between PE teachers' opinions in primary and secondary schools (test chi <sup>2</sup> )	Teachers' opinion	Primary school n = 57		Secondary school n = 61		Total n = 118	
		n	%	n	%	n	%
Methodology of health education <i>p</i> = 0.6365	No	20	35.1	21	34.4	41	34.7
	Yes	36	63.2	37	60.6	73	61.9
	No answer	1	1.7	3	4.9	4	3.4
Suggestions of activities developing pupils' health <i>p</i> = 0.1846	No	18	31.6	27	44.3	45	38.1
	Yes	38	66.7	31	50.8	69	58.5
	No answer	1	1.7	3	4.9	4	3.4
Synopses of pro-health classes <i>p</i> = 0.2421	No	38	66.7	32	52.5	70	59.3
	Yes	18	31.6	26	42.6	44	37.3
	No answer	1	1.7	3	4.9	4	3.4
Suggestions of up-to-date forms of movement, health-focused training, lifelong sports <i>p</i> = 0.2419	No	7	12.3	13	21.3	20	16.9
	Yes	49	86.0	45	73.8	94	79.7
	No answer	1	1.7	3	4.9	4	3.4
Need to use a new handbook <i>p</i> = 0.055	No	4	6.6	14	22.9	18	15.2
	Yes	46	80.7	41	67.2	87	73.7
	No answer	7	12.3	6	9.8	13	11.0
Need to take part in a conference on the new program basis <i>p</i> = 0.9966	No	11	19.3	12	19.7	23	19.5
	Yes	44	77.2	47	77.0	91	77.1
	No answer	2	3.5	2	3.3	4	3.4

Table 10. Physical education teachers' sex vs. their educational needs regarding health education

Educational needs and the level of significant differences between PE teachers' opinions divided by sex (test chi <sup>2</sup> )	Teachers' opinions	Men n = 63		Women n = 55		Total n = 118	
		n	%	n	%	n	%
Methodology of health education <i>p</i> = 0.1394	No	27	42.9	14	25.4	41	34.7
	Yes	34	54.0	39	70.9	73	61.9
	No answer	2	3.2	2	3.6	4	3.4
Suggestions of activities developing pupils' health <i>p</i> = 0.9901	No	24	38.1	21	38.2	45	38.1
	Yes	37	58.7	32	58.2	69	58.5
	No answer	2	3.2	2	3.6	4	3.4
Synopses of pro-health classes <i>p</i> = 0.041*	No	44	69.0	26	47.3	70	59.3
	Yes	17	27.0	27	49.1	44	37.3
	No answer	2	3.2	2	3.6	4	3.4
Suggestions of up-to-date forms of movement, health-focused training, lifelong sports <i>p</i> = 0.5204	No	13	20.6	7	12.7	20	16.9
	Yes	48	76.2	46	83.6	94	79.7
	No answer	2	3.2	2	3.6	4	3.4
Need to use a new handbook <i>p</i> = 0.7674	No	11	17.5	7	12.7	18	15.2
	Yes	45	71.4	42	76.4	87	73.7
	No answer	7	11.1	6	10.9	13	11.0
Need to take part in a conference on the new program basis <i>p</i> = 0.6211	No	13	20.6	10	18.2	23	19.5
	Yes	47	74.6	44	80.0	91	77.1
	No answer	3	4.8	1	1.8	4	3.4

\* *p* < 0.05

between the theory and the practice, because he/she often does not accept or does not know the current paradigm, or is not able to apply it in practice? According to Frołowicz not all the teachers think that the demands of the latest theory of physical education are right and

useful [6]. In addition, teachers will not take up any actions if they do not believe it is worthwhile that a change for better is possible. Then, they will not complain that "it is only a theory" or "how to put it in practice in such numerous groups?" [7].

Table 11. Physical education teachers' work experience vs. their educational needs regarding health education

Educational needs and the level of significant differences between PE teachers of different seniority (test chi <sup>2</sup> )	Teachers' opinions	Seniority up to 10 years n = 39		Seniority 10–19 years n = 50		Seniority 20 years and more n = 29		Total n = 118	
		n	%	n	%	n	%	n	%
Methodology of health education p = 0.4719	No	13	33.3	15	30.0	13	44.8	41	34.7
	Yes	25	64.1	32	64.0	16	55.2	73	61.9
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Suggestions of activities developing pupils' health p = 0.6970	No	15	38.5	18	36.0	12	41.4	45	38.1
	Yes	23	59.0	29	58.0	17	58.6	69	58.5
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Synopses of pro-health classes p = 0.7066	No	23	59.0	29	58.0	18	62.1	70	59.3
	Yes	15	38.5	18	36.0	11	37.9	44	37.3
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Suggestions of up-to-date forms of movement, health-focused training, lifelong sports p = 0.6111	No	8	20.5	7	14.0	5	17.2	20	16.9
	Yes	30	76.9	40	80.0	24	82.6	94	79.7
	No answer	1	2.6	3	6.0	0	0.0	4	3.4
Need to use a new handbook p = 0.6612	No	8	20.5	7	14.0	3	10.3	18	15.2
	Yes	26	66.7	37	74.0	24	82.8	87	73.7
	No answer	5	12.8	6	12.0	2	6.9	13	11.0
Need to take part in a conference on the new program basis p = 0.5208	No	9	23.1	10	20.0	4	13.8	23	19.5
	Yes	29	74.4	37	74.0	25	86.2	91	77.1
	No answer	1	2.6	3	6.0	0	0.0	4	3.4

The new model of education requires from the teacher effectiveness, i.e. accordance of effects with intended goals set up by the theory of physical education or by the educational program, but also imposed by life [8]. Teachers' competences which are indispensable in the modern physical education can, to some extent, reflect their opinions about application of some elements of didactics and also their educational needs.

Can teachers feel they are well prepared, especially to such a challenge as it is for them health education included in their lessons? It has appeared that even students who graduated a few years ago from schools educating PE teachers (234 subjects from AWFiS in Gdańsk surveyed in the years 2003–2004 and 200 subjects from AWF in Wrocław surveyed in 2005) expressed an opinion that they were not prepared enough to teach health education at school [9, 10]. This confirms a thesis that the changes in physical education in the Polish school should be accompanied by adequate changes in the curriculum of the future teachers [10]. The need to educate specialists in health promotion has been noticed by American researchers [11]. "One of the causes of the physical education crisis can be also the fact that during the PE teacher training more emphasis is put on preparation to exercise the body than to shape the personality able to be active for the body's sake on his/her own" [12, p. 57]. At this point we can notice another issue to discuss: what scope should the currently implemented education reform have? What has changed

for better in physical education, and what has to be changed in the future and in what way?

The findings of Śmiglewska's research carried out in the third year of the implementation of the educational reform have not confirmed that physical education teachers actually apply the praxiological assumptions and also they have proved insufficient pedagogical preparation of teachers [13]. However, the author underlines an optimist fact – a vast majority of physical education teachers already in the school year 2001/2002 felt the need for reforms, which meant that the process of reforming started at least in their minds [13]. Will this thesis be confirmed by the survey of teachers' educational needs and application of the modern elements of didactics in school practice of physical education in 2009? It seemed so, because an analysis of the opinions of the PE teachers in primary and secondary schools in Kuyavian-Pomeranian Voivodeship allow us to claim that they feel the need to make use of the basic elements of the modern didactics of physical education and they want to raise their competence, therefore they expect specific materials containing information about the program basis of physical education for 2009.

Teachers' needs concerning a raise in their competence regard first of all up-to-date forms of movement, health-focused training and lifelong sports, but also issues that regard health education teaching and activities developing pupils' health, as well as active-learning teaching and individualization during PE lessons, i.e.

application of active-learning methods. It is quite interesting that a little more primary school teachers than secondary school ones are interested in information about health education. However, the differences are not statistically significant. Another interesting fact is that the percentage of primary school teachers who expect a new handbook to be written and want to use it is by several percentage points higher than the one of secondary school teachers. Although the differences are not statistically significant, it is surprising to note a higher cognitive activity of teachers working at the lower stage of education, where the new formula of health education classes is not included. The need for a new handbook can prove that physical education teachers do not keep up with the modern theory and that they hardly know the recent literature on physical education, which is not rich yet, but is available periodically on the market. It can also be interpreted as a "call for practical solutions". Certainly, it is an important signal which confirms the previous surveys of the teachers dealing with pro-health education issues in primary schools. The surveys indicated that there was a need to take up actions intended to raise teachers' competence in health education by means of organizing different forms of professional training and equipping schools with tools and facilities to streamline the didactic process [14].

From the studies to date it has resulted that teachers' opinions may vary depending on sex or work experience [6]. Our studies regarding opinions on didactics and educational needs indicate that such differences do not occur. This may have been caused by gradual blurring of these differences in practice due to the implementation of the new program basis.

Since the point of departure for health improvement through physical activity is diagnosis [15], it was expected that the subjects would be interested in this element of didactics. A vast majority of teachers understands that applying a diagnosis in their work is necessary, but they indicate first of all fitness tests as a main diagnostic tool (only a low percentage indicates questionnaires and observations). Most PS teachers use only fitness tests. Secondary school teachers exceed by several percentage points their counterparts in primary schools as far as the questionnaire application is concerned. The differences are statistically significant. This may indicate that PE teachers, especially in PS, are not aware of what possibilities of diagnosis they have. Over 20% of the subjects, and as many as 28% of SS teachers, have not answered the question at all. On this basis it is possible to predict that teachers in this group do not apply a diagnosis and will not apply it in

the future, as they do not understand the need to use any. To give preference in diagnosis to fitness tests can indicate that PE teachers still have deeply rooted biotechnological preferences. That would confirm the findings of Frołowicz's study [6] which say that the changes occurred in teleology of physical education have still little to do with educational practice, as the teachers' real educational intentions differ from what they declare. As it often happens those teachers do not adapt their actions, e.g. evaluation ones to the theoretical evaluation systems they invented [16].

The answer to another question – is there a conformity between the educational needs declared by physical education teachers and the self-evaluation of their preparation to conduct classes in health education at school given by different groups of teachers? – is not easy, either. The findings of the studies carried out in the years 2002–2004 on different groups of teachers [17–18] show a high percentage (55–60%) of the teachers who claim that their preparation to conduct classes in health education at school was good or very good. Physical education teachers' opinions on their educational needs collected in 2009, which result from our survey, do not confirm the teachers' optimist declarations made a few years ago, although already in 2001 nearly 100% of the teachers noticed correlations between physical education and pro-health education [13].

Teachers' awareness (which resulted from Śmigiewska's research) still arouses hope of a further increase in their pedagogical competences, which can favour a change in quality of physical education. However, teachers need specialist courses and training to be well prepared to promote health. It is possible to develop an international cooperation in the future, which has already been suggested by American researchers [20].

There is an urgent need to create for physical education teachers educational opportunities and didactic materials (handbooks) containing information about up-to-date forms of movement, health-focus training and lifelong sports, as well as how to make pupils active and to individualize the process of physical education, about application of activating methods and health education methodology and other activities related to pupils' health development.

## Conclusions

1. Physical education teachers working in primary and secondary schools in Kuyavian-Pomeranian Voivodeship, irrespective of sex and work experience approve of the program basis of physical education.

2. As far as the application of different diagnostic

tools is concerned, statistically significant differences between primary and secondary school teachers have been noticed. Most of the primary school teachers declare the need to test only physical fitness, whereas the secondary school teachers more often add also surveys as a diagnostic tool. A numerous group of secondary school teachers (almost one third) do not indicate any diagnostic tool, which is disquieting.

3. Physical education teachers, irrespective of the type of school, sex and work experience, underline the need to broaden their knowledge in their subject's didactics (application of pupil's activating methods, diagnostic tools, monitoring, evaluation and giving marks) and health education (health-focused training, health education methodology and activities related to pupils' health development).

4. The changes in the educational program and organization of physical education and teachers' awareness about the needs of some elements of the modern didactics arouse hope to improve educational practice of PE teachers and consequently will lead to an increase in the quality of physical education.

## References

- Tones K., Green J., Health promotion. Planning and strategies. SAGE, London 2004.
- Krawański A., Human body and health in the modern system of physical education. [in Polish]. AWF, Poznań 2003.
- Ubbes V.A., Educating for Health – An Inquiry Based Approach to PreK-8 Pedagogy. Human Kinetics, Champaign 2008.
- Przetacznik-Gierowska M., Makieło-Jarża G., Basic general psychology [in Polish]. WSiP, Warszawa 1989.
- Bukowiec M., On Prof. W. Okon's theory of many-sided education and its usefulness in physical education [in Polish]. *Wychowanie Fizyczne i Sport*, 1990, 4, 109–113.
- Frołowicz T., Educational intentions of physical education teachers, between declarations and actions [in Polish]. AWFIS, Gdańsk 2002.
- Dudzikowa M., A myth about school as a place of many-sided development of pupils. Etnopedagogical esseys [in Polish]. Oficyna Wydawnicza Impuls, Kraków 2001.
- Bielski J., Methodology of physical and health educations. A textbook for physical education teachers and students of pedagogical subjects [in Polish]. Oficyna Wydawnicza Impuls, Kraków 2005.
- Wilk B., Students' opinions of the Academy of Physical Education and Sports from Gdańsk about their preparation for pro-health education program at school [in Polish]. *Rocznik PZH*, 2006, 57 Suppl., 43–46.
- Lewandowski M., Antoszczuk G., Kiciński B., Surynt A., Third year University' School of Physical Education in Wrocław student's opinion about their arrangement to health teacher role [in Polish]. *Rocznik PZH*, 2006, 57 Suppl., 65–69.
- Smith B.J., Potts-Datema W., Nolte A.E., Challenges in teacher preparation for school health education and promotion. *Promot Educ*, 2005, 12 (3–4), 162–164. doi:10.1177/10253823050120030116.
- Grabowski H., Some critical remarks about physical education and teacher training [in Polish]. Oficyna Wydawnicza Impuls, Kraków 2004, 57.
- Śmigiewska M., Changes in education vs. pedagogical reorientation of physical education teachers. Between creativity and professional abandon, the findings [in Polish]. *Rocznik Naukowy AWFIS*, 2005, 15, 131–146.
- Szewczyk T., Dudkiewicz K., Teachers' competence in health education [in Polish]. In: Pęckowski R. (ed.), The Polish Education System after the Reform Introduced in 1999. The Present State, Perspectives and Threads. Poznań–Warszawa 2005, 232–235.
- Drabik J., Pedagogical control of positive measures of physical health [in Polish]. AWFIS, Gdańsk 2006.
- Kostencka A., Motor abilities vs. a mark in physical education in the reformed Polish school [in Polish]. In: Michalski A., Napierała M., Zasada M. (eds.), Physical Education, Sport for Children and Young People. Wydawnictwo Akademii Bydgoskiej, Bydgoszcz, 2005, 118–123.
- Woynarowska B., Małkowska A., School's physical and social environments and actions in the field of health education, prevention and health promotion in school headmasters' opinions [in Polish]. In: Woynarowska B. (ed.), The Psychosocial School Environment vs. Health and Health Behaviour of Pupils in Poland. Uniwersytet Warszawski, Warszawa 2003, 133–162.
- Fedyń B., Self-assessment of teachers' methodological competence in health education [in Polish]. In: Woynarowska B. (ed.), Training Teachers and Educationalists in Health Education. Uniwersytet Warszawski, Warszawa 2005, 90, 89–94.
- Lewicki Cz., Teachers' competence and realization of health education in kindergartens and primary schools [in Polish]. In: Woynarowska B. (ed.), Training Teachers and Educationalists in Health Education. Uniwersytet Warszawski, Warszawa 2005, 85–89.
- Jourdan D., Samdal O., Diagne F., Carvalho G.S., The future of health promotion in schools goes through the strengthening of teacher training at a global level. *Promot Educ*, 2008, 15 (3), 36–38. doi:10.1177/1025382308095657.

Paper received by the Editors: October 23, 2009.

Paper accepted for publication: February 24, 2010.

### *Address for correspondence*

Alicja Kostencka  
Instytut Kultury Fizycznej  
Uniwersytet Kazimierza Wielkiego  
ul. Ogińskiego 16  
85-091 Bydgoszcz, Poland  
e-mail: akostwf@ukw.edu.pl



## COMPETITION

### COMPETITION OF RESEARCH PAPERS on PHYSICAL EDUCATION TEACHING for Prof. Bogdan Czabański's Award

#### Submission requirements:

- Only papers published in the year prior to the date of competition may be submitted
- Papers (offprints) must be sent before the end of March of each year to the Organizers' address:

**Akademia Wychowania Fizycznego  
Katedra Dydaktyki Wychowania Fizycznego  
ul. Witelona 25, 51-617 Wrocław, Poland  
tel. 0 (prefix) 71 347-31-69, fax 348-25-27  
www.awf.wroc.pl/czabanski  
e-mail: olepio@awf.wroc.pl**

- Independent academics must not take part in the competition
- Former award winners must not take part in the competition
- A research paper can be a team work effort, but the team of authors must not include an independent academic

#### Evaluation criteria:

- Submitted papers must be **research papers**
- All papers must be on the subject of physical education teaching

#### Jury:

Three independent academics, Professors of the University School of Physical Education in Wrocław, Poland:

- Prorector for Research
- Head of Chair of Physical Education Didactics
- Head of Chair of Swimming

The jury convenes annually on **April 24**. The jury's final decision will be made available to all participants.

Only one paper is awarded with the prize (diploma of merit and 1.000 PLN).

The award is presented each year during the inauguration ceremony of the academic year at the University School of Physical Education in Wrocław, Poland.



## REGULAMIN PUBLIKOWANIA PRAC – INSTRUCTION FOR AUTHORS

Redakcja półrocznika *Human Movement* przyjmuje do publikacji oryginalne prace empiryczne oraz przeglądowe dotyczące ruchu człowieka z różnych dziedzin nauki (m.in. medycyny sportu, fizjologii wysiłku fizycznego, biomechaniki, antropomotoryki, socjologii, psychologii, pedagogiki) w zakresie wychowania fizycznego, zdrowotnego, rekreacji i turystyki, rehabilitacji, fizjoterapii. Przyjmowane są również listy do Redakcji, sprawozdania z konferencji naukowych i recenzje książek. Prace mogą być napisane w języku polskim lub angielskim. Teksty polskie po uzyskaniu pozytywnej recenzji są tłumaczone na język angielski przez Redakcję. Autorzy nie otrzymują honorarium.

Warunkiem rozpoczęcia prac redakcyjnych nad artykułem jest dostarczenie do Redakcji trzech kopii maszynopisu (wydruku komputerowego) przygotowanego zgodnie z niniejszym regulaminem oraz dyskietki (3 1/2" w formacie IBM) lub dysku CD-ROM zawierających komplet materiałów. Na etykiecie dyskietki (CD-ROM-u) należy podać tytuł pracy oraz numery wersji użytych edytorów i programów graficznych. Praca może być wysłana pocztą elektroniczną (por. Poczta elektroniczna).

### List przewodni i oświadczenie

Do maszynopisu (wydruku komputerowego) autor powinien dołączyć list przewodni oraz oświadczenie, że treść artykułu nie była i nie będzie publikowana w tej formie w innych wydawnictwach bez zgody Redakcji czasopisma *Human Movement* oraz że zgadza się na ogłoszenie jej w tym półroczniku. W przypadku prac zespołowych oświadczenie może złożyć w imieniu wszystkich współautorów autor główny.

### Ocena pracy (recenzja)

Praca jest recenzowana przez dwie osoby. Autor może podać nazwiska potencjalnych recenzentów, lecz Redakcja zastrzega sobie prawo decyzji o ich doborze. Recenzenci nie znają nazwiska autora ani autor nie zna nazwisk recenzentów, dlatego do artykułu należy dołączyć tzw. ślepą stronę, tzn. tylko z tytułem pracy. W zależności od sugestii osób oceniających Redakcja podejmuje decyzję o dalszym losie pracy. Decyzja Redakcji jest ostateczna.

### Maszynopis (wydruk komputerowy)

Tekst prac empirycznych wraz ze streszczeniem, rycinami i tabelami nie powinien przekraczać 20 stron, a prac przeglądowych – 30 stron znormalizowanych formatu A4

The *Human Movement* journal, issued semi-annually, accepts for publication original papers and review papers in various aspects of human movement (e.g., sociology, psychology, pedagogy, exercise physiology, biomechanics, motor control, sport medicine) in a broad sense of the term: physical education, recreation, physiotherapy, health and fitness, and sport science. Authors are not paid for their articles. Letters to the Editor, reports from scientific meetings and book reviews are also welcome. Articles written in Polish and English will be accepted. After acceptance, articles in Polish will be translated into English by the Editorial Office.

Three copies of the manuscript and figures should be sent to the Editorial Office. If you send the printed version by e-mail, a floppy disk should be submitted containing the whole text of the paper. The label of the disk should include the name of the first author, paper title, as well as the version numbers of the word processor and graphics programs used. IBM 3 1/2" disks and CD-ROMs are acceptable. It is advisable to use Microsoft Word. Electronic manuscripts are preferred.

### Cover letter

Authors must submit a cover letter with the manuscript. Each submission packet should include a statement signed by the first author that the work has not been published previously or submitted elsewhere for review. It should also contain Author's acceptance of Publisher's terms. The paper should be accompanied with the correspondence address of the Author, the telephone number, fax number and e-mail address.

### Review process

Received manuscripts are first examined by the editors of *Human Movement*. Incomplete packages or manuscripts not prepared in the required style will be sent back to authors without scientific review. Authors are encouraged to suggest the names of possible reviewers, but *Human Movement* reserves the right of final selection. Manuscripts will be sent anonymously to two reviewers. As soon as possible after the review process is concluded, you will be notified by e-mail of the acceptance or rejection of your contribution for publication, our decision is ultimate.

### Preparation of the manuscript

Experimental papers should be divided into the following parts: title page, blind title page, abstract with key

(ok. 1800 znaków na stronie, złożonych 12-punktowym pismem Times New Roman z zachowaniem 1,5 interlinii). Redakcja przyjmuje teksty przygotowane wyłącznie w edytorze tekstu Microsoft Word. Strony powinny być ponumerowane.

#### STRONA TYTUŁOWA

Na stronie tytułowej należy podać:

1. Tytuł pracy w języku polskim i angielskim.
2. Skrócony tytuł artykułu w języku angielskim (nie dłuższy niż 40 znaków), który będzie umieszczony w żywej paginie.
3. Nazwiska autorów z afiliacją.
4. Imię i nazwisko autora (autorów) wraz z adresem do korespondencji, numerem telefonu, faksu i koniecznie e-mailem.

Kontakt z autorem będzie utrzymywany **wyłącznie** za pomocą poczty elektronicznej.

#### STRESZCZENIE

Przed ekstem głównym należy umieścić streszczenie w języku angielskim, zawierające około 250 wyrazów i 3–6 słów kluczowych (ze słownika i w stylu MeSH). Powinno się ono składać z następujących części: Purpose, Basic procedures, Main findings, Conclusions.

#### TEKST GŁÓWNY

Tekst główny pracy empirycznej powinien zawierać następujące części: wstęp, materiał i metody, wyniki, dyskusja (omówienie wyników), wnioski, podziękowania (jeżeli potrzebne), przypisy (jeżeli występują), piśmiennictwo (zawarte tylko w bazach danych, np. SPORTDiscus, Med-line). W pracach innego typu należy zachować logiczną ciągłość tekstu, a tytuły poszczególnych jego części powinny odzwierciedlać omawiane w nich zagadnienia.

*Wstęp.* Należy wprowadzić czytelnika w tematykę artykułu, opisać cel pracy oraz podać hipotezy oparte na przeglądzie literatury.

*Materiał i metody.* Należy dokładnie przedstawić materiał badawczy (w przypadku osób biorących udział w eksperymencie podać ich liczebność, wiek, płeć oraz inne charakterystyczne cechy), omówić warunki, czas i metody prowadzenia badań oraz opisać wykorzystaną do nich aparaturę (z podaniem nazwy wytwórni i jej adresu). Sposób wykonywania pomiarów musi być przedstawiony na tyle dokładnie, aby inne osoby mogły je powtórzyć. Jeżeli metoda jest zastosowana pierwszy raz, należy ją opisać szczególnie precyzyjnie, potwierdzając jej trafność i rzetelność (powtarzalność). Modyfikując uznane już metody, trzeba omówić, na czym polegają zmiany oraz uzasadnić konieczność ich wprowadzenia. Gdy w eksperymencie biorą udział ludzie, konieczne jest uzyskanie zgody komisji etycznej na wykorzystanie w nim zaproponowanych przez autora metod (do maszynopisu należy dodać kopię odpowiedniego dokumentu). Metody statystyczne powinny być tak opisane, aby można było bez problemu stwierdzić, czy są one poprawne. Autor pracy przeglądowej powinien również podać metody poszukiwania materiałów, metody selekcji itp.

*Wyniki.* Przedstawienie wyników powinno być logiczne i spójne oraz powiązane z danymi zamieszczonymi w tabelach i na rycinach.

words, introduction, materials and methods, results, discussion, conclusions, acknowledgements, references. In papers of a different type, sections and their titles should refer to the described issues.

Papers should be submitted in three printed copies or sent via e-mail. An experimental paper, together with the figures, tables and abstract, should not exceed 20 pages (30 pages for a review paper). A normal page is considered to be an A4 sheet, of 30 lines and 60 characters per line, with 12-point Times New Roman font, one and half-spaced text, with margins of 25 mm at the sides and at the top and bottom. Type or print on only one side of the paper. Use one and half spacing throughout, including the title page, abstract, text, acknowledgments, references, tables, and legends. Number pages consecutively, beginning with the title page. Put the page number in the upper-right corner of each page.

#### TITLE PAGE

The title page should contain: title of the article, name and surnames of author(s) and their affiliations, name and address of the author responsible for correspondence about the manuscript with fax, phone, and e-mail address; and a short running head of no more than 40 characters (count letters and spaces).

**BLIND TITLE PAGE.** Because reviews are blind, include a blind title page with only the title.

#### ABSTRACT

The second page should contain the abstract (ca. 250 words). The abstract should be divided into: Purpose, Basic procedures, Main findings and Conclusions. It should emphasize any new and important aspects of the study.

Below the abstract, authors should provide (and identify as such) 3 to 6 key words that will assist indexers to cross-index the article. If suitable MeSH terms are not yet available for recently introduced terms, present terms may be used.

**TEXT** should contain the following sections: Introduction, Material and methods, Results, Discussion, Conclusions, Acknowledgements (if necessary), References.

*Introduction.* State the purpose of the article and summarize the rationale for the study. Give only strictly pertinent references and do not include data or conclusions from the work being reported.

*Material and methods.* Clearly describe selection of the experimental subjects. Identify their age, sex, and other important characteristics. Identify the methods, apparatus (give the manufacturer's name and address in parentheses), and procedures in sufficient detail to allow other workers to reproduce the results. Give references to established methods, including statistical methods (see below); provide references and brief descriptions for methods that have been published but are not well known; describe new or substantially modified methods, give reasons for using them, and evaluate their limitations. When reporting experiments on human subjects, indicate whether the procedures followed were in accordance with the ethical standards of the responsible com-

*Dyskusja (omówienie wyników).* Autor powinien odnieść uzyskane wyniki do danych z literatury (innych niż omówione we wstępie), podkreślając nowe i znaczące aspekty swojej pracy.

*Wnioski.* Przedstawiając wnioski, należy pamiętać o celu pracy oraz postawionych hipotezach, a także unikać stwierdzeń ogólnikowych i niepopartych wynikami własnych badań. Stawiając nowe hipotezy, trzeba to wyraźnie zaznaczyć.

*Podziękowania.* Można wymienić osoby lub instytucje, które pomogły autorowi w przygotowaniu pracy bądź wsparły go finansowo lub technicznie.

*Piśmiennictwo.* Piśmiennictwo należy uporządkować według kolejności cytowania w tekście, w którym dla oznaczenia odwołania do piśmiennictwa należy posługiwać się numerami ujętymi w nawiasy kwadratowe, np. Bouchard et al. [23]. Piśmiennictwo (zawarte tylko w bazach danych, np. SPORTDiscus, Medline) powinno się składać z nie więcej niż 30 pozycji, z wyjątkiem prac przeglądowych. Niewskazane jest cytowanie prac nieopublikowanych.

#### Przykłady zapisu piśmiennictwa

Powołanie na artykuł z czasopisma [nazwisko autora (autorów), inicjał imienia, tytuł artykułu, tytuł czasopisma w przyjętym skrócie, rok wydania, tom lub numer, strony]: Shinohara M., Li S., Kang N., Zatsiorsky V.M., Latash M. L., Effects of age and gender on finger coordination in MVC and submaximal force-matching tasks. *J Appl Physiol*, 2003, 94, 259–270.

Gdy autorami artykułu jest sześć lub mniej osób, należy wymienić wszystkie nazwiska, jeżeli jest ich siedem i więcej, należy podać sześć pierwszych, a następnie zastosować skrót „et al.”

Tytuł artykułu w języku innym niż angielski autor powinien przetłumaczyć na język angielski, a w nawiasie kwadratowym podać język oryginału. Tytuł czasopisma należy zostawić w oryginale. W pracy powinny być uwzględnianie tylko artykuły publikowane ze streszczeniem angielskim: Jaskólska A., Bogucka M., Świdnicka R., Jaskólski A., Mechanisms, symptoms and after-effects of delayed muscle soreness (DOMS) [in Polish]. *Med Sportiva*, 2002, 4, 189–201.

Powołanie na książkę [nazwisko autora(ów) lub redaktora(ów), inicjał imienia, tytuł pracy przetłumaczony na język angielski, wydawca, miejsce i rok wydania]: Osiński W., Anthropomotoric [in Polish]. AWF, Poznań 2001.

Powołanie na rozdział w książce [nazwisko autora(ów), inicjał imienia, tytuł rozdziału, nazwisko autora(ów) lub redaktora(ów), tytuł pracy, wydawca, miejsce i rok wydania, strony]: McKirnan M.D., Froelicher V.F., General principles of exercise testing. In: Skinner J.S. (ed.), Exercise testing and exercise prescription for special cases. 2<sup>nd</sup> Ed. Lea & Febiger, Philadelphia 1993, 3–28.

Powołanie na materiały zjazdowe tylko umieszczane w międzynarodowych bazach danych, np. SPORTDiscus: Racz L., Tihanyi J., Hortobagyi T., Muscle fatigue during concentric and eccentric contraction. In: Avela J., Komi P.V., Komulainen J. (eds.), Proceedings of the 5<sup>th</sup> Annual Congress

mittee on human experimentation (institutional or regional). The Editors reserve the right to reject papers if there is doubt whether suitable procedures were used. Describe statistical methods with enough detail to enable a knowledgeable reader with access to the original data to verify the reported results. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Authors submitting a review manuscript should include a section describing the methods used for locating, selecting, extracting, and synthesizing data. These methods should also be summarized in the abstract.

*Results.* Present results in a logical sequence in the text, tables, and figures. Do not repeat in the text all the data presented in the tables or illustrations; emphasize or summarize only important observations.

*Discussion.* Emphasize the new and important aspects of the study and the conclusions that follow from them. Do not repeat in detail data or other material given in the Introduction or the Results section. Include implications of the findings and their limitations, including implications for future research. Relate observations to other relevant studies.

*Conclusions.* Link the conclusions with the goals of the study but avoid unqualified statements and conclusions not completely supported by the data. Avoid claiming priority and alluding to work that has not been completed. State new hypotheses when warranted, but clearly label them as such.

*Acknowledgments.* List all contributors who do not meet the criteria for authorship (e.g., a person who provided purely technical help or writing assistance). Financial and material support should also be acknowledged.

*References.* References (only the ones included in international data bases, e.g. SPORTDiscus, Medline etc.) should be submitted on a separate sheet of paper and in the order of appearance in the text. References should be numbered consecutively in the order in which they are first mentioned in the text. Identify references in text, tables, and legends by Arabic numerals in parentheses, e.g. Bouchard et al. [23]. Except in the case of review articles, the total number of references should not exceed 30.

A journal article should include: surname of the author(s); first name (**only initials**); title of the paper; title of the journal in the accepted abbreviation; year, volume (number), and pages. List all authors when six or less; when seven or more, list first six and add et al. Example: Shinohara M., Li S., Kang N., Zatsiorsky V.M., Latash M.L., Effects of age and gender on finger coordination in MVC and submaximal force-matching tasks. *J Appl Physiol*, 2003, 94, 259–270.

Articles not in English: Authors should translate the title into English and enclose the language of translation in square brackets. Do not translate the title of the journal. Only papers with English abstracts should be cited. Example: Jaskólska A., Bogucka M., Świdnicka R., Jaskólski A., Mechanisms, symptoms and after-effects of delayed muscle soreness (DOMS) [in Polish]. *Med Sportiva*, 2002, 4, 189–201.

A book should include: the author's or editor's surname

of the European College of Sport Science. July 19–23, 2000, Jyväskylä Finland, 600.

Powołanie na artykuł w formie elektronicznej: Donsmark M., Langfort J., Ploug T., Holm C., Enevoldsen L.H., Stallknech B. et al., Hormone-sensitive lipase (HSL) expression and regulation by epinephrine and exercise in skeletal muscle. *Eur J Sport Sci*, Volume 2, Issue 6 (December 2002). Available from: URL: <http://www.humankinetics.com/ejss/bisssues.cfm/>

*Przypisy.* Przypisy, objaśniające lub uzupełniające tekst, powinny być numerowane z zachowaniem ciągłości w całej pracy i umieszczone na końcu tekstu głównego.

*Tabele i rycinę.* Tabele i rycinę wraz z numeracją, podpisami oraz opisami należy umieścić na osobnych stronach, na których odwrotnie trzeba podać tylko tytuł pracy, bez nazwiska autora. Jeżeli w tekście nie ma powołania na tabelę lub rycinę, należy zaznaczyć miejsce jej umieszczenia. Rycinę muszą być czarno-białe lub w odcieniach szarości. Symbole, np. strzałki, gwiazdki, lub skróty należy dokładnie objaśnić w legendzie. Wykresy powinny być wykonane w programach Excel lub Statistica 5.0 i dołączone jako osobne pliki w formacie \*.xls lub \*.stg. Pozostałe rycinę (np. schematy) należy przygotować w programie Corel Draw (wersja 8 lub niższa) i dołączyć jako osobne pliki w formacie \*.cdr. Fotografie lub inne materiały ilustracyjne można dostarczyć w formie elektronicznej (\*.tif, \*.jpg – gęstość punktów obrazu 300 lub 600 dpi) bądź w postaci nadającej się do ostatecznego opracowania przez Redakcję.

Nie można powtarzać tych samych wyników w tabelach i na rycinach.

Praca, w której tabele i rycinę będą przygotowane niezgodnie z podanymi wymogami, zostanie odesłana do autora.

### Korekta autorska

Artykuł po opracowaniu redakcyjnym zostanie przekazany do autora w celu naniesienia przez niego korekty autorskiej. Obowiązkiem autora jest odesłanie korekty w ciągu jednego tygodnia. Kosztami poprawek innych niż drukarskie będzie obciążony autor.

### Poczta elektroniczna

Zachęcamy autorów do przesyłania prac w postaci elektronicznej (jako załączniki). Każda część pracy powinna być przesyłana jako oddzielnny załącznik: plik tekstowy, plik z rycinami, plik z tabelami, plik fotograficzny itd. Aby przyspieszyć przesyłkę, pliki należy skompresować w postaci \*.arj lub \*.zip. Komplet plików powinien być przesłany na adres hum\_mov@awf.wroc.pl

### Prawa Redakcji

Redakcja zastrzega sobie prawo poprawiania usterek stylistycznych oraz dokonywania skrótów. Prace przygotowane niezgodnie z regulaminem będą odsyłane autorom do poprawy.

(authors' or editors' surnames), first name initials, the title of the book in English, publisher's name, place and year of publication. Example: Osiński W., Anthropomotoric [in Polish]. AWF, Poznań 2001.

Chapter in a book: McKirnan M.D., Froelicher V.F., General principles of exercise testing. In: Skinner J.S. (ed.), Exercise testing and exercise prescription for special cases, 2<sup>nd</sup> Ed. Lea & Febiger, Philadelphia 1993, 3–28.

Conference proceedings and papers can only be referred to in the text if they are included in international data bases, e.g. SPORTDiscus. Example: Racz L., Tihanyi J., Hortobagyi T., Muscle fatigue during concentric and eccentric contraction. In: Avela J., Komi P.V., Komulainen J. (eds.), Proceedings of the 5<sup>th</sup> Annual Congress of the European College of Sport Science. July 19–23 2000, Jyväskylä Finland, 600.

Article in electronic form. Example: Donsmark M., Langfort J., Ploug T., Holm C., Enevoldsen L.H., Stallknech B. et al., Hormone-sensitive lipase (HSL) expression and regulation by epinephrine and exercise in skeletal muscle. *Eur J Sport Sci*, Volume 2, Issue 6 (December 2002). Available from: URL: <http://www.humankinetics.com/ejss/bisssues.cfm/>

*Tables and figures.* Each table together with its number, title, and annotations, should be submitted on a separate sheet of paper. Authors should identify the places where tables and figures are to be included within the text. Figures should be prepared in black and white and marked on the back with the title of paper only (do not include the name of the author). Legends for the figures should be submitted on a separate sheet of paper and should be self-explanatory. When symbols, arrows, numbers, or letters are used to identify parts of the illustrations, identify and explain each one clearly in the legend. **Only** Figures prepared in Excel, Statistica 5.0 or Corel Chart (version 8 or lower) will be accepted. The recommended file formats for figures are: \*.jpg, \*.tif, with an image resolution of 300 or 600 dpi.

Figures and tables should be numbered consecutively according to the order in which they have been first cited in the text. Data should not be repeated in tables and figures.

Photographs must be black and white glossy prints.

### Proofs

The corresponding author will receive one proof. Only minor corrections can be made at this time. Corrections other than printing errors may be charged to the author. It is the author's responsibility to return the corrected proofs within 1 week.

### Sending via e-mail

Authors who have an access to Internet are encouraged to send their work-files electronically using standard e-mail software. The e-mail software must have an option to send data files attached to the e-mail message. In such cases, all parts of the work should be sent as a separate files: text file, picture file(s), table file(s), photo file(s). To speed up

### Prawa autorskie

Publikacje podlegają prawu autorskiemu wynikającemu z Konwencji Berneńskiej i z Międzynarodowej Konwencji Praw Autorskich, poza wyjątkami dopuszczanymi przez prawo krajowe. Żadna część publikacji nie może być reprodukowana, archiwizowana ani przekazywana w jakiejkolwiek formie ani żadnymi środkami bez pozwolenia właściciela praw autorskich.

### Płatna reklama

Redakcja przyjmuje zamówienia na reklamy, które mogą być umieszczane na 2. i 3. stronie okładki lub na dodatkowych kartach sąsiadujących z okładką. Ceny reklam będą negocjowane indywidualnie.

the data transfer, files should be compressed (if possible) using \*.arj or \*.zip formats before transmission. Complete packages of manuscripts are to be sent to the following address: hum\_mov@awf.wroc.pl

### Reprints

Each Author will receive 1 copy of the issue in which his/her work appears.

### Advertising

The Editorial Board accepts advertising orders. Advertisements can be published on the second and third page of the cover or on the pages next to the cover. Advertisement prices will be negotiated individually.

## ZASADY PRENUMERATY CZASOPISMA HUMAN MOVEMENT THE RULES OF SUBSCRIBING THE HUMAN MOVEMENT JOURNAL

Cena rocznej prenumeraty (dwa numery) dla odbiorców indywidualnych w kraju wynosi 27 zł, dla instytucji 55 zł.  
Zamówienie wraz z potwierdzeniem dokonania wpłaty należy przesyłać na adres mailowy: hum\_mov@awf.wroc.pl lub

Redakcja czasopisma *Human Movement*  
Akademia Wychowania Fizycznego  
ul. Mickiewicza 98  
51-684 Wrocław

Numery czasopisma wysyłamy pocztą po otrzymaniu odpowiedniej wpłaty na konto:

**BPH PBK S.A. O/Wrocław**  
**42 1060 0076 0000 3210 0014 7743**  
**Akademia Wychowania Fizycznego**  
**al. Paderewskiego 35, 51-612 Wrocław**  
z dopiskiem: Prenumerata *Human Movement*.

Prosimy zamawiających o bardzo wyraźne podawanie adresów, pod które należy wysyłać zamawiane egzemplarze czasopisma. Pojedyncze egzemplarze można zamówić w ten sam sposób, wpłacając 16 zł (odbiorca indywidualny) i 30 zł (instytucja) na podane konto.

The price of annual subscription (two issues) for individual subscribers is PLN 27 and PLN 55 for institutions.

All subscriptions are payable in advance. Subscribers are requested to send payment with their order whenever possible. The orders should be sent to the Editorial Office:

e-mail: hum\_mov@awf.wroc.pl or  
*Human Movement* Editorial Office  
University School of Physical Education  
ul. Mickiewicza 98  
51-684 Wrocław, Poland

The issues of the journal are sent by post after receiving the appropriate transfer to the account:

**BPH PBK S.A. O/Wrocław**  
**42 1060 0076 0000 3210 0014 7743**  
**Akademia Wychowania Fizycznego**  
**al. Paderewskiego 35, 51-612 Wrocław, Poland**  
with the note: *Human Movement* subscription.

We ask the subscribers to give correct and clearly written addresses to which the journal is to be sent.

Single copies can be ordered in the same way, by transferring PLN 16 (individual subscribers) and PLN 30 (institutions) to the above mentioned account.