第19回日本バイオメカニクス学会大会プログラム

ヒトの動きの
しくみ。を探る

会　期：2006年 9月13日(水)，14日(木)，15日(金)
会　場：早稲田大学所沢キャンパス
大会HP：http://www.waseda.jp/assoc-jsb2006/

主催：日本バイオメカニクス学会
主管：早稲田大学スポーツ科学学術院

大会会長あいさつ

第19回日本バイオメカニクス学会大会会長
福永哲夫（早稲田大学スポーツ科学学術院）

日本バイオメカニクス学会第19回大会にご参加いただき心から感謝いたします。
おかげさまで、160題を超える一般発表演題の登録を頂きました。

本学会大会では一般発表の他に、特別講演、教育講演、シンポジウム、フィールドセッション、ランチョンセミナーを企画いたしました。

○特別講演として、Komi P.V. 先生をお迎えして
「SSC運動のメカニズムに関する最新情報」に関する講演をお願いいたしました。

○教育講演では
(1) 生体内部の映像化、
(2) 動きの仕組みとスポーツ科学の可能性、
(3) 歩行時の反射メカニズム
に関しての最新の情報を提供いたします。

○シンポジウムでは
(1) 反動動作のメカニズム、
(2) 動作分析の現場への応用、
(3) スキルの神経筋メカニズム
に関して最も活動的な研究者にお願いしての活発な議論の展開が期待されます。

○フィールドセッションでは
現役オリンピック短距離選手及びコーチを交えて、グラウンドでのデモンストレーションを中心に、「走動作のバイオメカニクス研究」に関して議論する予定です。

○「バイオメカニクス学生研究競技会」には
50題を越す多数の申し込みを頂きました。その中から抄録を慎重審議し10題を競技会賞候補として選出しました。当日のプレゼンテーションを評価したうえで競技会賞を決定したいと考えております。

○ランチョンセミナーでは
(1) 腱組織の適応と機能
(2) 加圧トレーニングのメリット、デメリット
(3) 転倒予防教室の実践と課題
についての最新情報を提供する予定です。

以上、学会中の皆様方の活発な議論の展開を期待したいと思います。

2006年9月13日
第19回日本バイオメカニクス学会大会会長　福永哲夫

目　次

抄　録

学会大会組織

1. 会　　長　福永　哲夫（早稲田大学スポーツ科学学術院）

2. 実行委員長　川上　泰雄（早稲田大学スポーツ科学学術院）

3. 実行委員会　村田浩一郎（早稲田大学スポーツ科学学術院）
太田めぐみ（早稲田大学スポーツ科学学術院）
神崎　　史

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5. 大会本部　早稲田大学所沢キャンパス　301教室
（会期中）

学会大会日程

	第1日目 9月13日(水)	第2日目 9月14日(木)	第3日目 9月15日(金)
8:00	受付		
		受付	受付
9:00		教育講演2 深代千之 （212教室）	教育講演3 中澤公孝 （212教室）
9:45	開会式（212教室）		
10:00	教育講演1 福永哲夫 （212教室）	一般演題 口頭発表 （A:205、B:210、C:S201教室）	一般演題 口頭発表 （A:205、B:210、C:S201教室）
11:00	一般演題 ポスター発表 （ログハウス）		
		総会	
12:00	ランチョンセミナー1 久保啓太郎 アロカ㈱ （211教室）	ランチョンセミナー2 安部孝 ㈱サトウスポーツプラザ （211教室）	ランチョンセミナー3 小松泰喜 酒井医療㈱ （211教室）
13:00	特別講演 P.V.Komi （212教室）	一般演題 ポスター発表 （ログハウス）	シンポジウム3 スポーツスキルの ニューロサイコバイオメカニクス （212教室）
14:00	シンポジウム1 反動動作のパワーアップ メカニズム （212教室）	シンポジウム2 動作分析を現場に生かす （212教室）	
			閉会式（212教室）
15:00			
			実験室公開 （スポーツホール）
16:00	バイオメカニクス 学生研究競技会 （211教室） 一般演題 口頭発表 （B会場:210教室）	フィールドセッション 朝原宣治、礒繁雄、 松尾彰文、土江寛裕 （陸上競技場*） *雨天の場合は212教室	
17:00			
18:00	懇親会 （食堂） バイオメカニクス 研究競技会賞表彰	スポーツイベント （スポーツホール）	
19:00			
20:00			

特別講演

9月13日(水)　13:00〜14:00　212教室

特別講演

STRETCH-SHORTENING CYCLE OF MUSCLE FUNCTION: WHAT HAVE THE PAST AND THE PRESENT LEFT US FOR THE FUTURE?

PAAVO V. KOMI
Ph.D., FACSM, FECSS
Professor, Exercise Physiology 1980-1990
Biomechanics 1990-2004
Director of the Neuromuscular Research Center 1997-

Education

Year	Degree	Institution
1963	Bachelor of Science	University of Helsinki, Finland
1966	Master of Science	University of Jyväskylä, Finland
1969	Doctor of Philosophy	Pennsylvania State University, USA

Employment

Jan. 1971 - Dec. 1979	Associate Professor of Anatomy and Kinesiology (with tenure), University of Jyväskylä, Finland
Jan. 1, 1979 – Dec. 31, 2004	Head of the Department of Biology of Physical Activity, University of Jyväskylä, Finland
Jan. 1980 - Jan. 1990	Professor of Physiology of Exercise, University of Jyväskylä, Finland
Feb. 1, 1990 – Dec. 31, 2004	Professor of Biomechanics University of Jyväskylä, Finland
Oct. 21, 1997- Dec. 31. 2006	Director, Neuromuscular Research Center, University of Jyväskylä, Finland

Relevant Memberships in International Scientific Organizations

International Society of Biomechanics	Member	1963 -
	Secretary General	1977 - 1981
	President	1981 - 1983
	Past President	1983 - 1985
American College of Sports Medicine	Member	1976 - 1983
	Fellow	1983 -

New York Academy of Sciences	Member	1976
International Society of Electrophysiological Kinesiology	Member	1968 -
World Commission of Sports Biomechanics	President	1983 - 1989
IOC Medical Commission	Member	1983 - 2003
International Council of Sport Science and Physical Education (ICSSPE)	President	1991 - 1996
European College of Sport Science (ECSS)	President elect	1995 - 1997
	President	1997 - 1999
	Past President	1999 - 2001
IOC Sport for All Commission	Member	2000 -

Awards

ASLA - Fulbright scholarship to the University of Iowa (Prof. Charles M. Tipton), 1966 - 1967
Corresponding Fellow, American Academy of Physical Education, 1986
Alumni Fellow Award, Pennsylvania State University, 1987
Doctor Honoris Causa, Universite Joseph Fourier, Faculté de Médicine, Grenoble 1992
Doctor Honoris Causa, Hungarian University of Physical Education, Budapest 1992
Distinguished Service Award, American Academy of Physical Education, 1992
The Philip Noel Baker- Research Award (ICSSPE), 1998
Citation Award, American College of Sports Medicine, USA, 1999
Muybridge Research Award, International Society of Biomechanics, 1999
Olympic Order Award, International Olympic Committee, 2001
Doctor of Science, Honoris Causa, University of Waterloo, 2002
Doctor Honoris Causa, Free University of Brussels, 2002
Doctor Honoris Causa, University of Osaka, 2004
Honorary Member Award, International Society of Biomechanics, 2005

Major Research Interest

Neuromuscular function of exercise, Muscle fatigue, Biomechanics.
Directs one of the most advanced biomechanics laboratories in Europe.

International Scientific Congresses Organized

President, Vth International Congress of Biomechanics, Jyväskylä, Finland, June - July 1975.
President, International Symposium on Sport Biology, Vierumäki, Finland, October 1979.
President, XVth International Congress of Biomechanics, Jyväskylä, Finland, July 1995.
President, Vth ECSS Congress, Jyväskylä, Finland, July 2000.
President, International Congress on Science and Nordic Skiing, Vuokatti, Finland, June 2006.

1. Introduction

Discussion of muscle function during exercise has traditionally dealt with the isolated forms of muscle actions: isometric, concentric and eccentric. All of them are not very common in normal movement situation, as will be shown shortly. **Isometric action** is defined as "activation of muscle while the length of the entire muscle-tendon unit (MTU) remains the same". The use of isometric action in locomotion is not, however, meaningless; it plays a very important role in the process of preactivation of the muscle before the other actions take place. **Concentric action** refers to "the muscle shortening while it is active", and the **eccentric action** means "lengthening of the active muscle". From these two "dynamic" forms, the eccentric action plays perhaps a more important role in locomotion. When the active MTU begins its lengthening – after the preactivation (isometric) phase - it forms a basis for a **stretch-shortening cycle (SSC)**, the natural form of muscle function in sports and normal daily life involving movement of the joints or the whole body. SSC is described in fig. 1 for the leg extensor muscle for the ground contact phase in running: The preactivated triceps surae muscle begins its eccentric action upon the first ground contact, when the MTU lengthens and receives activation signals from the nervous system. This eccentric or braking phase is then followed without considerable delay by the shortening (concentric) action, which depending on the intensity of effort, can take place in many cases as a recoil phenomenon with relatively low electromyographic (EMG) activity. Consequently, SSC has important functions in locomotion: (1) to take up the unnecessary delays in force-time relationship by bringing the preactivated force up to the required level to meet the expected eccentric loading, and (2) to make the final concentric action (push-off phase in fig 1) to produce higher power (in maximal effort) or to generate force more economically (submaximal conditions) as compared to the corresponding isolated concentric actions. Cavagna et al (1965, 1968) were among the first ones to describe the mechanisms of this performance potentiation in SSC by using elegant control situations of force and stimulus in his device designed in his first experiments for isolated frog sartorius muscle (Cavagna et al, 1965) and later also for human forearm flexors (Cavagna et al 1968) Another important contributor to the current concepts of SSC is Asmussen (Asmussen & Bonde-Petersen, 1974). Fig 2 is from our own experiments for the knee extensor muscles (Komi, 1983), and it is meant to describe that, in addition to the velocity of stretch in the eccentric phase, the time delay (coupling time) between stretch (eccentric) and shortening (concentric) has great influence on the force (and power) output in the final concentric phase of SSC. Improvement of economy of the push-off phase has subsequently been shown to improve in SSC exercise when the coupling time between braking and push-off phases in short (Aura and Komi, 1987).

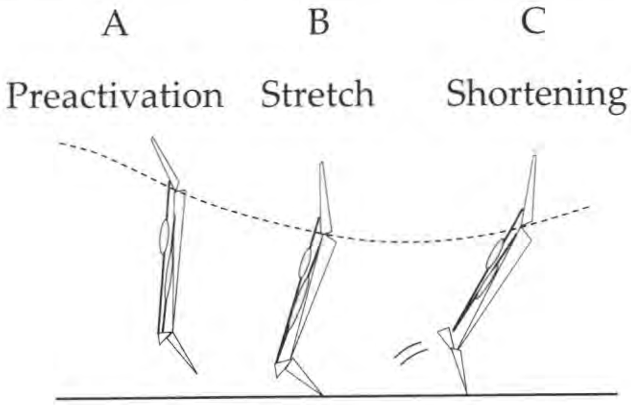

Fig 1. In human walking, hopping and running considerable impact loads occur when contact takes place with the ground. This requires preactivation from the lower limb extensor muscles before the ground contact to make them ready to resist the impact (A) and the active braking phase (B). The stretch phase is followed by a shortening (concentric) action (C) (adapted from Komi, 2000).

At the level of MTU it is easy to demonstrate the performance potentiation when the instantaneous force is plotted against the velocity of the MTU lengthening and shortening during ground contact of running (fig 3). The force was recorded with the buckle transducer from the Achilles tendon (Komi, 1990). Although the curve does not include the classical Hill curve for comparison, it suggests considerable force potentiation in the concentric phase in a similar manner as reported by Gregor et al (1988) in cat experiments. This force potentiation is dependent, among other things, on the velocity of stretch and intensity of effort in the concentric phase. These and other features of force and power potentiation will be discussed in more detail in the second abstract from our group in this conference (Ishikawa and Komi, the present volume). The mechanism of the performance potentiation is not an easy problem to solve, as it must take into consideration also the two major components of MTU: fascicles and tendinous tissues. These two components operate together as the fascicle-tendon interaction. Consequently, the true answers of the mechanisms cannot be revealed, if the measurements are made on the single component only. This notion applies especially to the ultrasound measurements of the fascicles and tendons (and also aponeurosis) during locomotion.

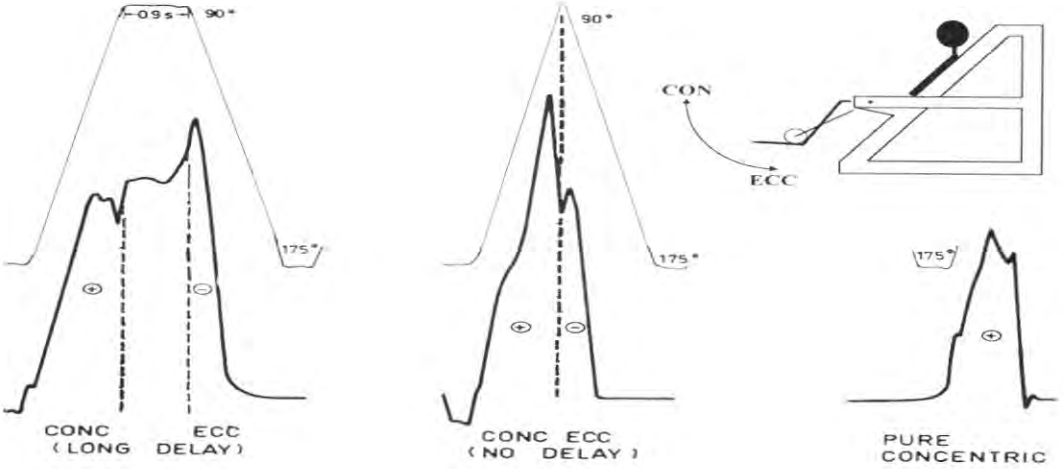

Fig 2. Demonstration of the importance of the short coupling time between eccentric and concentric phases on performance potentiation in the concentric phase. Right: Pure concentric contraction of knee extension from approximately 100° to 175°. Middle: Concentric contraction is preceded by eccentric (⊖) contraction and no delay is allowed when contraction was changed. The eccentric action (prestretch) began somewhere in the middle of movement from 175° (Knee in an extended position) to 90° position. Note the clear force potentiation in the concentric (⊕) phase as compared to the condition on the right. Left: Longer delay (0.9s) was allowed between the eccentric and concentric phases. Therefore, the potentiation effect on the concentric phase was reduced (Komi 1983)

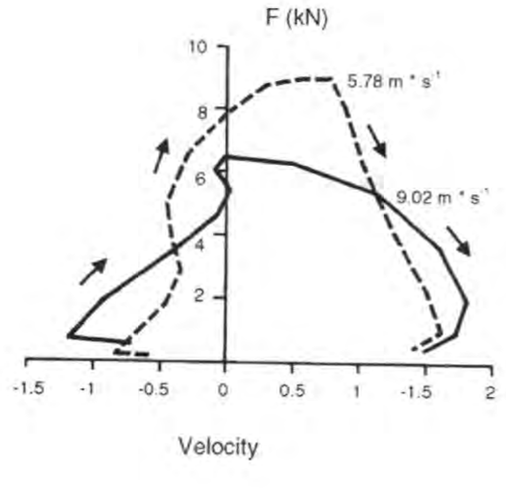

Fig 3. Examples of instantaneous force–velocity curves measured in human running. The records were obtained with the buckle transducer (Komi, 1992) and represented the functional (contact) phase on the ground. In each curve the upward deflection signifies stretching (eccentric actions) and the downward direction shortening (concentric action) of the muscle tendon complex during ground contact.

2. Adaptation of muscle to SSC exercise

The in-vivo force measurement systems, buckle transducer technique (Komi, 1992), and optic fiber technique (Komi et al, 1996; Finni et al, 2001) have revealed that a nonfatiguing SSC exercise demonstrates considerable performance enhancement with increased force at a given shortening velocity. Characteristic to this phenomenon is very low EMG activity in the concentric phase of the cycle, but very pronounced contribution of the short-latency stretch-reflex component. The stretch reflex contributes significantly to force generation during the transition (stretch-shortening) phase in SSC action such as hopping and running (e.g. Komi & Gollhofer, 1997). As is obvious the occurrence of the stretch reflex requires that the muscles (fascicles) are truly stretched during the braking phase of SSC. This has been clearly demonstrated for the soleus (SOL) muscle. The results for the gastrocnemius muscle are somewhat controversial (see Fukunaga et al 2001 and Ishikawa et al 2006), but our own results with higher ultrasound "sampling" frequency (96 Hz) are very convincing to demonstrate a very short fascicle stretching in the gastrocnemius (GA) muscle right upon the first moments of the ground contact. For details see Ishikawa and Komi (this volume of abstracts)

The common assumption has been that in SSC activities both the muscle fiber compartment and the tendon would change their lengths in phase. This assumption has been challenged, because muscle fibers have been estimated to stay at a constant length (Belli & Bosco, 1992) or they can even shorten (Griffiths, 1991) while the whole muscle-tendon complex may be lengthening. These suggestions naturally question the applicability of the instantaneous force-length and force-velocity curves (Komi, 2000; Finni et al, 2001) equally to both parts of the muscle-tendon complex.

Despite the common use of SSC during locomotion the studies are surprisingly low in number regarding the adaptation of SSC training. More focus has recently been given to the fatiguability of exhaustive SSC exercise. These studies have considerably increased our knowledge about the nature and mechanisms of the neuromuscular fatigue. Especially challenging has been to observe considerable neural, mechanical and structural changes in the course and following the exhaustive SSC fatiguing protocol (for references, see Nicol, Avela & Komi, 2006). This emphasizes the following important aspects to characterize SSC: (1) variation (depending on the impact condition) of the preactivity and (2) of the subsequent braking and push-off parts of the ground contact of running or hopping, for example. The neural control, including central and peripheral components, plays key roles in these adjustments and may naturally be related to corresponding adjustments in mechanical behaviour and structural modifications of MTU. This happens especially in the situations of muscle damage, a common feature in intensive and exhaustive SSC exercise. The neural adaptations are often so dramatic that they have influence on the overall control of movement of the exercising muscles. SSC fatiguing exercise has also a very special feature: the functional recovery from damaging (exhaustive SSC exercise) takes place in a bimodal fashion, first described by Nicol et al (1996) passive stretch reflexes) and later confirmed for several other neural as well as for mechanical and structural parameters (e.g. Avela & Komi, 1998; Dousset et al 2006). It is important to emphasize here that in this bimodal fashion of recovery from exhaustive SSC exercise the neural and mechanical attributes change in parallel, thus supporting Asmussen's (1979) original suggestion of "parallelism" between these two components in the fatigue phenomenon.

3. Challenges for the future

It would be a mistake to assess that SSC is thoroughly explored and well understood in its all details. There are still many issues remaining for future research. In the following some of the major aspects are described as most relevant ones for those interested in going deeper into the mechanisms and applications of SSC:

3.1. Mechanism(s) of the force and power potentiation in SSC. Here the outstanding problems deal with both molecular level structures in the sarcomeres and the lateral force transmission in the intracellular matrix. On a more macro level there is a need to understand more exactly the relative roles of facilitatory and inhibitory reflexes and how they potentiate/control the power production in SSC. This refers also to the problem that the entire concept of fascicle-tendon interaction needs to be examined in all possible intensities and durations of SSC. Equally important is to revisit the motor unit recruitment during various types of SSC.

3.2. Adaptation of SSC in the course of various training, detraining, and fatigue modalities. At present the training studies are far from the true nature of SSC: the used impact loads, joint angular velocities are often outside the dynamics of SSC. The same criticism applies to the measurement parameters that are used to assess the effects of various adaptation formats. Isometric measurements have been too often applied to measure the fatigue and training influences of a certain type of SSC exercise, for example. It is very likely that use of isometric modes only will not reveal true mechanismic effects of training and fatigue as they should occur in truly natural exercise.

3.3. Influence of aging on SSC function. This area is wide open for many research projects.
The problems are similar as mentioned above in 3.2.: Aging studies should focus on problems of natural movements such as SSC. The parameters to describe the ageing induced disturbances should also be selected so that they characterise the requirements of SSC as much as possible. This may not always be a possibility in older subjects, as it may be dangerous to test them in high velocity of stretch loads. But the requirement of dynamic nature of the parameters should be kept in mind in aging studies. For example, it would be more important to understand the stiffness and compliance changes of the tendon tissue in dynamic loading situations as compared to the currently used isometric tests. The same will apply to the possible aging induced problems in the fascicle-tendon interaction.

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