

# Biomechanics services: A question of co-operation

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By Falk Schade

## ABSTRACT

*The interaction between a coach and a biomechanical diagnostician is a crucial element of developing a modern high-level athlete's performance. The aim of such co-operation should be to improve performance, but differences in approach, interests, understanding and technical terminology between the coach and diagnostician can complicate the process. Based on his experience working in the German federal sports system, the author explains that the role of the diagnostician is to provide an interface between science and practice. As such, the diagnostician cannot be fully in either camp but must be comfortable working in and speaking the language of both. He outlines the philosophy and the main areas of co-operation: 1) performance enhancement, 2) injury prevention and rehabilitation, 3) coaches education, stressing the importance of communication and need for diagnosticians to build teams within their fields of expertise and with experts from different fields, like physiology and psychology. He then presents examples of co-operation, highlighting the interaction between the coach and diagnostician. He concludes by stating that secrets for successful biomechanical services do not exist, it is all about face-to-face communication, work, dedication and sustainability.*

## AUTHOR

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## Introduction

*“I would like to measure the stride lengths of my long jumper, how can I do it?”*

*“Is it better to start the approach from a rest position or to begin with some pick-up moves?”*

*“Could you help me with my pole vaulter – we made a certain change in the planting technique and would like to know how much it influences the performance. In fact, we would like to know if the change has a positive effect on the energy level of the vaulter-pole system at take-off.”*

*“Could you assist us in developing a routine check for the strength abilities of jumpers?”*

*“What is the optimum weight and movement velocity for my shot putter doing squats for improving shot put performance?”*

*“Could you make some high-speed video recordings during a workout for me?”*

*“What is the optimum configuration of stride length for my sprint hurdle?”*

The interaction between a coach and a biomechanical diagnostician is a crucial element of developing a modern high-level athlete's performance. The example quotes above give an impression of the wide range and complexity of coaches' requirements and questions in the field of biomechanics - and not all of them are answerable.

Though the following report cannot claim to be a complete overview of biomechanical services in athletics, it is an attempt to describe the main elements of the co-operation between diagnostician and coach from the diagnostician's point of view. It is based on the experience of working in the German federal sports system and as an employee in the system the author's perspective is strongly influenced by specific structural circumstances. Unfortunately it also limits the amount of information that can be presented. However, it is hoped that the points covered will help coaches and diagnosticians understand the basics of such services and how they might increase the value they obtain, regardless of the system in which they work.

### Philosophy of Co-operation

Biomechanical diagnosticians exhibit various attitudes towards their work in elite sports. Absolute belief in the power of science, e.g. sport biomechanics, can be found as can a complete neglect of scientific findings in favour of a focus on qualitative movement evaluations. On the level of interaction, certain scientists will consider themselves to be somehow superior to the coach but there are also those who are so

subservient to tell coaches only what they want to hear. In most cases the reality of the situation will be somewhere between the extremes. We can all understand that the deepest and latest insights into neuromechanical functions, for example, are useless if individual instructions cannot be derived, or, even worse, they can be derived, but no one listens or believes in the findings due to a lack in confidence in the source.

According to the "Cologne Model of Co-operation", the role of the biomechanical diagnostician in elite sports should be that of an interface between science and practice (Figure 1).

To handle this role, diagnosticians should feel comfortable in both of two areas: the scientific and the applied. Therefore they should be involved in both of these partially contradictory fields of work and understand the completely different aims and languages of the communities they comprise.

Whereas the scientific approach tries to generate general knowledge and find cause and effect relationships while tending to neglect the relevance of single cases, those in the applied field of elite sports are interested in highly individual strategies to increase the individual performance of single athletes and tend to follow the maxim: "Who wins is right", and "you do not need to know how it works to make it work". While sport biomechanics in general is interested in means and standard deviations, the practice of elite sports is interested in those individuals who are far from the average.

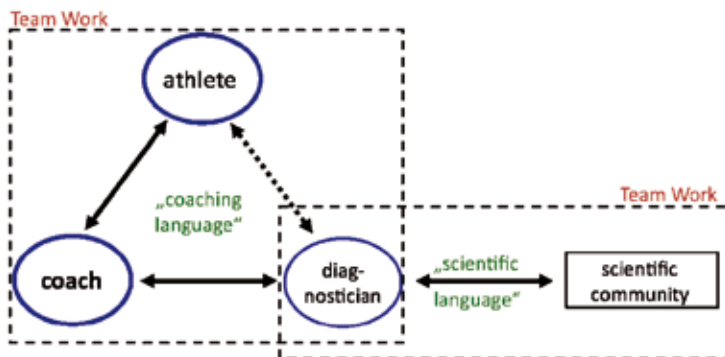


Figure 1: Cologne model of co-operation (the diagnostician is an interface between practice and science).

The aim of the co-operation between the coach/athlete on one hand and the biomechanical diagnostician on the other should be the development of the athlete's performance and related areas. This might sound self-evident, but sometimes the interests of support staff differ from the goals of the athlete and coach. In the author's case, employment at an Olympic Training Centre requires that enhancement of the athlete's performance is the first goal. Depending on the diagnostician's position, additional aims, such as support of scientific studies, might be acceptable, but can only be accepted if both parties get relevant and similar benefit.

The co-operation between the coach/athlete and the biomechanical diagnostician should follow the ideal of teamwork based on three "Cs":

- Competence,
- Communication,
- Confidence.

Competence is a pre-condition for effective goal-oriented processes, but the fields of competence differ between coach and diagnostician. The coach's competence covers several fields, but for an effective co-operation with a diagnostician his/her readiness to co-operate is also essential. To close the gap between theory and practice, the biomechanical diagnostician's competence should include scientific knowledge, accumulated and kept up to date by a close contact with a scientific group at, for example, a university. At the same time it should include contact with and experiences in coaching itself and through these a familiarity with the "coaching language".

To develop confidence, scientific knowledge and findings should be communicated properly. Without confidence the co-operation will not work. This means that the communication with the coach and athlete has to take place at eye level (or: on a par with each other) and that the diagnostician has to be able to break findings up to practically relevant and generally understandable statements. The main communication within the practice team should be carried out between the coach(es) and diagnostician. Communication between diagnostician and

athlete contains the risks of misinterpretation and interference in the coach/athlete relationship. It therefore should only be conducted with the compliance of the coach.

To increase the impact of the diagnostic support, it is necessary that diagnosticians themselves build teams within their fields of expertise and with experts from different fields, like physiology and psychology, and share their experiences.

### Areas of Co-operation

The main areas of co-operation between the coach/athlete and the biomechanical diagnostician are:

- Performance enhancement,
- Injury prevention and rehabilitation,
- Education (coaches education, further education, development of discipline and age related coaching master plans)

#### *Performance enhancement*

Usually, the most requested area of support is performance enhancement, which comprises different fields according to the respective possibilities of biomechanical diagnostics, available controlled/mastered biomechanical equipment and creativity. It covers movement analysis based on kinematic data (e.g. take-off angle, height and velocity of the centre of mass, release velocity of an implement) and measured ground reaction forces and derived parameters, the direct measurement of approach velocities (using double beams or laser speed measurement), the measurement of the acceleration of throwing implements (i.e. acceleration of the javelin using telemetric accelerometers) and the determination of general and specific athletic skills (i.e. reactive or maximum strength of the lower extremities).

The applied methods should neither disturb (non-reactive to) the athlete. Diagnostics can either be conducted during training or during competition. The time interval between acquisition of the data and presentation of the results is highly important. The point time of the presentation should be announced to the coach prior to the diagnostics to avoid disappointment, but

should be as fast as possible. Increasing the time interval for data delivery can only be justified if the relevance of the presented results is adequate. For example, approach velocities measured during training should be presented immediately after the trial, whereas energy parameters gathered during a pole vault competition, which takes some days of analysis, can be presented maybe one week later. Biomechanical results that might lead to a change in short-term coaching strategies should be presented as soon as possible, but results leading to a change in long-term coaching strategies can be presented even a few weeks after collection, if the information justifies it.

Biomechanical diagnostics in the area of performance enhancement can either refer to aspects of movement technique or aspects of biomotor abilities. In some cases, it is difficult to recognise whether a weak movement technique is the result of insufficient technical abilities or biomotor deficiencies, and indeed this is a very important question to investigate. Co-operation in this area usually takes place in the following steps:

- Posing of a relevant question that has a chance of being answered,
- Design of a diagnostic set up,
- Application of the diagnostics,
- Development of training interventions on the basis of the findings and experiences of coach/athlete and diagnostician.

Throughout the process creative communication between coach and diagnostician are necessary to guarantee maximum impact, particularly in the first and last steps.

### *Injury prevention and rehabilitation*

This area does not belong to the author's scope of expertise but it is clear that the relevance of injury prevention and rehabilitation has increased in recent years, as it supports the long-term development of talented individuals and maintains their stay on elite level. Interpretation of diagnostic findings and development of useful instructions in this area are as difficult and complex as in the area of performance enhancement. When the need arises for such support, the author turns to specialised colleagues within the "scientific team" (see sidebar on page 28).

### *Education*

Coaches' education and further education are essential for developing elite athletes. Two pillars of successful coaches' education are high specific competences of the lecturer and, even more relevant, an on a par (eye level) interaction between lecturer and coach. Even though there are differences in specific competences, there is no reason for any disrespectful discussion. Further education of elite coaches seems to be most effective when both lecturers/scientists and coaches can have a creative discussion. If the coach is open to reflect on his/her work, it is the lecturer's/scientist's task to guarantee the educational success.

### *Initiating Co-operation*

The German Federal Sports System runs about 20 Olympic training centres or *Olympiastützpunkt* (OSP) around the country, which are ultimately financed by the government. These offer services for elite sports ranging from career management to injury prevention/rehabilitation training, psychological support and performance diagnostics. The individual sports associations (i.e. the German Athletics Federation) make contracts with the OSPs, determining the extent of the services required, especially for the national teams. The initiation of the co-operation between a coach/athlete and diagnostician can either be a result of this agreement: (A) coaches/athletes are asked to use the responsible diagnosticians, which is valid for diagnostics at federal level, or (B) by personal motivation on the part of the coach/athlete (C) or the diagnostician, which is valid on a regional or local level.

Case (A) is more or less a forced relationship and it needs to be handled with extra care on the part of the diagnostician. Creating confidence should be the focus of an initial co-operation. From the diagnostician's point of view, case (B) is the easiest constellation to handle, because confidence already exists. But it contains the risk of disappointing the coach/athlete if expectations cannot be fulfilled. Case (C) is the most difficult way to start a co-operation: The diagnostician will hold the view that he/she can really be of some benefit to coach/athlete, but they have not yet worked together. In this case, it might be appropriate to start with basic services like video

support or speed measurement prior to applying complex ambiguous diagnostic tools.

In cases (A) and (C), it can occur that the ideas of the contents of the biomechanical support differ between the coach and the diagnostician. Unfortunately, there is no recipe to cope with this problem, but it might be helpful to show respect and discuss ways to find an agreement.

### Examples

The impact of biomechanical services on an athlete's performance generally cannot be quantified. This is because performance in athletics is too complex to evaluate the impact of a single factor. However, the aim of a co-operation should be to achieve at least a positive effect on the training process. In the following section, a detailed example of biomechanical diagnostics in the pole vault, some examples of other biomechanical services concerning performance enhancement and an excursion into the area of prevention and rehabilitation are presented.

### Routine competition movement analysis (central support)– pole vault

Figure 2 shows the result sheet of a routine competition analysis that is applied during four major national pole vault competitions per year for elite and promising athletes. This system has been applied for the last seven years, but is still being developed in a co-operation between the national pole vault coaches and the author. Experiences from the coaches' further education have been used while the scientific basis, the application of the concept of energy storage and return to the pole vault, has been generated within a scientific work group at the German Sport University of Cologne, with which the author is involved.

The sheet is sent to the coaches one week after a competition (20 to 30 trials can be analysed within 3-4 days) and it contains information about the approach run, pole plant, maximum pole bend position and bar clearance. The parameters reflect basic information like stride lengths or the change in height of the upper grip hand during the jump as well as more

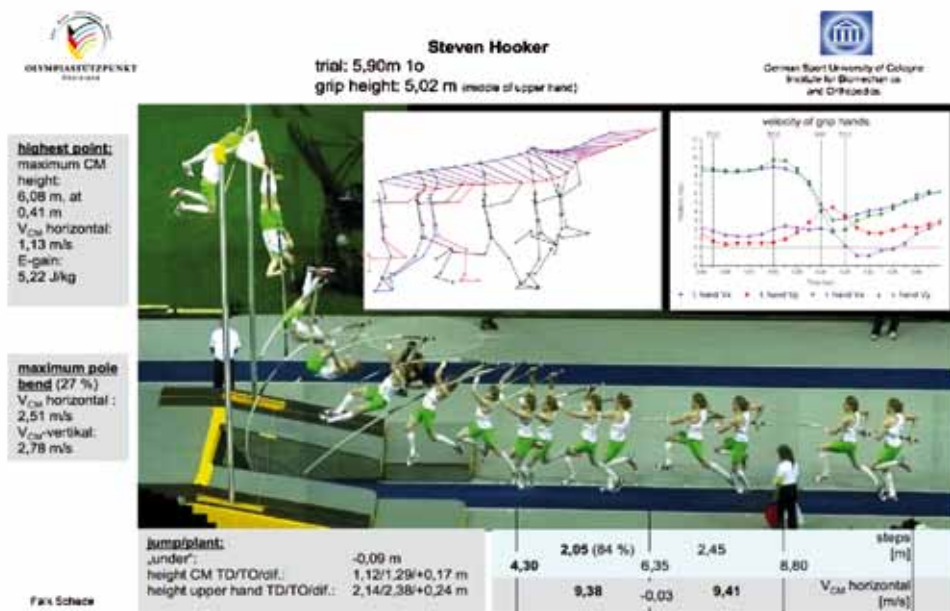


Figure 2: Example of a routine movement analysis in the pole vault (the calculation of the parameters is based a 2-dimensional kinematic data acquisition (50Hz)).

complex information that helps to explain the energy exchange between athlete and pole, like the extent of maximum pole bend and the energy gain for the whole jump. In addition, the achieved maximum centre of mass height is calculated. To facilitate the connection of the calculated parameters and the movement of the athlete, a stromotion presentation of the vault has been chosen. For the same reason a stick figure is presented.

To account for the importance of the pole plant, the horizontal and vertical velocity of both grip hands are presented. The exact energy exchange between athlete and pole, the effective work of the athlete during the pole phase and the energy change of the vaulter-pole system during the jump and plant complex can be determined, but this is only possible during training experiments. The analysis of the data will take a few weeks, which is too extensive for routine diagnostics. Nevertheless the presented sheet is highly accepted by the coaches, especially when taking individual long-term developments into consideration.

#### *Training experiment (local support) - javelin throw*

In this case, the coach and diagnostician have been co-operating for several years. The problem at first was that an elite thrower was not rigid enough in the brace leg during release, even though the relevant biomotor abilities were sufficient. The idea jointly developed by coach and diagnostician was, in the first step, to quantify the “give” in the leg to present the athlete with objective data about the movement and then to increase the load on the brace leg and thereby make the athlete feel the deficit. To quantify the give in the knee joint, a Kistler force platform in the release area of the runway and a high-speed video camera operating at 150 frames per second were used. Additionally, two double beams quantified the approach velocity during the last stride. The load was increased using the “pull support” of a rubber band, which increases the horizontal approach velocity. The data and high-speed recordings were presented immediately after each trial. During the session, a positive change in movement behaviour occurred and this was stabilised in the following weeks.

#### *Training monitoring (local support) – elite pole vaulter*

In this case, the coach contacted the diagnostician for assistance with the question whether his athlete might benefit from increasing the approach length in the pole vault from 16 to 18 strides. It was expected that an increase in the final velocity could be controlled and therefore would be beneficial. Using a laser speed measurement device during several training sessions, it became obvious, that the 18-stride approach was not appropriate. The athlete achieved maximum velocity much too early in the approach, which lead to a decrease of the velocity within the last two strides. The coach/athlete postponed the change in approach length.

#### *Training experiment (local support) – sprint hurdles*

During a further education activity a coach described the parameters he quantified in training on his own. Amongst others things he measured were the time for the hurdle clearance of a female sprint hurdler. He figured out that when trying to minimise the time for hurdle clearance the athlete became slower. In fact, it is possible to minimise clearance time at the cost of the hurdler's geometry at touchdown

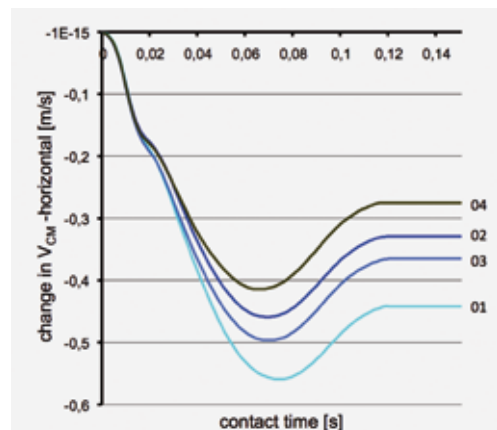


Figure 3: Change of the horizontal velocity of the centre of mass (CM) during the last ground contact in front of the third hurdle for a female sprint hurdler (The athlete was performing four trials with different instructions. The calculation of the change in velocity is based on measured ground reaction forces in front of the hurdle (Kistler force platform, 1000Hz). The contact times varied around 115 ms).

after the hurdle, which reduces running velocity. The diagnostician suggested a training experiment to measure the influence of different instructions on the change in horizontal centre of mass velocity during the last ground contact in front of the hurdle (Figure 3).

The coach was convinced to start a co-operation. In addition to a force measurement device at take-off, a video camera was used for qualitative analysis and double beams were used to measure two interval times, one prior to take-off and the other from take-off to one step after the hurdle. For the four trials studied, the approach velocity was the same, but the change of the horizontal centre of mass velocity during take-off and the second interval time changed significantly. The instruction “make the last step prior to take-off short”, which really caused a shorter last step led to the best results (see Figure 3: trial 04). The combination of objective quantification, video feedback and adequate instructions affected the hurdler’s performance positively.

#### *Training monitoring at local support – javelin*

For the javelin coach mentioned above, a telemetric acceleration-measuring device has been developed. It can easily be fixed to the implement or machines for special strength training. The online measurement of the acceleration of the javelin can be synchronised with video recordings of the throw. This system is used to analyse the acceleration of the javelin as a function of the movement behaviour and helps to detect covered deficits of the movement technique.

#### *Movement analysis at local support – hammer throw*

Figure 4 shows stick figures of a 3-dimensional kinematic movement analysis of the hammer throw. In addition to information like hammer velocity and acceleration and change of radius during the turns, the stick figures also show the instant of take-off and touchdown of the free leg in connection with the hammer position and they are useful to connect biomechanical data and movement behaviour. Animated stick figures are part of a synchronised result video, which also contains two camera

perspectives and several time courses of further biomechanical parameters that the coach is interested in.

#### **Conclusion**

Within the next few years the impact of biomechanical diagnostics on performance in athletics could well increase due to the increasing quality of biomechanical analysis. Further insights into muscle tendon mechanics and the improving possibilities of understanding individual performance will effect the development of individual training strategies and the optimisation of individual movement solutions.

However, further development depends, on the one hand, on scientists focusing on case studies. For this, an increase in the acceptance of case studies within the scientific community and increasing the co-operation with diagnosticians might be necessary. On the other hand, the coaches community should stay open minded and lay down preconceptions towards biomechanics.

Finally, the author would like to stress that secrets for successful biomechanical services do not exist, it is all about face-to-face communication, work, dedication and sustainability. In fact, due to his function, the diagnostician does not really belong to the coaches team or to a scientific work group. To get the most out of a diagnostician it might be worth coaching him and giving him a feeling of being involved.

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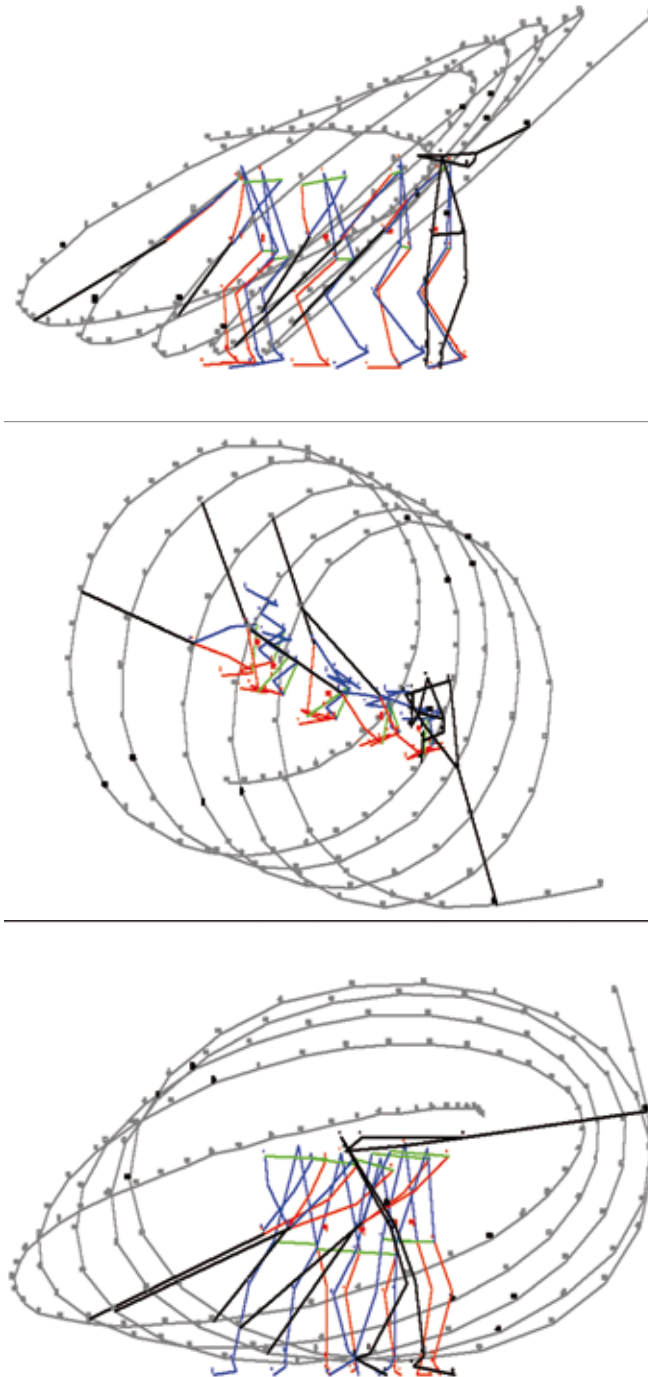


Figure 4: Example of visualisation of the hammer path during the hammer throw from different perspectives (The stick figures are based on a 3-dimensional (50 Hz) kinematic movement analysis. Bold hammer positions represent takeoff and touch-down of the right foot during the turns).

### Analysis of muscle-tendon unit mechanical properties in vivo: a practical device for coaching, prevention and rehabilitation of tendon injuries

Analysis of skeletal muscle function and its role on athletic activities has been an objective in sport sciences for decades and has provided helpful devices for sport exercise. There is increasing evidence that the non-rigidity of tendons influences the function and performance capability of skeletal muscles and, thereby, affects the performance capability of the entire musculoskeletal system. This is based on the fact that, next to the transfer of muscle forces to the skeleton, the main functions of the tendon during movement are to store mechanical energy and to provide favorable conditions for the muscle to generate forces due to the force-length-velocity relationship.

For example, recent empirical studies have demonstrated a significant contribution of Achilles and Patellar tendon stiffness to running economy, sprint performance as well as on dynamic stability control. Both of these tendons are subject to substantial loads - up to 15 times body weight - during locomotion. Due to the high and continues magnitude of stress and strain placed on these tendons in athletics activities, they are subject overuse injuries and ruptures.

Indicators for tendon damage after mechanical loading are a decrease in the elastic modulus, stiffness and cyclic energy dissipation of the tendon. In particular the initial strain, defined as the strain at which the target stress is first reached, has been reported to be the primary mechanical parameter governing tendon damage accumulation while loading. On the other hand, it is known that biological tissues can adapt to exercise or immobilisation affecting their mechanical properties. Since anabolic and catabolic responses can differ substantially between muscular and fibrous connective tissues, a discrepancy in adaptation rate and magnitude within the muscle-tendon unit can increase the risk factors for tendon injury and rupture. Therefore, a device has been constructed which allows the analysis of the mechanical properties of the human leg-extensor muscles and tendons in vivo and non invasive using ultrasonography and dynamometric measurements (see Figure 1). The new developed diagnostic tool for the analysis of human muscle-tendon mechanical properties is mobile and easy to handle for coaches and clinicians. Moreover, the data are processed automatically by a custom made software and allows an online examination of an athletes actual state with respect to his muscle and tendon mechanical properties.

Monitoring muscular and tendineus mechanical properties of an individual athlete over his/her career would provide a helpful practical device in coaching, prevention and rehabilitation of tendon injuries.

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Kiros Karamandis, PhD, is since 2001 a scientific member of the neuromechanics research group at the Institute of Biomechanics and Orthopaedics at the German Sport University Cologne. His major research interest is the adaptation of muscles and tendons and its effect on locomotion mechanics focusing on the improvement of quality of life and performance capability of the entire musculoskeletal system in different subjects groups.

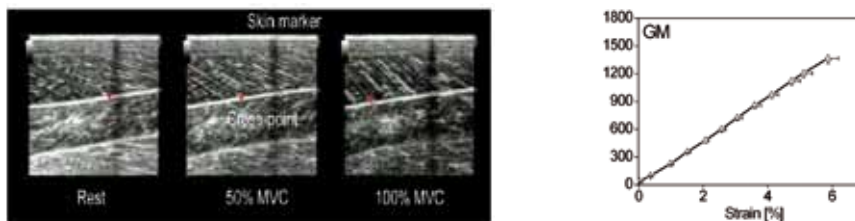


Figure 1: (a) Ultrasound images of the gastrocnemius medialis muscle at 0, 50 and 100% of the maximal voluntary isometric contraction (MVC) performed on a dynamometer. The elongation of the tendon and aponeurosis during MVC is determined by digitising the insertion of the muscle fascicle into the distal aponeurosis (cross point) frame by frame from 0 until 100% of the MVC. A marker is set between the probe and the skin in order to examine any motion of the probe in relating to the skin. (b) Strain values of the gastrocnemius medialis tendon and aponeurosis in relation to the calculated tendon force of six endurance runners (mean - SEM). The normalised stiffness can be determined by slope of the calculated tendon force versus strain of the tendon and aponeurosis between 50 and 100% of the maximal tendon force by means of linear regression.