Development of innovative training solutions in the field of functional evaluation aimed at updating of the curricula of health sciences schools

MODULE BIOMECHANICS FOUNDATIONS

Didactic Unit F: REQUIREMENTS OF A BIOMECHANICAL ASSESSMENT SYSTEM. CONCEPTS OF VALIDITY, RELIABILITY AND ACCURACY

F.1. What features should an appropriate biomechanical assessment system count on?

Index

1. Biomechanical assessment tests in different contexts

What a biomechanical assessment test is.

A biomechanical assessment test is a complementary test done by means of biomechanical techniques. It should be used in different contexts. For example, it is used as a complementary test for functional evaluation in a clinical context, to either enhance performance or reduce the injury risk a in a sportive context, for job evaluation in a occupational context or for investigation in this different fields of knowledge. Figure 1 shows images from different biomechanical assessment tests in a clinical context (1).

Figure 1: Images corresponding to different biomechanical assessment tests. Cervical motion analysis with fogogrammetry (A), hand grip strength analysis with a hand dynamometer and posturographic assessment with force platform (C), respectively.

Elements in a biomechanical assessment test.

There are different biomechanical assessment tests, the elements that determine them are:

- What function, activity or gesture is subject to assessment.
- What instrumental technique it is based on.
- What assessment protocol has been used.
- What results it provides, in what units and with what data analysis techniques have been obtained.
- Existence of standardized criteria for interpretation.

For example, Gait analysis (activity is gait) by means of force platform, photogrammetry and surface electromyography (all of them are biomechanical measurement techniques) during walking in a straight line at spontaneous speed (protocol). It provides dynamical and kinematical parameters like ground reaction forces in Newtons, range of motion in lower limbs in degrees or gait velocity in meters per second and muscle activation patterns (results) that can be compared with normal data from a non-impaired population (standardized criteria for interpretation).

Another example is Grip strength analysis (function is hand strength) by means of a dynamometer (biomechanical measurement technique) during one second of maximum hand strength (protocol). It provides maximum strength in Newtons (results) than can be compared with normal data from non-impaired population (standardized criteria for interpretation).

Common biomechanical tests in the clinical context.

There is some heterogeneity regarding the procedures used, despite this fact, functional evaluation with biomechanical tests is widespread in the clinical field. The most widely used biomechanical tests in the clinical context, classified according to their purpose of assessment and instrumental technique, are:

- Assessment of activities of daily living. Some examples are walk (**Błąd! Nie można odnaleźć źródła odwołania.**), sit to stand, lift loads or move an object by means of force plates and/or movement analysis techniques.
- Balance function assessment, using computerized posturography, based on force analysis technique.
- Assessment of mobility in upper, lower and spinal limbs, through movement analysis techniques.
- Strength assessment in upper, lower and spinal limbs, using force analysis techniques.

(In the complementary material you can view videos with protocol details of some of these tests).

Each test provides results in different units. But mostly, biomechanical tests are aimed at informing about the assessed function and it is common for the results to be expressed compared to reference standards.

Biomechanical tests are used as a complementary test in the assessment of patients with involvement of the musculoskeletal system or balance function and its main applications are:

- Evolutionary control.
- Treatment planning.
- Assessment of the work capacity of a worker
- Assessment of bodily harm.
- Medical-legal expertise.

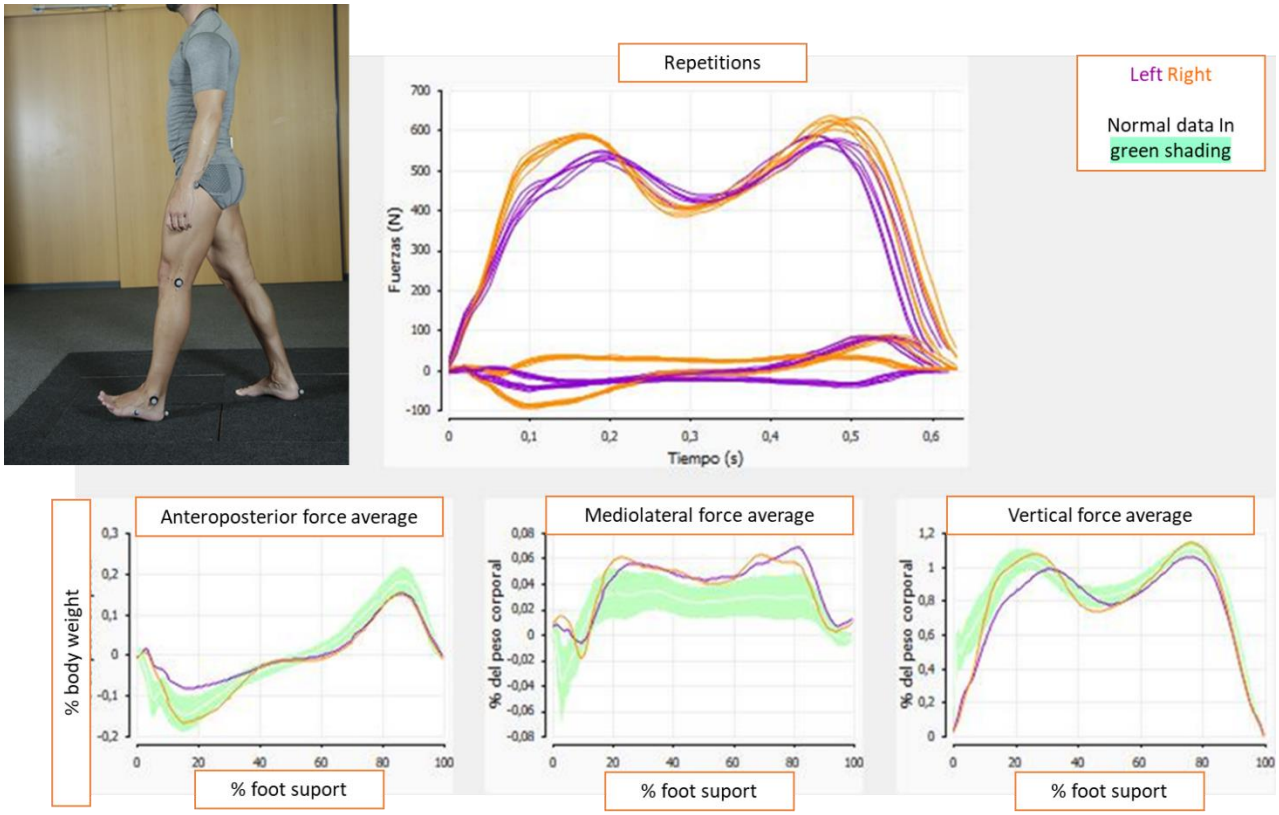

Figure 2: Gait assessment using force plates and photogrammetry. It provides graphical and numerical results than be compared with normal data. Picture shows just dynamical data from force platforms. It can be used in evolutionary control after an injury to the lower limb, to plan rehabilitation treatments, such as orthotics or botulinum toxin infiltration or for evaluation of return to work

Figure 2 shows an example of biomechanical test that can be applied in different clinical situations. It provides graphical and numerical results than be compared with normal data. The upper right graph represents the pattern of forces during support in its three anteroposterior, mediolateral and vertical components) for the right (orange) and left (purple) support. Asymmetry is observed.

The graphs below show each of those three components of force compared to a reference standard. It can be used in evolutionary control after an injury to the lower limb, to plan rehabilitation treatments, such as orthotics or botulinum toxin infiltration or for evaluation of return to work

Common biomechanical test in other contexts

Common biomechanical test used in a sportive context

Sport biomechanics is the area of science concerned with the analysis of the human body movement during sport activities in order to be studied for different applications. As a global concept this branch of science is utilised to attempt to either enhance performance or reduce the injury risk in the sport and exercise task being executed (Figure 3).

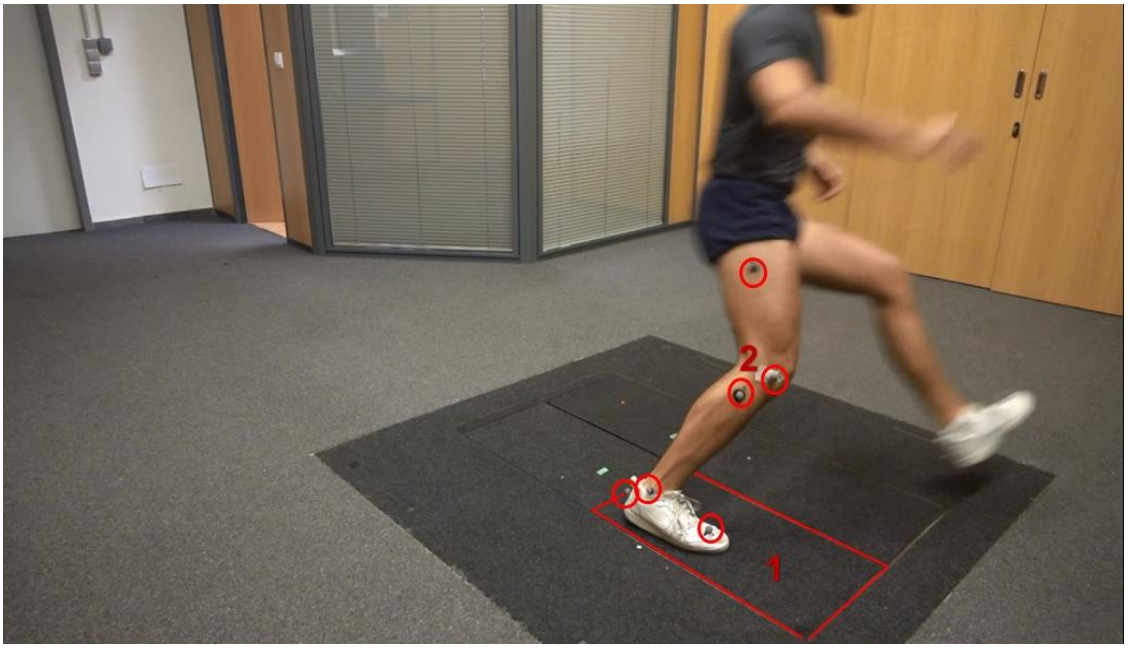

Figure 3: Side-step cutting movement testing (1. force plate, 2. reflective markers used by the 3D motion analysis system).

Biomechanics is applied to the field of sport and exercise sciences amongst others to:

- Enhancement of an athletes' sport performance by quantifying their mechanical faults and targeting them, if modifiable, to try and reach the highest movement efficiency.
- Injury prevention assessments, in order to identify weak areas of the athletes' sporting activity execution which could expose the musculoskeletal unit to a lesion. Determining the safest methods for performing a particular sport or exercise task.
- Study the outcome effect of an intervention, such as an ergogenic aid, surgical procedure, tracking a rehabilitation protocol and evaluating a safe return to sport.
- Assessment of neuromuscular functions, muscular recruitment and loading.

- The analysis of sport and exercise equipment e.g., footwear, playing surfaces, racquets…etc.

For all the different applications there is a great array of pieces of equipment which can be used in laboratory and outdoors. There is no standard about biomechanical tests in sports but these are mainly used to obtain kinetic and kinematical values and tend to be synchronised (Figure 4).

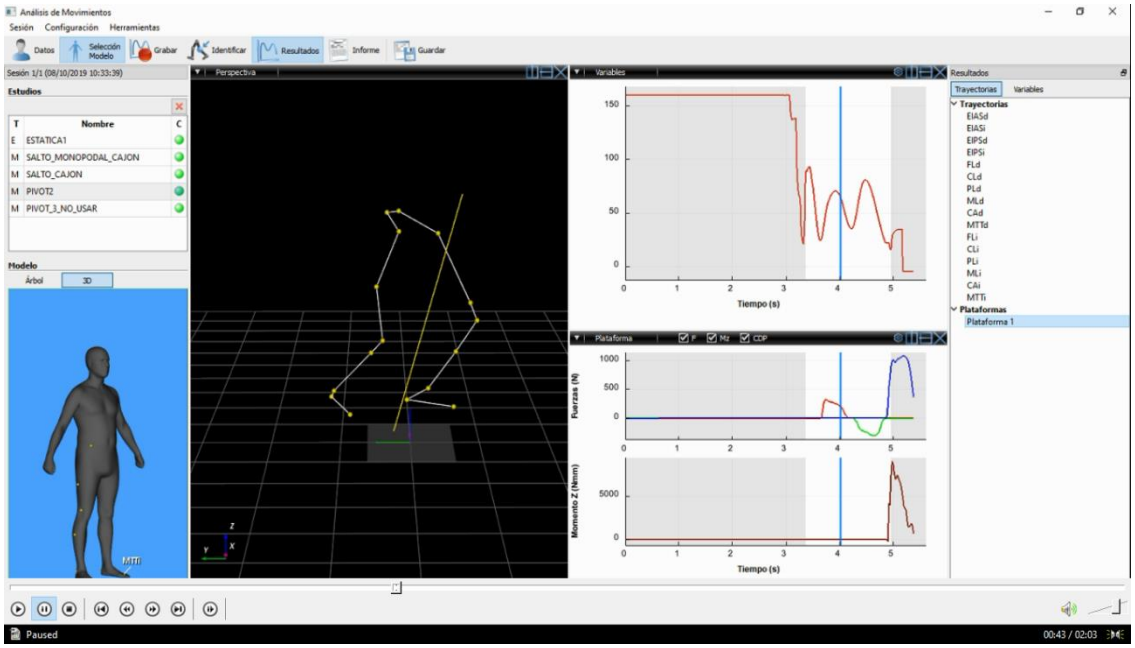

Figure 4: Interface of a motion analysis system showing momentum and force.

Common biomechanical test used in an ergonomic context

Ergonomics is the area of knowledge concerned with the study of the conditions of adaptation of a workplace to the physical and psychological characteristics of the worker. Ergonomics seeks greater performance at work.

Biomechanics measurement is applied to the field of ergonomics amongst others to:

- To know postures, biomechanical load, repetitions ... during the execution of a task for risk assessment. Occupational risk assessment methods are based on the observation of the worker during his tasks. Sometimes, instrumented assessment is used for greater validity and objectivity in the evaluation.
- Evaluate the reduction of effort for the worker while using exoskeletons. Exoskeletons are used in industry to improve workers' working conditions, reduce physical load, and prevent injury

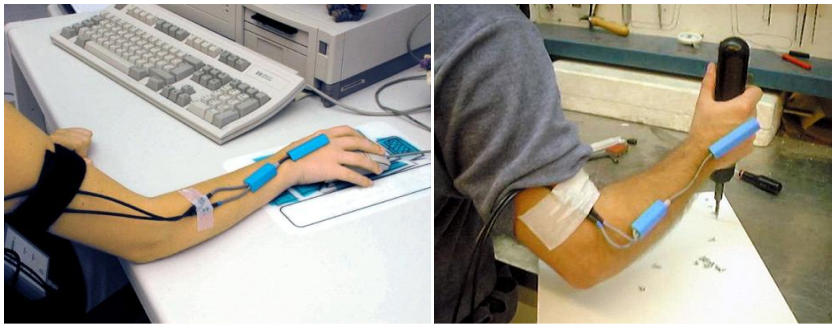

Figure 5: Biomechanical recording of posture during working tasks with electrogoniometers.

In these applications, biomechanical assessment takes place at the workplace and there are portable techniques. In ergonomics area there are standards for risk assessment however, there is no standard about biomechanical tests. Biomechanical techniques are commonly used to record objective information on postures, physical load, or repetitive movements.

Common biomechanical test used in an investigation context

There are many research studies that use biomechanical assessment techniques in different fields. In the context of assessing the musculoskeletal system they are used to:

- Compare different surgical or rehabilitative treatments.
- To assess the effect of a treatment on a patient.
- Describe the biomechanical pattern of a pathology.

For example, in the study *Effects of medially posted insoles on foot and lower limbs mechanics across walking and running in overpronating men* of Konosen et al. (2), A biomechanical assessment analysis is presented where the effect of supinator orthoses in walking and running conditions is evaluated, both in the rearfoot and in the forefoot, through the instrumentation with markers and the use of a 3D photogrammetry system made up of 10 cameras.

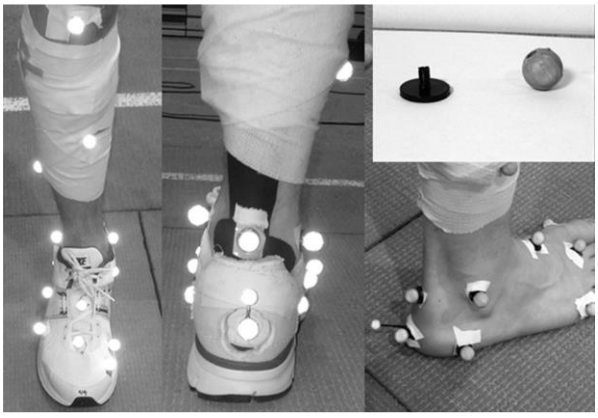

Figure 6: Foot and ankle instrumentation detail in the Konosen study

The main conclusions of this study suggest that the use of orthoses mainly affects the movement of the forefoot, reducing the movement of maximum eversion when walking and running.

As a part of your theoretical training you should watch some videos about biomechanical assessment using instrumented techniques that you will access from internet. There are many resources available that you can find just by searching**: "Biomechanical assessment instrumented techniques"**, you can choose the most interesting for you depending of your field of interest.

Yoy can see: https://www.lboro.ac.uk/research/phc/perfomance/biomechanics/ as a good example.

Try to identify:

- Context of use and objective of evaluation.
- Function, activity or gesture subject to assessment.
- Instrumental technique it is based on.
- Protocol.
- Results.

2. Requirements of biomechanical tests

Sometimes a lot of attention is paid in testing to the quality of the measurement technique; however, the usefulness of these techniques depends on their technical quality or sophistication, and on their ability to represent reality to achieve objectives. Specifically, these objectives are the possibility of discriminating between different situations (for example, sick and healthy or good and bad execution of a sports gesture) in a reliable, valid way and at a reasonable cost.

The use of sophisticated assessment tools, together with powerful statistical analysis techniques, must be accompanied by the fulfilment of a series of fundamental criteria of validity, reliability and usability, which are essential characteristics for a maritime measurement technique accepted from the point of view clinical and scientific.

The fundamental criteria that biomechanical evaluation techniques must meet are briefly presented below.

- **Validity:** is the property that indicates that the measure really represents the aspect that you want to assess.
- **Reliability:** is the property that indicates that the measurement offers equivalent results when performed under equivalent conditions
- **Usability:** it is the property that indicates that a test can be used by specific users to achieve specific objectives with effectiveness, efficiency and satisfaction in a specific use context. Usability means focusing on users.

To deepen these aspects, you can consult *Topic: F2. What do validity, reliability and usability mean in biomechanical assessment and why are they important?* in this same didactic unit.

Good and bad examples about requirements

Grip strength assessment with a thermometer?

If you use a thermometer for grip strength assessment…

Are you performing a **reliable** measurement?

Are you performing a **valid** measurement?

It can be repeatable because it offers equivalent measurements of temperature when we take different measurements using the same protocol, but it is not a valid measurement for grip strength assessment.

Grip strength assessment must be performed with a valid instrument for strength measurement. A thermometer is valid for temperature measurement, but not for strength assessment.

Grip strength assessment with a hand dynamometer?

If you use a hand dynamometer for grip strength assessment…

Are you performing a **reliable** measurement?

Are you performing a **valid** measurement?

Are you performing a **usable** measurement?

Reliability of measurement depends on the reliability of the dynamometer and protocol used. Repeatability must be demonstrated by intra-subject and inter-evaluator reproducibility studies.

Many studies have demonstrated the reliability of hand dynamometer for grip strength assessment with controlled protocol.

Hand dynamometer has demonstrated be valid for grip strength assessment in many studies during years.

The usability depends on aspects such as: cost-benefit for the user, safety for the patient, instructions for use of software and instrumental technique, associated documentation... Medical devices must have the corresponding certification, which includes validity, reliability and usability.

A good biomechanical evaluator must know the characteristics of the instrumental techniques he uses and ensure that they are suitable for his measurement object.

3. Key ideas

The key ideas of this session are:

- A biomechanical assessment test is a complementary test done by means of biomechanical techniques and it should be used in different contexts.
- There are different biomechanical assessment tests, the elements that determine them are:
    - What function, activity or gesture is subject to assessment.
    - What instrumental technique it is based on.
    - What assessment protocol has been used.
    - What results it provides, in what units and with what data analysis techniques have been obtained.
    - Existence of standardized criteria for interpretation.
- There is some heterogeneity regarding the procedures used, despite this fact, functional evaluation with biomechanical tests is widespread in the clinical field. The most widely used biomechanical tests in the clinical context, classified according to their purpose of assessment and instrumental technique, are:
    - Assessment of activities of daily living.
    - Balance function assessment.
    - Assessment of mobility in upper, lower and spinal limbs.
    - Strength assessment in upper, lower and spinal limbs.
- Biomechanical tests are also used in sportive, ergonomic or investigation contexts.
- The fundamental criteria that must be met by biomechanical assessment techniques are:
    - Validity: is the property that indicates that the measure really represents the aspect that you want to assess.
    - Reliability: is the property that indicates that the measurement offers equivalent results when performed under equivalent conditions
    - Usability: it is the property that indicates that a test can be used by specific users to achieve specific objectives with effectiveness, efficiency and satisfaction in a specific use context. Usability means focusing on users.

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