Video analysis system of the gait cycle and posture of people wearing high heels

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Abstract. Gait cycle analysis is a comprehensive source of information, usable in the medical field, in locomotion, sporting recovery procedures or to increase performance in various sporting fields. Study methods of walking cycle parameters are very diverse, starting from biomechanical analysis, computer simulations and modelling, and completing with video analysis of kinematic and dynamic parameters. The use of optical and video methods is very widespread in all medical, sporting, ergonomic and even economic fields. Thus, the first part of the paper analysis the general aspects regarding the use of optical methods of acquisition and processing of video sequences of the normal gait cycle. Also, in the same context of the introductory part of the paper the aspects of the biomechanics of the normal and high heels cycle for the females are presented. In the second part of the paper is presented an experimental setup for investigating, with the sample of subjects chosen, the cycle of gait with shoes having different dimensions of the heel height. In the third part of the paper are presented the recordings made on *footscan* pressure plate and also the data acquisition on the especially sensory insole worn by the subjects. In the final part of the paper are presented the results of the processing of this information and the conclusions from the experiment.

1. Introduction

The posture of the human body in stability or in the gait cycle can indicate a number of issues related to the behavior of the subjects, their health or comfort behavior, and sometimes the level of adaptability to the environment. A number of scientific and research papers address various aspects of the whole body or component segments in order to identify and / or use functional parameters in order to achieve performance or to rehabilitate neuro-motor functions affected by various causes. As mentioned in the American Chiropractic Association documents [1], posture is defined as being “the position in which we hold our bodies while standing, sitting and lying down” or waking and running. “Good posture is the correct alignment of body parts supported by the right amount of muscle tension against gravity. Without posture and the muscles that control it, we would simply fall to the ground.” From a functional point of view, posture is in turn related to the state of stability and balance of the human body, and the gait movement is related to the health of the skeleton, joints, muscles and the central nervous system. Analyzes and measurements to be performed on the human body cycle should identify as clearly as possible the causes that can alter the normal structure and not just the effects. From the point of view of rigid body dynamics there are two approaches, namely: the problem of direct dynamics in which the forces applied to a mechanical system are known and the main objective is the determination of the parameters of the movement, respectively the second one, which by the inverse dynamics the movement of the mechanical system is defined with initial details, and the main objective is to determine the forces that generate this movement [2]. In general, all human body motion analyzes refer to a 3D coordinate system, from which, with the aid of center of mass (COM) movement trajectories or other markers positioned on different segments, one can obtain a full "image" of posture, stability or balance.

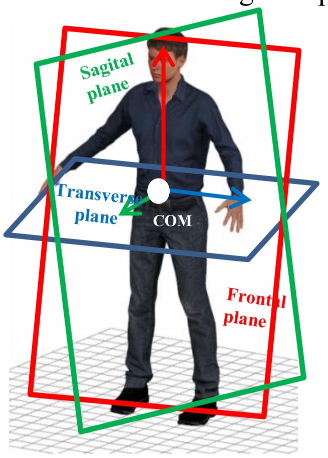


Figure 1. Coordinate system for analysis human body [3]

In biomechanical analyzes of posture and stability an extremely important issue is the shape and dimensions of the footwear of the subjects and the way (trajectory, duration) in which they move with them. As shown in a series of researches [4,5] in the sagittal plane, flexion of the knee is greater, and hip flexion is lower when walking with high heel shoes (HHS). These changes in the muscles activation system during gait with HHS are still not well documented and the assessment methods are varied (from electromyography, to video or sensory methods). In addition to these aspects, it is necessary to analyze and approach the HHS port by female subjects as a series of studies [6] show that approximately 86% of “American women wore shoes that were smaller than their feet, possibly for reasons of reducing the space for foot motion in the shoe. The inference from this evidence is that if arch height increases because of high heels, the foot will shorten, causing the shoe to become too long for the foot, which would alter fit, comfort, and stability”[6]. Interesting aspects are identified in HHS port analyzes not only in the normal walking cycle, but also in running, jumps or stepping, in more complex dynamic actions and leading to higher instability rates, with different studies showing that there is an interaction between speed travel and height of HHS [7]. Also other results from experiments indicate that subjects wearing HHS are moving more slowly, with a cadence that remains constant, with a base of support (BOS) (the distance between the planting surfaces of the feet on the ground) slightly enlarged but with the length of the steps reduced in comparison with no heels gait. All these observations indicate that the use of HHS with exaggerated dimensions to the anthropometric dimensions of the human subject is unbeneficial and causes inconvenient behavior, changes in the shape and structure of the foot, and an increase in instability that may generate over time her, lesions and loco-motor dysfunctions. A pertinent analysis of how the human subject moved with HHS, especially on the inclined plane (0^0-30^0), was able to highlight a number of aspects that change the comfort of the human subject during the walking cycle or even change the bipedal position by changing the position of center of pressure (COP) on the BOS [9]. As shown in [10] “Dynamic Systems Theory (DST) provides a non-linear framework to analyze human movement by representing inter-segmental interactions in angle-angle diagrams. DST offers an accurate solution to study coordination in human movement, but it also requires expensive hardware and very specialized biomechanical software.” However, some combined experimental systems (mechanical, video, optoelectronic) can overcome financial barriers, providing effective and feasible results for specific applications.

2. Theoretical aspects of gait cycle with or without HHS

The cycle of gait on horizontal surfaces as well as on inclined or stepped surfaces generates a series of changes in the osteo-muscular systems that are reflected in the walking trajectory, the trajectory of the

COM projection at the pressure center or the pressure distribution across the plantar surface.

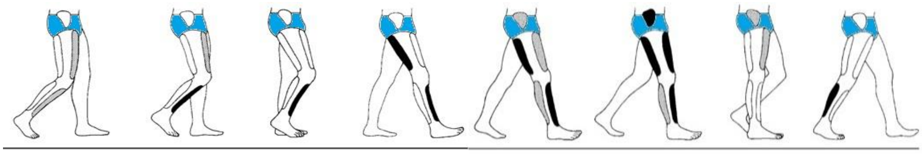


Figure 2. Gait cycle [2]

As mentioned in the fundamental biomechanical studies of gait [2] "traditionally the gait cycle has been divided into eight events or periods, five during stance phase and three during swing. The names of these events are self-descriptive and are based on the movement of the foot. The stance phase events are as follows: Heel strike initiates the gait cycle and represents the point at which the body's center of gravity is at its lowest position; Foot-flat is the time when the plantar surface of the foot touches the ground; Mid-stance occurs when the swinging (contralateral) foot passes the stance foot and the body's center of gravity is at its highest position; Heel-off occurs as the heel loses contact with the ground and push-off is initiated via the triceps muscles, which plantar flex the ankle; Toe-off terminates the stance phase as the foot leaves the ground. The swing phase events are as follows: Acceleration begins as soon as the foot leaves the ground and the subject activates the hip flexor muscles to accelerate the leg forward; Mid-swing occurs when the foot passes directly beneath the body, coincidental with mid-stance for the other foot; Deceleration describes the action of the muscles as they slow the leg and stabilize the foot in preparation for the next heel strike." Recently, the use of wearable sensor combinations (accelerometers, gyroscopes, force sensors) made it possible to measure the gait cycle parameters both in the experiment area and in the outdoor areas in which the human subject moves under real conditions, as well as continuously wireless recording and without large data loss [11]. The use of the heel shoes changes the gait cycle as well as the number of steps or the position of the whole body. The higher the heel, the more difficult the cycle to perform, and the more the movement of the ankle (of the planting surface) from the ground is changed. To simplify experimental instrumentation, it is considered that the foot movement is approximately flat and executed only in the sagittal plane [12]. But the most important data related to the HHS gait cycle is the ability to record planting pressure directly on the foot that is in the shoe with a possible option by using force sensors connected to an Arduino acquisition board [13,14].

3. Experimental setup

Experimental setup used in this research consists of a set of equipment that allows recording of planting pressures during a walking cycle and respectively recording the posture video and the trajectory of human body segments involved in locomotion (lower limb, joints) in the sagittal direction - along the pressure plate (Figure 4). Subjects participating in the experiment were selected according to initial criteria series that determined their choice in relation to their comparable anthropometric dimensions, without loco-motor dysfunctions, feminine gender and performing the same type of activity. In addition, the 4 subjects were chosen according to the following parameters: mean age (23 years), average height of 160.83 cm, mean body weight 51.5 kg and average shoe size 37.5. All the subjects provided informed consent prior to the test. The experimental protocol was conducted according to the Declaration of Helsinki [15]. They have been informed about the protocol of the experiment and the devices that were used. The recording of data on planting pressures and posture during the walking cycle was performed using the experimental structure of Figure 3 and four forms of footwear (small, medium 4 cm, large 8cm and very large 10 cm) (Figure 4.)

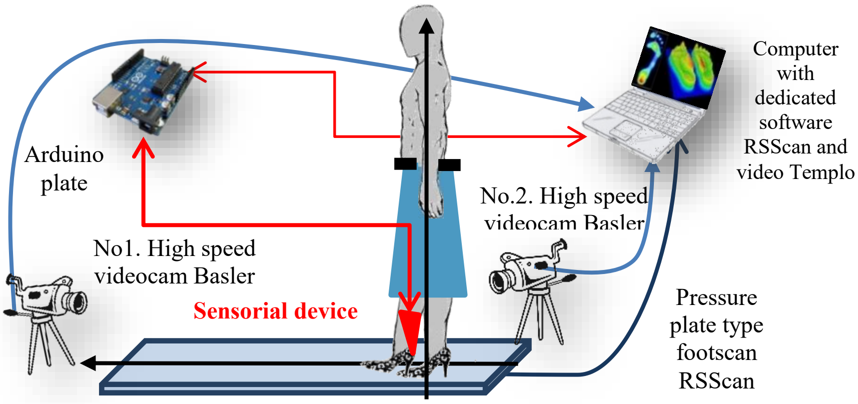


Figure 3. Experimental setup

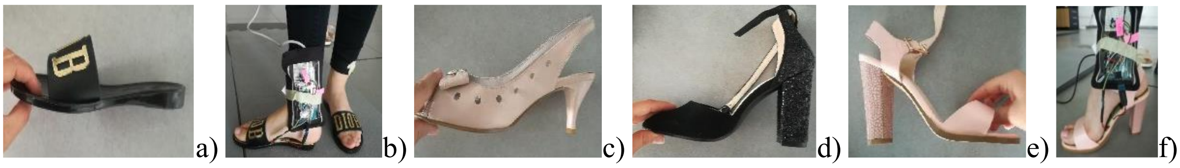


Figure 4. Types of shoes with heights of different heels and attachment device

4. Results and conclusions

The recorded data was processed by pressure plate software, *RSScan footscan 7.97 Gait 2nd generation*, and video sequences using Templo Contemplas and Kinovea dedicated software. As can be seen from Figure 6, the trajectories highlight the difficulty of moving with HHS (blue) and the comparable movement values in the version with the heel shoe of 4 cm (green), respectively with the values of the heelless shoe variant (red).

Figure 5. Video processing of knee trajectories in the cycle with and without HHS

When a sensorial device was attached to the foot and recorded simultaneously on the pressure plate, this similarity of variation was revealed in the case of the 4 subjects investigated and for which the four shoe variants were used (Figure 7 from - heelless, with a 4 cm, 8 cm and 10 cm high heel).

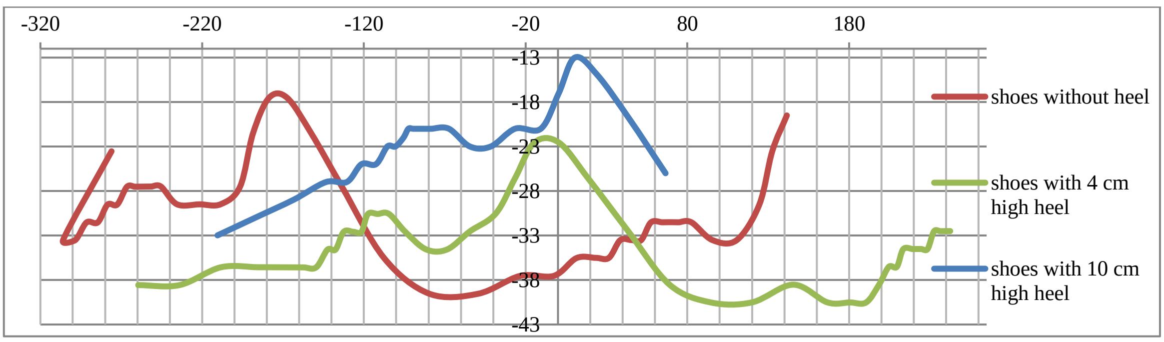
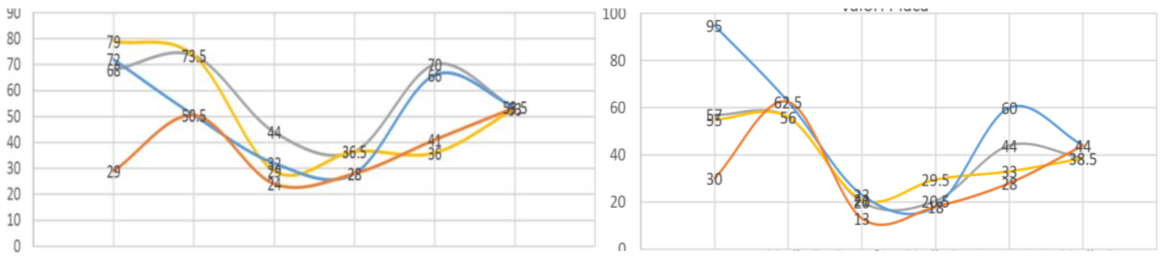


Figure 6. Example of knee trajectories during gait with and without HHS for the same subject

At the same time, video sequence software applications allowed the identification of subjects with difficulty in adapting to the HHS.



a) b)

Figure 7. Comparative values recorded on the sensor system (a) and on the pressure plate (b)

In this sense, the values of speed variations, acceleration, horizontal displacement (sagittal-axis Oy) or vertical recorded with the sensory and video system (simplified) can become basic parameters of the analysis and can be used in experimental research in the outdoor situation to evaluate, under any environmental or surface conditions, the behavior of subjects wearing HHS.

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