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Original Article

A new technical method to analyse the kinematics of the human movements and sports gesture

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Abstract
To improve the performance of an athlete or to identify an incorrect postures that can cause injuries, it is essential to study the kinematics of the movements. Normally,are used approaches that "photograph"the execution of the gesture and look at the angular opening of the joint of interest, ignoring its dynamics.
These types of analyses have major limitations. In fact, they do not allow to observe the execution of a movement on all three anatomical planes at the same time and also provide mostly qualitative information. In fact, in order to obtain three-dimensional data, it is necessary to have three cameras that record the same execution of the gesture from different points of view (one for each anatomical plane), or a single camera that at each gesture execution is positioned with respect to a different anatomical plane.Furthermore, analysing the movement without his dynamic information limits its study because all the information related to the chained execution of kinematic, kinetic and muscular activities are lost. To overcome these limits and to obtain more complete and accurate information, the aim of this study is to propose a new method for analysing the kinematics of a sports gesture, which takes into account the all range of motion of a joint. In fact, it calculates the angular excursions between identifying events of the gesture, thus evaluating the angular variation of the joint between peaks of flexion and extension. This approach is more informative, compared to the classic space-time analyses, and therefore can be considered useful in the study of the kinematics of a sports gesture.
Keywords: human movements, sports gesture, kinematics

Introduction

Physical activity and sport are now part of the habits of most people and they are practiced to improve physical qualities, the state of health and to maintain the state of well-being (Ascione et al., 2018; Di Palma & Agosti, 2020; Raiola et al, 2015). Posture and its control are therefore aspects to be taken into consideration in sports. However, every sport activity solicits the musculoskeletal system, and the effects of these stresses can be amplified and become excess stimuli if those who perform them do not have a suitable postural pattern and an optimal postural tonic system. During sport the body is under strain, so it is essential to be able to define the correct technique and posture to have during athletic movement, to optimize performance, keep the athlete healthy and avoid fatigue, pain and injury (Oja et al., 2015). This care is essential in any situation, even in cases of amateur or occasional sportsmen. Therefore, it becomes essential to be able to study the execution of the sports gesture in a precise and reliable way(Ascione et al., 2019; Belfiore et al., 2020; Di Palma et al, 2016; Di Palma & Tafuri, 2016). Specifically, it becomes necessary to analyze the kinematics of movement through the knowledge of classical mathematical physics (static, dynamic, kinematic) and geometry, taking advantage of photographic and cinematographic shots, which record the execution and report it on a computer screen. Even more if the mode of observing the movement from video becomes stereo: the use of motion capture systems (MoCap) allows the acquisition of the movement in three dimensions (3D) and to analyze the movement with a micrometric accuracy(van der Kruk & Reijne, 2018). In this way, the movement of the body can be observed and analyzed in geometric terms and this allows a full understanding of the modalities of expression of the motor action. However, the kinematic reports, albeit detailed, are limited to providing a "photograph" of the motor action, such as not to allow to read (and therefore understand) the phenomenology of movement, that is to say how that articular system organized itself to achieve that motor result. In this direction, the aim of this work is to propose a new technical method of kinematic analysis which, starting from the curve of the kinematic reports which expresses the joint movement on the three planes of the space, observes the progress of the movement taking into account the variation in the time of the entire joint range, thus describing the angular excursion of the joint. In this way the articular kinematics from "photography" becomes "phenomenon".

Methods

Motion analysis is a technique applied to different areas ranging from sport to scientific research, to the clinic, to entertainment (Perry & Burnfield, 1993). It allows the measurement and description of different aspects of a motor act and is aimed at improving performance, deepening physiological knowledge, post-injury assessment and technological improvement of equipment present in the training environment.

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In sports, one of the most popular motion analysis techniques is certainly the video-recorded one(Napolitano et al., 2019). Specifically, with video instruments, the movement is recorded and then analyzed. By projecting the recorded frames, one by one, and fixing the figural contours on a computer screen using a computer-graphic technique, a graphic representation of the continuous movement is obtained.

An analysis of this type allows you to review the execution of a sports gesture allowing you to identify any errors and obtain the best possible performance. In fact, the various figures in succession provide valid information about the angles in which the various parts of the are located during the execution of the gesture.

This technique allows the assessment of movement on the three sagittal, frontal and transverse anatomical planes, depending on the number of cameras available and gives the possibility to review the same movement for a more in-depth analysis. The main advantage of this approach is the faculty of an a posteriori study with the possibility of multiple observations and relatively economic costs. The data can also be analyzed and compared with other data collected at different times, to evaluate, for example, the progress made in a rehabilitation process. However, this type of technology has a disadvantage: if the qualitative evaluation is carried out with a single video recording, it limits the vision of the gesture on a single angle and therefore it also limits the evaluation itself. The latter therefore remains global and generic, limiting itself to the most evident movements. Furthermore, this type of analysis allows to have quantitative information (and therefore very precise) only when analyzing a single frame. In fact, by tracing straight lines on it, it is possible to calculate the position of a body segment or the angular opening of a specific joint. However, this remains valid for the specific frame in question, without having information of any kind on the variation of this angle. To solve these limitations, MoCap systems are used which allow an analysis of the movement by providing information on the kinematics (accelerations, speeds and displacements) and on the dynamics (forces and angular moments) of the sports gesture with the help of sensors, infrared cameras and force platform. Depending on the type of instrumentation used, it is possible to have different information. Specifically, it is possible to calculate the kinematics of a sports gesture, focusing not only on a single frame but the entire duration of the gesture.

Results

Based on data derived from kinematic data of MoCap, we propose a new method for analyzing the kinematics of a sports gesture, which takes into account the all range of motion of a joint. Specifically, in this work it was chosen to examine the curves of the large joints on the sagittal plane of the lower limb (hip, knee and ankle) during the gait cycle (see figure 1). This choice was dictated by the fact that flexion-extension movements occur on a sagittal plane, which have a greater angular range than other possible movements. Furthermore, the study of the gait cycle and of the movement of the lower limbs during its phases is among the most investigated in the scientific literature both because it is a valid outcome in the understanding of motor re-education training protocols but also because it is the motor act that we all perform more frequently daily, from the athlete to the elderly(Baker et al., 2016; Esquenazi, 2014).

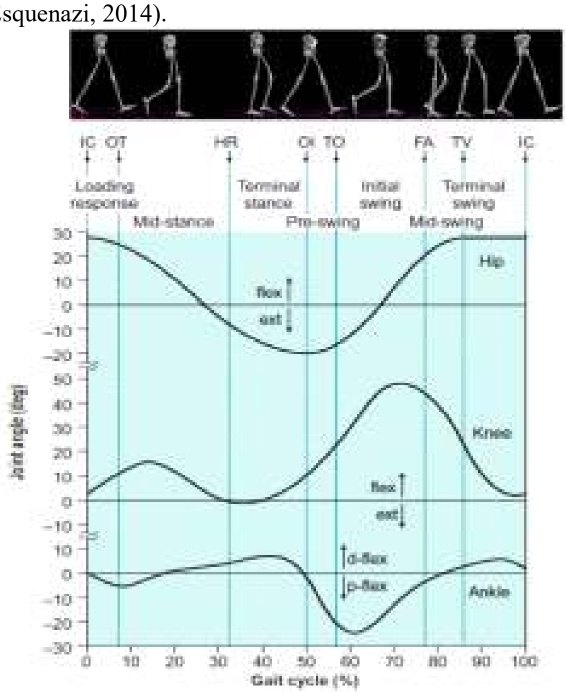

Figure 1. Sagittal plane joint angles (degrees) during a single gait cycle of hip (flexion positive), knee (flexion positive) and ankle (dorsiflexion positive). IC = initial contact; OT = opposite toe off; HR = heel rise; OI = opposite initial contact; TO = toe off; FA = feet adjacent; TV = tibia vertical. **Source:** (Whittle, 1993)

Starting from the kinematic curves of the lower limbs, within a normalized gait cycle, we have defined some reference points on them, as summarized in table 1.

Joint	Reference Points	Gaitcycle
Hip	H0	0%
	H1	4%
	H2	Min(30%-70%)
	H3	Max(70%-90%)
	H4	Min(90-100%)
Knee	K0	0%
	K1	Max(0%-20%)
	K2	Min(20%-60%)
	K3	Max(50%-90%)
	K4	Min(80%-100%)
Ankle	A0	0%
	A1	Min(0%-15%)
	A2	Max(20%-60%)
	A3	Min(45%-80%)
	A4	Max(70%-100%)

Table 1. Reference points take on kinematic curves of lower limbs joints.

Using these reference points, for each articulation, we calculated the ROMs as angular excursion calculated between two successive reference points, as shown in figure 2.

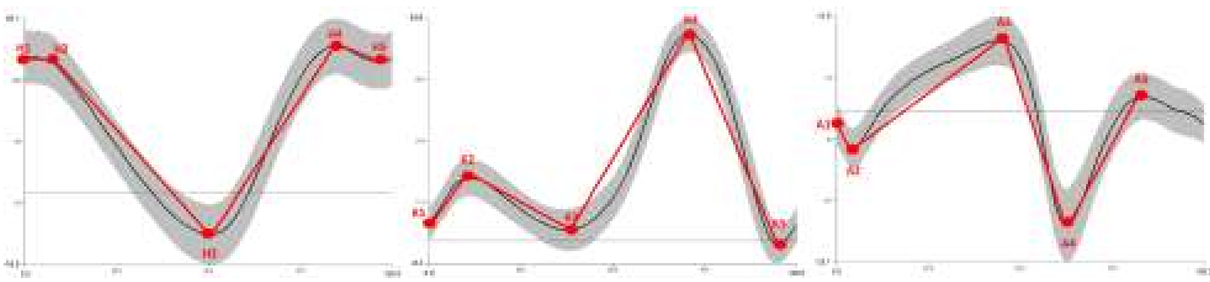

Figure 2. ROM excursions of hip, knee and ankle joint angles.

Below, we report the case of the Hip joint, but the same type of calculation is valid for the knee and hip joint.

$$\Delta H_1 = |H2 - H1|$$
$$\Delta H_2 = |H3 - H2|$$
$$\Delta H_3 = |H4 - H3|$$
$$\Delta H_4 = |H5 - H4|$$

Discussion

The aim of this work was to define a new method for analyzing the kinematics of a sporting gesture. Specifically, considering the main joints of the lower limb, we analyzed the angular excursions on the sagittal plane during the journey.

An incorrect posture produces effects from a physical, relational and sports performance point of view, limiting the ability of an athlete to obtain the required results very clearly. Furthermore, significant damage can also be produced to the joints, muscles and tendons which over time require very invasive interventions. For this reason, it is essential to study the execution of a sporting gesture from a kinematic point of view.

To date, one of the most used techniques is certainly video-recorded analysis, which allows you to record the execution of the gesture with the aid of a video camera and then analyze it frame by frame. However, this type of approach has significant limitations. In fact, it allows to analyze only one (anatomical) plan at a time. It also offers the possibility of doing a quantitative kinematic analysis only frame by frame, without taking into account the angular variation over time.

The proposed method instead takes into consideration the entire angular excursion and not a single frame, to analyze a sporting gesture from a kinematic point of view. In fact, after having identified some reference points on the angular trajectory of a joint that represent the peaks of flexion and extensions, it calculates the distance between two successive reference points. Each of these distances takes into account both the angular variation and the time required to reach these variations. This type of analysis is much more informative than the classic kinematic analysis because it gives the possibility to analyze the execution of the gesture as a whole in a much more precise and reliable way.

This method has proven to be useful not only in sport, but also in the clinic, identifying path changes in some neurological pathologies (Sorrentino et al., 2016) such as Parkinson's(Agosti et al., 2016), multiple sclerosis(Liparoti et al., 2019) and cognitive decline (Amboni et al., 2018).

In conclusion, it is possible to affirm that this method is widely reproducible on all kinematic curves, therefore on all articulated angular movements, even in sporting gestures. To our knowledge there are no other methodologies that allow to observe the motor gesture in phenomenal terms. An observation of the movement made using the method described by us would allow the coach, the athletic trainer but also the re-educator to monitor the sporting gesture and make the training or re-education intervention highly specific. If in general the study of human movement requires ever higher specificity, the sciences of motor and sports activities must also follow this technological trend and move in that direction, both in terms of training and injury prevention.

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