Published in the Slovak Republic
European Journal of Physical Education and Sport
Has been issued since 2013.
E-ISSN: 2409-1952
2019, 7(1): 3-10

DOI: 10.13187/ejpe.2019.1.3
www.ejournal7.com

Articles and Statements

The Implications of Synchronization in Biomechanics

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Abstract

Spatial synchronous of video-derived kinematic (2D or 3D) and kinetic (i.e. EMG or force plate) acquisition routinely allows a simultaneous collection of coordinated biomechanical dynamic configurations from human movements. Synchronization technic could assist to identify the differences between modes of walking. Use of synchronize technologies differentiated abnormal and pathological gait patterns in clinical setting. Synchronization technic could also assist to greater understanding of areas of muscle weakness, potential stresses and injuries in variety of individual in different conditions. Simultaneous kinematic and kinetic measures could contribute to design rehabilitation program to optimum functional recovery. Likewise, the use of coordinated kinematic and kinetic biomechanical features could address individuals' adaptability to sport facilities to optimal physical performances or pattern modifications paradigms. It seems, practicing synchronizing approaches will benefit diverse sporting and clinical sectors in board ranges and frequent utilizations of this technology for more biomechanical discovery are warranted.

Keywords: biomechanics, synchronization, kinematic, kinetic.

1. Introduction

Synchronization in Biomechanics

Synchronization in biomechanics studies routinely permits a simultaneous collection of coordinated biomechanical data using video-based kinematic variables from human movement and digitized records of analog data like electromyographic (EMG) signals and force platform signals from body muscles at the same time that enables multiple measurements to characterize large quantities of biomechanical features in vary of human activities (Komisar et al., 2017; Abraham, Kalakanis, 1993). Spatial synchronous of video-derived kinematic (2D or 3D) and kinetic (i.e. EMG or force plate) acquisition such as gait analysis in sportic research and therapeutics program are come practice (Olenšek, Matjačić , 2012; Glass , 2001; Yen and Radwin ,1995) (Figure 1).

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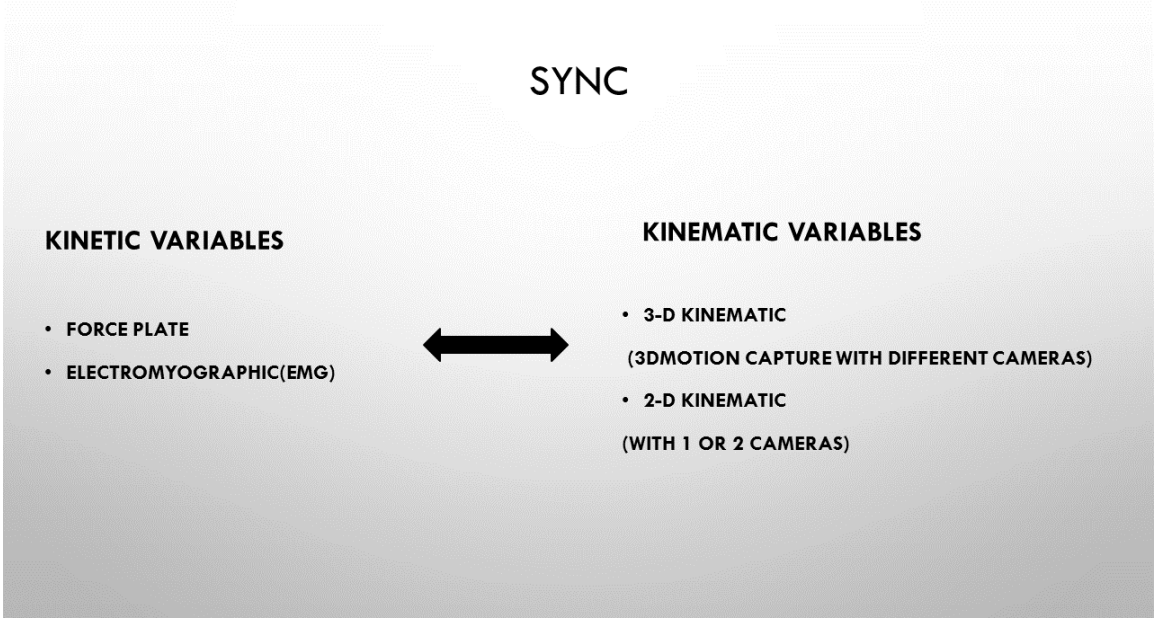

Fig 1. Coordinated kinetic and kinematic variables

Use of synchronize technologies can help to develop better understanding of the mechanism that is behind daily perplexing phenomenon to prime walking rhythm or pattern in different individual (Zivotofsky, Hausdorff , 2007). On this premise, synchronization technics could assist to identify the differences between forward and backward walking to improve the effectiveness of the therapeutic intervention.

2. Discussion

Regarding to this, Sun and colleges (2018) recently have provided remarkable guidance for intervention campaigns to improve walking gait performances using foot inter-segment kinematics and kinetics associated with walking speed. Normative foot 3D kinematic and force plate (or kinetic appliance) synchronized feature variables in this research showed GRFs significantly increased with walking speed and peak values of the knee and ankle moments in the sagittal and frontal planes during forward walking (FW) in comparison with slow walking (SW) and normal walking (NW). Following this, Sun et al., (2018) stressed this outcome could be set as a reference to distinguish abnormal and pathological gait patterns in clinical setting. Similarly, Itoh and colleges (2015) in a supplement reported selected integrated of 3D kinematic and kinetic features during forward and backward walking in gait initiation elicited GRF and step length were less in backward walking than forward walking whilst backward walking generated more force than forward walking that can be beneficial at balance exercise in rehab managements.

Additional weight system on body during different walking patterns may help individual with movement disorder .On this basis, Patiño and colleagues (2007) examined the kinematic, kinetic and electromyographic characteristics of young adults ' walking on a fixed platform without a vest and with partial body weight support (PBWS) of 0, 10, 20 and 30 %. They observed significant differences in spatial-temporal variables, the maximum and minimum angles for the thigh, knee, and ankle, and the amplitudes of the anteroposterior horizontal and vertical GRF components with greatest changes in part at PBWS of 30 %.

More importantly , synchronize acquisition of different digitized implications can also aid to greater understanding of areas of muscle weakness, potential stresses and injuries to promote performances in recreational and competitive sports (Vladimir, Marian, 2015; Kovacs, Ellenbecker, 2011).

For instance, Revak and colleagues (2017) evaluated to assignee Achilles tendon loading during heel-raising and-lowering exercises in healthy men. Subsequently, processing of integrated 3D kinematic motion capture and force plate data which processed using a lower – extremity –

musculoskeletal model showed Achilles tendon peak stress, force, and strain were lowest during the Seated exercise and were highest during the Unilateral exercise . Alternatively, Bilateral and seated heel – raising and – lowering exercises resulted in less Achilles tendon loading. Consequently, the author of this study suggested that bilateral exercises with less body weight could be desirable in earlier rehabilitation process, whereas unilateral exercise may be more useful in later exercise progressions.

To intensify athletic performances, countermovement jumps that is loaded with a weighted vest often use to enhance lower body power to improve jump performance. In accordance to this, Janssen et al., (2012) investigation was set to determine how lower extremity kinematics and kinetics affected by loaded jumps during landing in sports such as volleyball. Subsequently, simultaneous integrated kinematic and kinetic landing components in this study showed hip flexion were significantly greater in the unloaded condition and there was no significant difference in any other kinematic or kinetic variables. In addition, the outcome of this study supported the fact that loaded block jump trainings can help to improve jumping performance.

Malfait et al. (2016) by using a model of coordinated knee and hip kinetic (EMG and force plate) and 3Dkinematic of video analysis recordings could clearly predict the quadriceps and hamstring neuromuscular activations pattern in drop jump landing. They revealed an erect landing pattern that was characterized by less hip and knee flexion and was accompanied with an increased medial and posterior neuromuscular activation of dominant hamstrings medialis activity during the preparatory and initial contact phase and an increased lateral neuromuscular activation of dominant vastus lateralis activity during the peak loading phase. They subsequently suggested more investigations are specifically required to determine the neuromuscular landing pattern that is related to higher ACL injury risk.

Proximal hip control may influence the loading on the knee and the incidence of the anterior cruciate ligament (ACL) injury in cutting and jumping in athletic sports in both sexes. Relatively, Pollard and colleagues (2007) using synchronized hip joint 3Dkinematic and force plate measures, stated female athletes demonstrated greater hip internal rotation and used less sagittal plane hip motion compared to the male athlete in cutting maneuver. They further pointed out these differences in hip proximal control strategies that exhibited by female athletes might be due to the weaker musculature type in female athletes.

Mkaouer and colleagues (2013) using a force plate that was synchronized with a two dimensional(2D) movement analysis system assessed the take-off kinetic and kinematic variables during two types of acrobatic gymnastics while performing the backward stretched somersault. They stated backswing connections were different in the take-off angle, linear momentum, vertical velocity and horizontal and vertical displacements. More importantly, they indicated higher elevation of the center of mass in the flight phase would allow best performance with lower the risk of falls, in part when could combined to a great angular momentum by a gymnast .

Lin and Karduna (2016) using coordinated 2D kinematic and EMG data in another study stated that four-weeks strengthening exercise program enhanced the strength of rotator calf muscles in exercise group compared to the control group in healthy individual. However, the exercise protocols did not completely change rotator calf muscles EMG patterns and scapular kinematics in training group in comparison with those control counterparts.

Dwyer and colleagues (2010) by simultaneous comparison of lower extremity 3D kinematics and hip muscle activation electromyographic (EMG) during closed kinetic chain (CKC) exercises (single-leg squat, lunge, and step-up-and-over) could differentiate the performed tasks between sexes that could serve during rehabilitation programs. Correspondingly, they reported the sex differences during each tasks particularly observed in sagittal-plane movement patterns. They in more details explained women had smaller degrees of knee flexion and larger degrees of hip extension angles in comparison with men across all exercises. Women also, demonstrated higher activation levels of the rectus femoris and gluteus maximus muscles during CKC tasks compared with men. Nevertheless, men exhibited larger degrees of hip flexion during the single-leg squat compared to the women.

Likewise, Momeni and colleagues (2014) utilized a synchronized model of 3D motion capture and EMG during semi-reclined cycling at different workloads in healthy individual to design better exercise regimen for older adults and to develop more effective rehabilitation strategies for individual who are in need. Subsequently, they stated muscles activity patents and their

co-activations (i.e, RF & BF) that were significantly affected with changing cycling workloads in healthy participants, which is an important consideration during cycling exercise in particular for elderly and individual with compromised musculoskeletal systems.

Elsewhere , an integrated kinematic and kinetic study of netball shoulder pass by Hetherington and colleagues (2009) divided the associated skills into comprehensive phases of analysis that allowed more accurate observation of errors while skill execution . In this study, the implementation of a video and force platform at the same time in this study showed greater deceleration torque of the arm than acceleration in the upper limb after the propulsion phase. Peak ground reaction force of 850 N in the frontal (Fz) direction was found to coincide with the point of maximum velocity of the participant's COP occurred in 40 ms and before ball release during wind up and propulsion phases.

Sekiya and Takahashi (2003) also described the most effective mechanical pattern of rolling motion using synchronized 3D kinematic system and force platform in normal adults as a useful guide for treatments of individual with neurological dysfunctions. They revealed hip abduction-adduction angle was almost natural and remained constant during rolling motion .They further stated the hip rotation angel was at a neutral with a slight internal rotation at the beginning and then linearly rotated toward the end in rolling motion.

In addition, different designs of simultaneous integrated kinematic and kinetic features can contribute to design rehabilitation program to optimum functional recovery at desirable levels of physical activity in particular sportic activities or in rehabilitation practices (Suputtitada, 2017; Borzikov et al., 2015).

To give an instance, Risberg and colleagues (2009) designed a neuromuscular and strength exercises project to restore the patients' dynamic knee stability in order to return to the jumping activities in competitor with ACL injuries. Correspondingly , coordinated model of the 3D kinematic and force plates data, that processed using a 3D visual inverse-dynamic software, showed some improvements in knee extension moment after walking intervention, but not after hopping since longer rehabilitation period was required to full recovery after ACL injury .

Likewise, shoulder kinematic and kinetic of wheelchair biomechanical loads and posture configurations could help clinicians and therapists to optimize the wheelchair setup and to avoid injuries in wheelchair users during wheelchair propulsion. Correspondingly, Koontz and colleagues (2002) using 3D shoulder invers – dynamic upper limb model that was included of 3D motion capture and force plate revealed peak shoulder posterior forces occurred near the end of the propulsion phase, which was along with simultaneous maximal shoulder flexion and minimal shoulder abduction during wheelchair propulsion. More subsequent coordinated data showed the shoulder range of motion (ROM) was vary at different speed in wheelchair users.

Elsewhere, Lerner and colleagues (2017) utilizing the synchronized technique evaluated the effects of a robotic exoskeleton that could provide knee extensor assistance on lower limb joint mechanics during treadmill walking in children with crouch gait from Cerebral Palsy (CP). The coordinated 3Dkinematic, and force plate and EMG data that processed using an inverse dynamic model in this investigation showed knee extension assistance improved posture knee kinematic but without any changes in knee moments. The knee extension assistance also improved the function at the hip, but not at the ankle in individuals with gait-deficits indicating that further investigation are warranted.

More empirical evidence by Murgia and colleagues (2015) unveiled that biomechanical integrated technologies of kinematic and kinetic variables could aid to improve the associated – gait – disturbances movements in patients with Parkinson's disease . Similarly, Kertis and colleagues (2016) stated simultaneous 3D Kinematic and kinetic assessments clinically could be a beneficial assessments in individual with osteogenesis Imperfecta (01) who experience ambulatory and upper limbs challenges .

More recently Christensenet and colleagues (2018) using a model of coordinated kinematic and kinetic configuration evaluated the positive benefit of resistance eccentric movement pattern in patients following total knee arthroplasty (TKA). Synchronization of 3D kinematic and force plate figures in this study elicited resistance eccentrically biased movements compared with resistance concentrically movements produced higher levels of extensor angular impulse on the surgical limb in patients after TKA in rehabilitation setting.

Indeed, biomechanical analysis of synchronized kinematic and kinetic configuration frequently is utilized to contribute in in clinical gait assessments and to design of various clinical intervention protocols for optimum functional recovery after stroke.

For instance, Mao and colleagues (2018)'s observation of integrated 3D kinematic and force plate alerted variables in subacute stroke survivors during Sit-to-Stand (STS) tasks showed the total time of STS task owing to the lower knee moment, abnormal timing point and lower GRF was significantly longer in people with subacute stroke compared to the healthy controls. Similarly, Millington and colleagues (1992) using a modulated synchronization of 2D kinematic and force plate, and electromyographic data in a same application successfully characterized onset areas of difficulties (i.e. onset of muscle activity) which elderly had while getting up from a chair during STS movements cycle. Novak and Brouwe (2013) by use of simultaneous 3D motion capture and force plate implication distinguished the differences of stance phase during ascend and descend of staircase in healthy individual and people with stroke.

Equivalently, Teixeira-Salmela and colleagues (2001) used a synchronization of 2D kinematic and force plate to evaluate the effect of muscle pattern of combined strength (isometric, concentric and eccentric) and aerobic trainings on temporal gait parameters in individual with chronic stroke. Selected period of synchronised data in this study showed significant enhancement in gait speed after training protocols, which was associated with higher level of power owing to an increased positive work by the ankle plantar flexor and hip flexor/extensor muscles in chronic stroke survivors. Moreover, Olmer (1994) using a synchronization pattern of 2D kinematic and EMG features from gait analysis enabled to determine the volume changes, motor coordination, volume partitioning, typical patterns from Sync configurations in pulmonary function and its alterations in aged populations.

More interestingly, the use of coordinated kinematic and kinetic biomechanical variables can address individuals' adaptability to sport facilities to optimum physical performances or pattern modifications during mechanical loads in various sporting and clinical uses.

For instance, Pratt and Sigward (2018) recently using a synchronized of 3D motion capture and force plate analyzed an inertial sensor angular velocity function to identify the gait deficits during single limb loading in induvial following anterior cruciate ligament reconstruction (ACLr). The reported sagittal plane peak thigh angular velocity was the best predictor of peak knee power absorption and peak knee extensor moments during a single limb-loading task in individuals with altered knee loading following ACLr.

In another recent study, Ter and Colleagues (2015) used an integrated 3D kinematic and force platform to evaluate the pressures sites of upper extremity sites while walking – assisted gait. The integrated data which incorporated with Visual3D motion analysis upper body model elicited without changeling the usage of walking pattern, the internal force and joint moment for the wrist, elbow and shoulder could determine the pressures sites in these areas while using an instrument walker .This implication will benefit prolonged usages in large populations in rehab practice .

Furthermore, Boyer and Andriacchi (2009) used a synchronizing approach to investigate individual's joints (hip, knee, ankle) adaptions to a rockered shoe design to prevent injuries during running. The analyzed synchronous of 3D motion capture and force plate variations through inverse dynamic analysis revealed major difference in sole geometry in terms of most potential sites of injuries that accommodated to the rockered running shoe were found only at the ankle joint in sagittal plane compared to the knee and hip joint. This finding outlined that the load modification during running using a rockered shoe was required to apply in ankle joint without any major considerations to other joint dynamics.

In addition, Campbell et al. (2007) recruited a synchronized of 3D kinematic and force plate approach to guide the clinicians who apply braces to their patients for potential changes and the potential risk that brace application my cause to the unbraced limb. They found that wearing a knee brace affect reduced both hip and knee flexion joints but not ankle in braced (B) group compared to non-braced (NB) group during jogging gait. They further explained any changes in the kinematic in jogging could occur at joints proximal to the braced joint such as hip and pelvis or un-braced limbs in order to sustain the reaction force per each successive step. However, they also indicated these repetitive changes in hip joint are determinate factors to hip and low back function that could lead to the injuries in B group.

3. Conclusion

In biomechanics , synchronizations of video-based kinematic, (2D or 3D) align with digitized records of analog data such as electromyographic (EMG) signals or force platform or both allow characterizing large quantities of biomechanical configurations in variety of human movements. Mechanically speaking, the use of synchronizing techniques could aid to distinguish mechanism that is behind daily perplexing phenomenon in different modes of walking in sportic and rehabilitative sectors. It also used to conduct greater understanding of areas of muscle weakness, potential injuries to promote performances in competitive sports. Biomechanical analysis of diverse synchronized kinematic and kinetic features frequently is used to design of diverse clinical paradigms for optimum functional recovery after stroke. More intriguingly, coordinated kinematic and kinetic biomechanical configurations can address individuals' adaptability to sport facilities to optimal physical pattern modifications during mechanical loads in various sporting and clinical practices. Therefore, the synchronous of video – derived kinematic and kinetic acquisition importantly demands to be considered as common practice in sporting research and therapeutics programs.

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