Computer-Supported 3D Kinematic Patterns Capture and Analysis in Handball

Gruić, I., Medved, V.

University of Zagreb, Faculty of Kinesiology
vladimir.medved@kif.hr

Background

Gross human movement biomechanics resides on a well-known inverse dynamics paradigm, established for the first time in times when high-speed photography served as a motion capture technique (Braune & Fischer 1895). Since then, the high-speed photography method has successfully served for years to accurately record and accumulate kinematic data that were subsequently either directly interpreted or processed. The 20th century, being the age of electronics, brought the first technical solutions to automatically detect characteristic points (markers) in a TV picture frame (in 1967, transition from black to white detection principle) as the starting point for gathering kinematic data (Furnee 1989). This marks the beginning of the development of a plethora of commercial technical solutions to realize accurate and rapid (semi)automatic 3D kinematic data capture (Medved 2001). The beginnings of our Biomechanics Laboratory at the Faculty of Kinesiology, University of Zagreb, were also marked with using a 64 frames/sec Bolex photographic camera for that purpose (Mejovšek 1989). However, later, with the coming of 2000-ies and up to our times we have equipped our Lab with the commercial optoelectronic 3D kinematic measurement system ELITE, by BTS Bioengineering Technology (Milan, Italy; ELITE goes for ELaboratore di Immagini Televisive). The first version of our system was sited initially at the Faculty of Mechanical Engineering and Naval Architecture - and later given at our disposal by courtesy of late professor Muftić, doyen of biomechanics in Croatia and one among founders of the HATZ - where data acquisitions and analyses already were provided, supported by the computer software of that time (Terze 1996). The actual system provides adequate support both for measurement and data processing and analysis purposes (Mahnić et al. 2014).

In the locomotion biomechanics community at one moment in time computers had begun to significantly overtake processes of both data capture - enabling a computer vision of sorts - and processing (succinctly presented in Medved 2001, Chapter 4.2.1.5). Thus, for instance, in 2007, a paper by Baker appeared entitled: „The history of gait analysis before the advent of modern computers“, properly marking this transition. Today's state of the art, which in addition to classical inverse dynamics approach witnesses more and more the introduction of novel methodologies like neural networks, data mining, etc. (Begg & Palaniswarmi 2006). Profits of availability of high power and elegant computer graphics solutions in this realm, as evidenced for example by contributions of the collaborating lab at the University of Salerno (Vastola et al. 2016). Wartenweiler Memorial Lecture by Cappozzo at International Society of Biomechanics (ISB) meeting in Glasgow in 2015 (Cappozzo 2015) properly illustrates the depth and sophistication of the methodology of the field, albeit limitations also caused principally by difficulties in the faithful biomechanical representation of complex human body anatomy.

We present an example from the handball sport game, where 3D kinematic data are (semi)automatically captured and stored to enable further processing in order to study complex sports movement patterns manifested. It was originally reported in (Pažin et al. 2016). This kind of motion capture technology establishes itself as an important component of a quantitative analysis vehicle of respective movement patterns. It is understood that, besides utilising multiple rigid body representation of human body enabling inverse dynamics approach, ultimately one strives to arrive at the kinesiological interpretation of performed movements at the neuro-muscular level. The handball game reaches in this manner a higher level of exactness and precision in the description and understanding of its various postures and movement patterns exhibited. The flexibility of our system, enabling various positioning schemes of body markers, as well as the simultaneous introduction of other measurement modalities such as multichannel surface electromyography (sEMG) (Medved & Cifrek 2015) enables to empirically assess the in depth biomechanical and physiological function of the neuro-musculo-skeletal system. This system is under great pressure when executing energetically demanding and skilful handball movement patterns, so that each contribution to its better definition and understanding is potentially applicable in the training process. We particularly strive to apply this methodology for improved training procedures.

Measurement Example and Discussion

Handball is one of the most complex kinesiological activities. Handball movement patterns and techniques have a high degree of performance variability. Their focus on generating maximum speeds and forces is always attempted to be realized by well-known motor patterns of running, jumping and throwing. In our institution kinematic analyses of handball techniques have a certain tradition. These analyses followed all recognized achievements of the Croatian handball which marked World's top quality performance for the last three decades. Initially, the commercial APAS system was used (APAS goes for Ariel Performance Analysis System). (Zvonarek & Hraski, 1997, Zvonarek et al., 1997, Šibila et al., 2005, Pori et al., 2005, Ohnjec, Antekolović & Gruić, 2010). Anatomical reference points within the International Biological Program (IBP, Mišigoj-Duraković, 2008) were determined manually. The 3D reconstruction required at least two VHS cameras with 50 - 60 Hz sampling rate depending on the velocity of movement measured. So far, the analysis of kinematic parameters was mainly done on jump-shot techniques with specific phases of skidding (moving the body's centre of gravity) (Zvonarek et al., 1997, Ohnjec et al., 2010, et al.), not on the basic stance shot, feints, defensive activity, etc. The obtained results generally had a moderate application in training practice.

The present kinematic model for analysis of handball techniques uses the optoelectronic ELITE system (Pažin et al., 2016). It contains 8 cameras, operates at 100 Hz sampling rate, and has an integrated force platform Kistler (Swiss firm), embedded into the floor of the Laboratory. One of the possible protocols that has so far been most commonly used in our laboratory is the Davis protocol developed for the needs of gait analysis (Medved & Kasović 2007). By taking the Davis model as a reference with the initial 20 markers, retro-reflecting markers were deployed to further 12. Figure 1 shows the subject equipped with markers, ready for measurement.

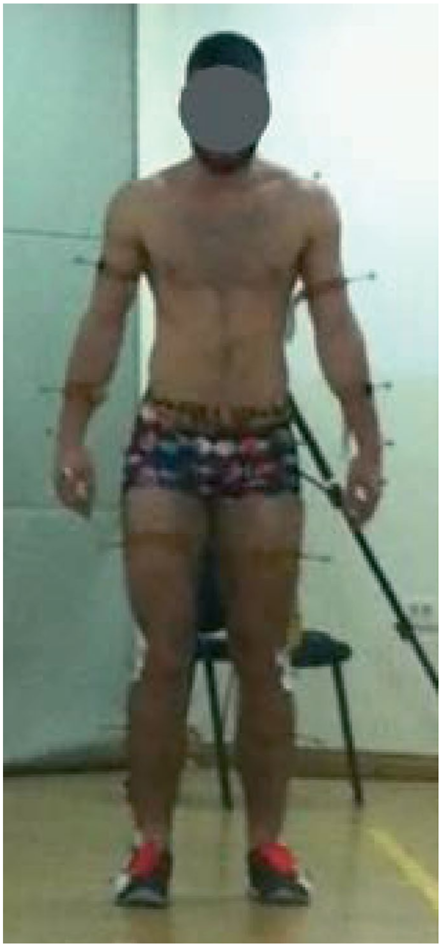

Fig. 1 – Experienced younger senior handball player, specialized to be the central backcourt attacker and organizer, performed a selection of most relevant specific throwing, jumping and moving handball techniques, amongst which "stance-shooting" technique was chosen (as a representative of most important basic throwing techniques) to be visualized along with a newly articulated "extended Davis kinematic" used for registration and analyses (in Pažin et al, 2016).

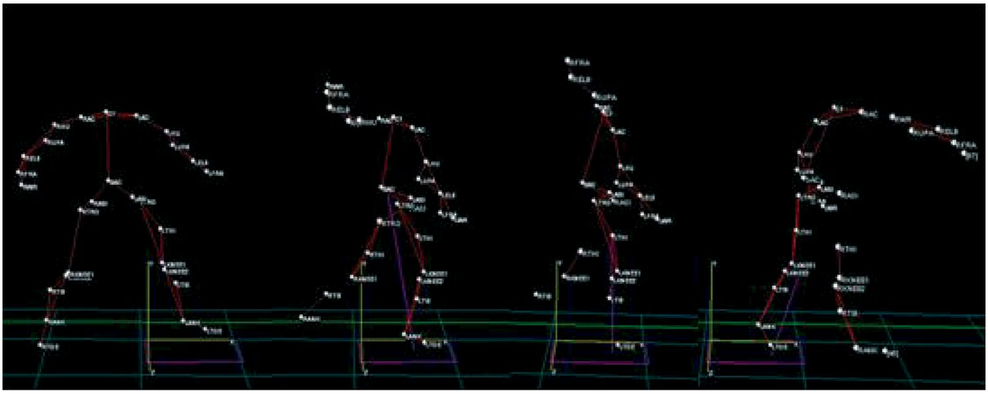

Fig. 2 – 3D kinogram: Phases of basic stance-shot kinematics: 1) preparatory phase, 2) phase of initiation of throwing kinetic chain, 3) phase of crossing coronal (frontal plane) and 4) end of throwing phase. Combining this kind of graphic visual representation with computer-stored numerical values of temporal and spatial movement variables enables a quantitative analysis and interpretation by an expert, i.e. trainer. This particular recorded simulated shot is characteristic of a skilled handball player. (Figure reproduced from Pažin et al. 2016.)

Figure 2. shows four successive 3D recordings of body kinematics in an attempted stance shot in the Laboratory (simulation, no ball). The most important information on the obtained motion capture shots and their analysis is given in figure caption.

Among additional measurement and sensing possibilities at disposal in our institution we would like to mention the 8-channel telemetric sEMG system TELEMG by BTS and pedobarograph pressure measuring device (Zebris Medical, Gmbh) that can be included according to modified measurement protocols. In addition to the equipment existing in the Biomechanics Laboratory, there are also other systems that might be used such as the Microsoft Kinect Sensor, property of Kinanthropometry Laboratory, acquired through the project "Development of System for Digital Measurement of Human Body" (Gruić et al. 2018). There is the Xsens 3D Motion Tracking System, recently acquired by the Laboratory for Sports Games. Finally, within the partnership program with the Section for Biomechanics, Kinesiology and Applied Computer Science and the Department of Sport Science at the University of Vienna, Austria, (they house the VICON system in the Laboratory. VICON goes for Video CONvertor for biomechanics) we strive to quantify elementary dynamics and contact between two teams through the synthesis of large scale standard biomechanics with a small scale sport game analysis. The framework of this research project is entitled "System Dynamics and Contact between Teams in Handball".

Conclusion

Accurate angle measurements in individual joints, angular velocities, accelerations and internal forces and moments of forces in the centres of the individual joints, together with the accompanying standard diagnostic information, are needed in the learning process, both from sportive and from physiological and medical standpoint (energy expenditure, traumatology) to provide feedback on subjects' own performance, to provide reliable criteria for performances evaluation and to enable analysis of differences in performance levels. However, the greatest benefit of the findings of previously conducted and assumed future research arises from the assumption that knowledge of the limit values of handball performances, which implies exertion of maximum velocities and forces, would enable multilayer transfer of knowledge to physiological and medical aspects of human locomotion in this sports game and vice versa.

References

Baker R. 2007. The history of gait analysis before the advent of modern computers. Gait & Posture 26(3), 331-342.

Begg R & Palaniswarmi M. 2006. Computational Intelligence for Movement Sciences: Neural Networks and Other Emerging Techniques. Idea Group Publishing, Hershey, PA.

Braune W & Fischer O, 1895. Der Gang des Menschen (Translation into English by Maquet and Furlong: The Human Gait, Springer Verlag, Berlin. 1987.

Cappozzo A, 2015. Observing and revealing the hidden structure of the human form in motion. Wartenweiler Memorial Lecture - History of Biomechanics. ISB Symposium Glasgow. 2015.

Furnee, E.H. 1989. Dissertation. TV/Computer Motion Analysis Systems: The First Two Decades. Delft, The Netherlands: Delft University of Technology.

Gruić I., Katović D., Bušić A., Bronzin T., Medved V. and Mišigoj-Duraković M. (2018). Construction and validation of protocol for digital measurement of human body. In: Jan Cabri, João Paulo Vilas-Boas, Pedro Pezarat Correia (Eds.) Sport Sciences Research and Technology Support. icSPORTS. Communications in Computer and Information Science, vol (in the press). Springer

Mahnić M, Ujaković F, Janjić S, Petrak S & Medved V. 2014. Comparative analysis and adjustments of anthropometric parameters on system for kinematic movement analysis and 3D body scanner. In: Proceedings - 7th International Scientific Conference on Kinesiology

Medved V. 2001. Measurement of Human Locomotion. CRC Press, Boca Raton, Fl.

Medved V & Cifrek M. 2015: Kinesiological Electromyography in: Annual 2015 of the Croatian Academy of Engineering, pp. 279-299. (reprint of Medved & Cifrek, Chapter 15 in Biomechanics in Applications (Edited by Vaclav Klika). InTech 2011, pp. 349-366. with added Abstract)

Medved V & Kasović M. 2007. Biomehanička analiza ljudskog kretanja u funkciji sportske traumatologije. Hrvatski Športskomedicinski Vjesnik, 2007;22:40-47.

Mejovšek M, 1989. Disertacija. Konstrukcija i evaluacija biomehaničkog n-segmentalnog modela za analizu gibanja muskuloskeletnog sistema ljudskog tijela. Zagreb: FFK.

Mišigoj-Duraković, M. 2008. Kinantropologija: biološki aspekti tjelesnog vježbanja. Kineziološki fakultet Sveučilišta u Zagrebu. Zagreb.

Ohnjec, K., Antekolović, Lj., Gruić, I. (2010) Comparison of kinematic parameters of jump shot performance by female handball players of different ages, Acta Kinesiologica 4.2: 33-40

Pažin K, Bolčević F & Gruić I. 2016. Kinematička analiza tehnike u rukometu. U: Zbornik radova Kondicijska priprema sportaša

Pori P, Bon M & Šibila M. 2005. Jump shot performance in team handball - a kinematic model evaluated on the basis of expert modelling. Kinesiology 37 (2005) 1:40-49.

Šibila, M., Štuhec, S., Bon, M., Pori, P. (2005). Kinematic analysis of Aleš Pajovič jump shot technique. 4th International Scientific Conference on Kinesiology, 2005, Opatija, Croatia.

Terze Z. 1996. Disertacija. Primjena dinamike sustava krutih tijela na proučavanje čovjekova gibanja. Zagreb: FSB.

Vastola R, Medved V, Albano D, Coppola S, Sibilio M. 2016. Use of optoelectronic systems for the analysis of technique in trials. Journal of Sports Science 4(5), 293-9.

Zvonarek N & Hraski Ž (1997). Kinematičke osnove skok šuta s vanjske pozicije. 6. ZAGREBAČKI SAJAM SPORTA 26.2-01.03.1997. ZBORNIK RADOVA. Fakultet za fizičku kulturu u Zagrebu; Zagrebački velesajam; Zagrebački športski savez.

Zvonarek N, Vuleta D & Hraski Ž. 1997. Kinematička analiza dvije različite tehnike izvođenja skok-šuta u rukometu. Kineziologija - sadašnjost i budućnost: zbornik radova 1. Međunarodne znanstvene konferencije, Dubrovnik (str. 180-182). Zagreb: Fakultet za fizičku kulturu.