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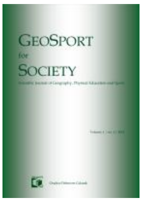

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Linear kinematic analysis of cinematic biomechanics in semi-squat knee flexion: a case study

Dan Alexandru SZABO[1*], Nicolae NEAGU[1], Andreea ILIEȘ[1], Mariana ARDELEAN[1]

1. George Emil Palade University of Medicine, Pharmacy, Science, and Technology, Romania, Address: Str. Gheorghe Marinescu, No. 38, C.P. 540139, Târgu Mureș, Romania, e-mails: dan-alexandru.szabo@umfst.ro, nicolae.neagu@umfst.ro, iliesa1911@gmail.com, mariana.ardelean@umfst.ro

* *Corresponding author*

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Abstract: The study emphasized the necessity of kinesiology and biomechanical movement analysis in today's physical education, kinesiotherapy, and sports. Our experiment observed a biomechanical motion configuration of semi-squat knee flexion, vertical position, angle, speed, and acceleration. The Kinovea software, version 0.9.3, is utilized as a study tool for biomechanical investigation employing some specific kinesiological characteristics of the movement. The findings of the biomechanical action emphasized the unique semi-squat knee flexion and extension, displaying the complete action from a certain linear angle, angular velocity, and acceleration.

Keywords: biomechanical movement, kinesiology, semi-squat knee flexion

Introduction

Angular and linear kinetics and kinematics can be accomplished using the inverse dynamics method described by Whittlesey and Robertson (2004) as 'the mechanism by which forces and moments of force are indirectly determined by the kinematics and inertial properties of moving bodies (Sanders et al., 2016). The center of mass (CM) location can be accomplished by modeling the body as a set of rigid connections (Sanders et al., 2016). Linear and angular momentum can be extracted from linear and angular displacements concerning the digitized coordinates' reference axes. Angular moments of the body segments concerning each axis are then calculated, and the net torque of each axis is derived as derivatives of the entire body angular momentum of each axis (Sanders et al., 2016).

The inverse dynamic method can also help swimming research provide quantitative knowledge on linear and angular motion (Sanders et al., 2016).

A modern kind of prosthetic management has newly gone recommended - position management (Geethanjali, 2016). This supports on the findings of past dimensionality-decrease experiments conducted on hand kinematics (Santello et al., 1998; Todorov and Ghahramani, 2004; Ingram et al., 2008; Portnova-Fahreeva et al., 2020). In some experiments, the Principal Component Analysis was used to simplify complex hand grip kinematics by discovering a decreased proportion of linear input signal combinations that describe much of the heterogeneity found in data capture. These variations cover a latent variety of kinematics (Portnova-Fahreeva et al., 2020). The sports practices will enhance skills (Sopa, 2015; Sopa, 2019a; Sopa, 2019b), sustain wellbeing, build community harmony and connectivity (Sopa, 2014), and facilitates the learning of correct movement from a biomechanical point of view.

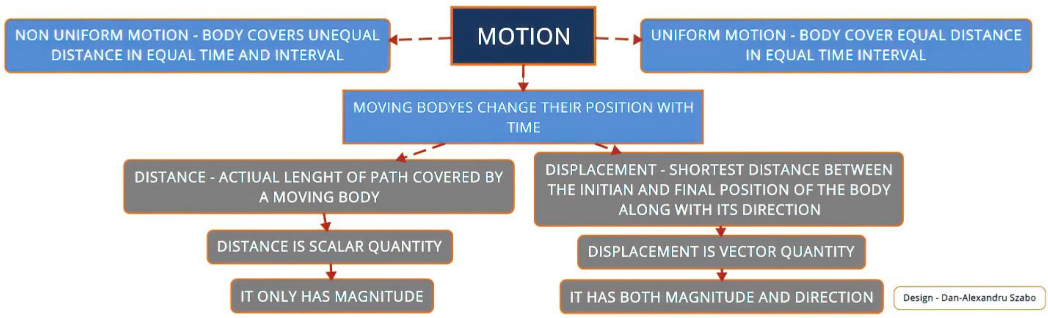

Figure 1. The human motion

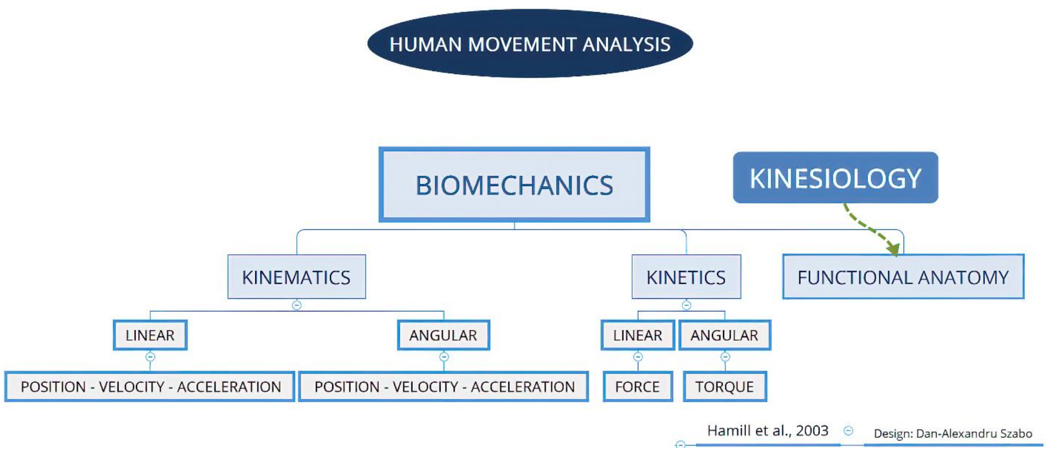

Figure 2. Human movement analysis
(Source: Hamill et al., 2003)

Traditionally, three types of data are known to explain human movements fully: kinematic, kinematic, and electromyographic (EMG) (Winter, 1991; Lencioni et al., 2019). Kinematic data include displacement and alignment of body parts, joint angles, and spatial-temporal gait parameters. Kinetic data include ground reaction forces (GRF), mechanic moments, lower limb powers, kinetic and potential energy (Lencioni et al., 2019). Muscle activation patterns are studied by electrical signals (EMGs) consistent with muscle fiber contraction, which can be recorded non-invasively by surface electrodes connected to the skin over the muscle belly (Lencioni et al., 2019).

Sports biomechanics is usually practiced employing wearable detectors which empower non-invasive data acquisition during movements (Taborri et al., 2016). Moreover, wearable detectors allow athletic activity to be conducted in the biological world, overwhelming the ecological constraint of laboratory experiments, such as the use of the optoelectronic 3D device, nevertheless evaluated to be the golden criterion for movement evaluation (Tabori et al., 2016; van der Kruck and Reijne, 2018).

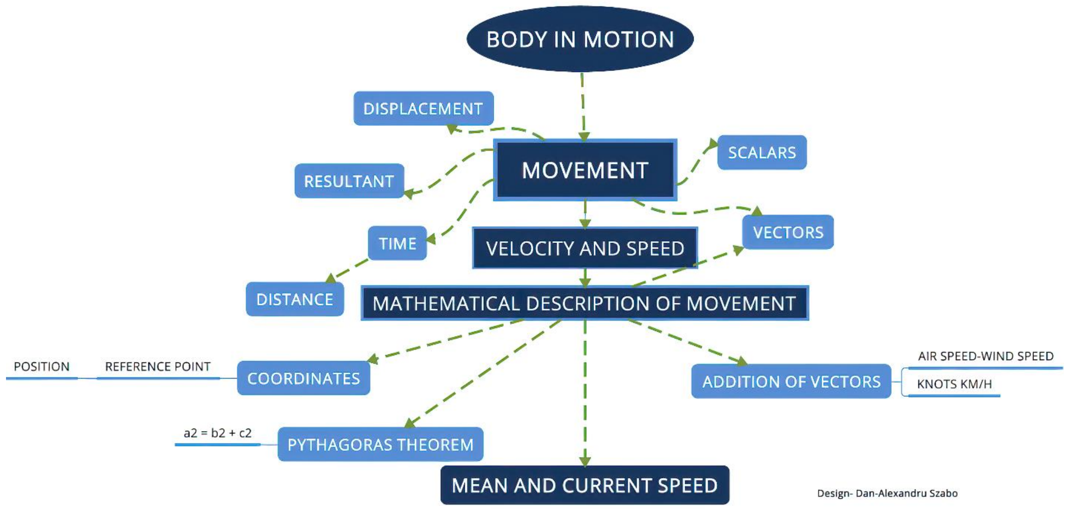

Figure 3. The body movement

Inertial sensors (Kos and Umek, 2019; Kinnunen et al., 2019; Gopfert et al., 2017), force sensors (Lee et al., 2017; Buckeridge et al., 2015; Kos and Umek, 2018a), and electromyography sensors (Brochner et al., 2018; Cruz Ruiz et al., 2015) appear frequently utilized for objective and covert quantification of kinematics, kinetics, and muscle movement during sports events. One exciting path for wearable sensor usage is the real-moment biofeedback processes (Kos and Umek, 2018b) that can give improved input knowledge to athletes and/or coaches at the same time (Kos and Umek, 2019; Umek and Kos, 2016; Kos et al., 2019). Lee et al. (Lee et al., 2017) found that hip, knee, and ankle joint forces and moments, measured based on a conventional inverse dynamic study using motion capture data and the ground response force, were higher mid-turn than for short-turn ski carving. Purevsuren et al., (Purevsuren et al., 2018) concluded that short trackers had intense internal rotational moments when the knee was flexed. However, this conclusion may not be accurate because pressure insoles can only approximate the usual force component on the plantar surface and hence the moment (free moment) and force components parallel to the plantar surface. Instead, horizontal plane forces are essential for short-track speed skating (van der Kruk et al., 2018). In comparison, only short skating was used in the study when skaters are either approaching, leaving, or within a curve (van der Kruk et al., 2018). Applications of surface electromyography (SEMG) in sports science have been increasingly widespread and diversified over the last decade (Merletti and Muceli, 2019). Thanks to wireless networks' emergence, SEMG is now primarily used as a descriptive instrument and in quantitative studies. Bipolar (i.e. using a series of two electrodes) setups are widespread in sports science to record non-invasive summation of action potentials through the skin, giving an analog signal as output that defines the electrical potential difference (voltage) measured between the two electrodes (Merletti and Muceli, 2019).

Methodology

Study Design and Subjects

The study methodology was clarified, and informed consent was received from the subject to interpret the findings and publish them. Both activities have been carried out following the specifications of the Helsinki Declaration.

This thesis focuses on the premise of using Kinovea, version 0.9.3, kinetic, and biomechanical analysis program, and we can strengthen the teaching method in biomechanics and kinesiology (Szabo et al., 2020).

The case study analyzes the leg's biomechanical linear movement on a student's semi-squat knee flexion. The student was in the first term at the Master's curriculum Physical Therapy and Functional Rehabilitation at ”G. E. Palade” University of Medicine, Pharmacy, Science, and Technology from Târgu Mureș, Romania. The objective of this experiment appears to emphasize the circumstance that specialized biomechanical measurements, such as linear kinematics, can exclusively be obtained through the aid of videotape analysis tools minus any additional mechanisms of assistance (Szabo et al., 2020).

Both assessments were transported abroad in the practical workshop in Biomechanics and Kinesiology from 16-September 2020 to 28-September 2020 at the headquarters of the Discipline of Human Movement Sciences (Szabo et al., 2020).

Procedure

The testing technique involved multiple trials of execution of semi-squat knee flexion and was reported as the strongest and accurate scientific execution. The program used to analyze the movement of the subject was Kinovea, version 0.9.3.

Table 1. Linear kinematics – from frame 0 to frame 2568

Time (ms)	SPEED			ACCELERATION		
	Angle 1 - o	Angle 1 - a	Angle 1 - b	Angle 1 - o	Angle 1 - a	Angle 1 - b
0	-	-	-	-	-	-
33	14.4588089	19.88516617	20.06421852	-	-	-
67	13.91840935	18.05595398	17.57689857	-16.50285912	-55.76958466	-49.3273735
133	12.87868881	14.6063633	15.55068398	-26.75684929	-44.2489357	-68.76911163
167	11.57306957	13.21319866	12.1863184	-45.64212036	-42.52270126	-108.4627838
200	9.834025383	11.76978779	8.315422058	-31.9717617	-41.17425156	-72.73350525

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267	10.49862099	9.806860924	8.878773689	37.76114273	-8.549201965	49.04633331
300	11.9592638	9.896280289	10.60621071	22.76117897	5.938308716	39.62181854
333	12.01695824	10.20298958	11.52183914	-25.6070919	4.003691673	21.79558563
400	8.318258286	9.666053772	11.81884766	-42.19184113	-16.22542381	-24.61861038
433	7.436578751	9.081001282	10.41789436	-12.46854496	-11.00447941	-22.66716576
467	7.486515045	8.931974411	10.30678177	14.32147217	4.285830975	19.49443817
533	9.998731613	10.00110817	11.16951084	45.38505554	15.63881397	-45.73445892
567	11.41944122	10.41012096	8.667492867	41.42559814	8.368052483	-61.88111115
600	12.76212215	10.55931854	7.04158783	46.51765823	2.498581171	-15.22095871
667	15.52557755	10.40012455	15.24921608	-12.23161125	-8.871285439	468.5710754
700	13.70657158	9.985014915	38.90926361	-100.9677048	-12.24093246	953.4970093
733	8.79029274	9.583564758	78.85444641	-101.2564087	-6.708684444	1373.266724
800	9.644400597	10.06261921	186.4218597	6.18184042	28.05942345	1609.255493
833	7.364401817	11.40926552	237.8653259	52.57108307	56.15736008	1351.076538
867	13.15127659	13.80872631	276.5485535	353.4708862	86.25759888	916.4918823
933	50.93548584	21.01438332	310.6651001	604.8991699	113.4147415	332.1832886
967	71.29470062	24.7288723	321.1611023	593.0803833	100.9663849	349.0402222
1002	90.49829102	27.74958038	333.9486389	525.3041992	76.14069366	348.1257324
1068	118.5794907	30.91671181	348.7219543	320.1601563	21.49717712	83.69590759
1102	127.6933594	31.242033	349.9667664	194.1765137	1.975132942	69.21057129
1135	131.532486	31.04846764	353.3388062	-9.88407135	-8.989545822	161.7615509
1202	115.1553726	30.28544426	370.3468323	-376.0195923	-6.385743141	252.4327393
1235	101.9507599	30.2163887	377.5965576	-310.9258118	5.826210499	133.3746338
1268	94.41434479	30.67409515	379.2438965	-91.56030273	20.87622833	34.03640366
1335	104.5520248	32.47192383	389.2814026	293.887146	15.65455437	426.9640503
1368	115.4474411	32.65325928	408.3486633	266.2252197	-8.261001587	550.5096436
1402	122.3111954	31.92085457	426.004425	77.00702667	-35.59354019	361.1493835
1468	109.9370422	27.80055618	424.9711304	-402.7821045	-82.52157593	-419.5175781
1502	93.71585846	24.77411652	404.4550781	-509.6691589	-89.65662384	-787.5653687
1535	75.93837738	21.81980324	372.4347534	-505.2731323	-77.10263824	-1124.958008
1602	47.93202209	18.37613678	275.2306824	-323.6434326	-33.48536301	-1786.376831
1635	38.42105484	17.3970871	210.2477264	-267.2239075	-38.91363525	-2096.359375
1668	30.10623169	15.78031254	135.3881683	-192.6002197	-62.85666656	-2362.535645
1735	25.50746727	10.24510956	39.42596436	-12.38614082	-79.69115448	1098.280151
1768	24.7469635	7.888103962	125.9126282	-33.15065765	-58.85387802	2490.628418
1802	23.29607582	6.319125175	205.5691071	110.7941589	-49.75124741	2219.383545
1868	52.61846161	3.383494377	330.6090698	659.7818604	35.57683945	1525.462524
1902	76.15002441	6.942567348	375.721283	680.927063	142.7825623	1175.789185
1935	98.04128265	12.90813637	409.0428162	637.3983154	186.5229492	819.1052856
2002	141.1400299	26.00279808	440.5660706	724.3531494	203.0322723	171.5869598

2035	166.9888153	32.9287529	441.8077087	794.690918	210.7038116	-60.0773468
2068	194.1517334	40.05828476	436.5584717	780.5303955	208.7981262	-223.8317108
2135	238.3856354	52.79893112	413.3502197	447.4147644	158.6675262	-490.3284302
2168	248.9017487	57.44140244	394.1679993	146.3161926	112.2802963	-668.7575073
2202	248.1459961	60.28884888	368.7391968	-194.8187103	52.16920853	-758.1934814
2268	215.0220337	59.12810516	330.7597046	-681.0819092	-89.96979523	-81.02420044
2302	190.4727631	54.91982651	338.1860352	-734.1412354	-158.1170044	480.055603
2335	166.0494385	48.58054352	362.7829285	-734.6373901	-215.2737122	799.817749
2402	112.7065735	31.14025688	408.4132996	-988.630127	-300.6525574	148.2341919
2435	75.51820374	20.50376701	401.4280396	-1223.613892	-325.2480164	-613.8639526
2468	31.08256721	9.443833351	367.4640808	-806.2472534	-268.9533386	-1269.656372
2535	55.64744186	8.405345917	271.4120178	-	-	-
2568	-	-	-	-	-	-

Results

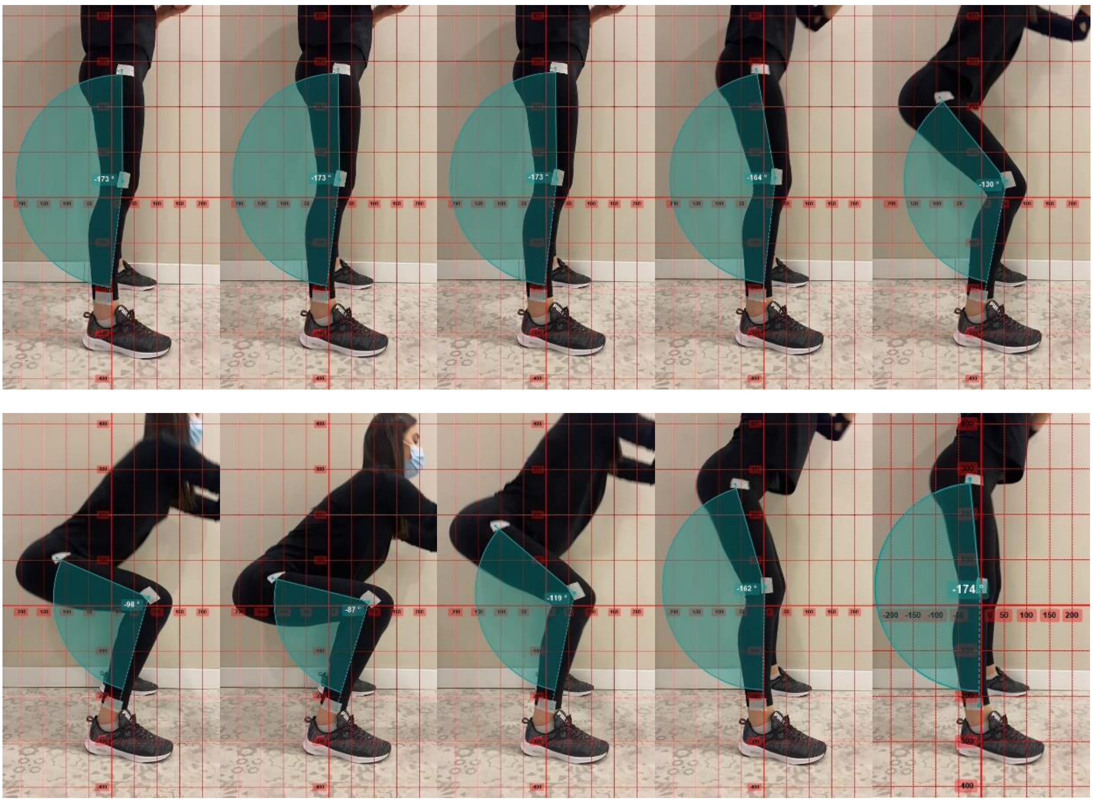

Figure 4. Graphical representation of linear variation in the semi-squat knee flexion

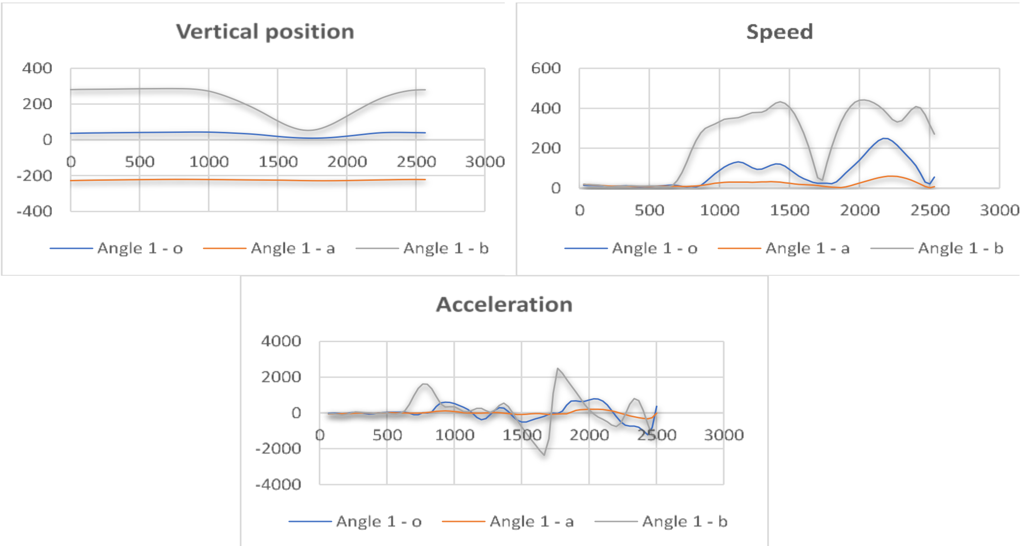

Figure 5. Representation of vertical position, speed and acceleration in the semi-squat knee flexion

Discussion

The purpose of this study was to investigate the linear kinematics and kinetics extracted from digital video. This complements the work of Sanders et al. (2015) and Szabo et al. (2020) to determine the reliability of linear and angular kinematics and kinetics. Although several systematic analyses already available in the literature have shown the efficiency, relevance, and utility of inertial sensors for sports applications (de Magalhaes et al., 2014; Johnston et al., 2019; Camomilla, et al., 2015), an outline of particular applications that can be applied by evaluating kinematics, kinetics, muscle function, and physiological parameters via a wearable. Our research highlighted the importance and viability of kinematic analysis in discovering the mechanism of lower member movement. Other scientific research also highlighted the importance of informatics programs in sports (Szabo et al., 2019) and preventing body dysfunctions (Sopa et al., 2019).

The evaluation of motor performance in sport is becoming more critical due to strengthening competitiveness and financial incentives among athletes. Wearable devices can provide crucial training and competitive success results. Among other sensor options, inertial sensors are the most commonly used, while force measurement devices and electromyography allow more knowledge on kinetics, and related muscle activity levels may offer further insight into the motor actions of athletes (Taborri et al., 2020).

The forces created by an athlete will provide helpful insight into their future success and risk of injury. Variables based on stand-alone force measures include the pressure center (CoP) (Buckeridge et al., 2015), the force path as a surrogate indicator of performance (Kinoshita et al., 2017), and the impact powers (Saponara, 2017). In

vol. 14, no. 1, 2021, pp. 56-66

conjunction with kinematic tests, force data were used to approximate mechanical capacity (van der Kruk et al., 2018), joint kinetics (Lee et al., 2017; Purevsuren et al., 2018), and muscle intensity (Urbanczyk, 2019).

The effect of workload and cadence on muscle coordination is essential, as muscle coordination has an impact on mechanical performance (Blake et al., 2012; Wakeling et al., 2010) and strength production (Dorel et al., 2012; Samozino et al., 2007; Wakeling et al., 2010), but few studies have looked at spatiotemporal muscle excitation-workload-training relationships across multiple muscles.

In an ice hockey kinematic analysis, scientists (Buckeridge et al., 2015) found that joint kinematics and plantar intensity application techniques remained remarkably stable through trials for a given subject. This was predicted during cyclical events such as running. Muscle function is customarily adjusted to retain the preferred direction of motion, i.e., maintaining joint angle trajectories (Nigg, 2001). Excellent reliability was observed for joint kinematics and plantar strength tests, while overall waveform intensity EMG showed moderate to an excellent agreement for each of the five measured muscles (Buckeridge et al., 2015).

Effective coaching results may be accompanied by proper and prompt input to the athlete on goal success shortcomings (Camomilla et al., 2015). Systematic, analytical, and accurate performance measurement and assessment, carried out using qualitative and quantitative analysis of mechanical variables that decide performance, will improve the correlation between research and coaching practices, especially in elite sports. An alternative to classical laboratory-based assessment is the use of magneto and inertial sensors that can calculate movement-related data, linear and angular motion, without room constraints and bulky setup (Armstrong et al., 2007, Dellaserra, 2014). The latest generation of inertial sensors is compact, low-cost, easy-to-use, and allows exercises to be carried out during training or competition, opening new insights in sports sciences. The use of wearable inertial sensors has recently been analyzed in swimming (de Magalhaes et al., 2014), running (Norris, 2014), and strength and ballistic evaluation (Mc Master et al., 2014).

Conclusions

The research theory has been verified, and, using Kinovea, version 0.9.3, kinetic, and biomechanical analysis program, the teaching method in the practical work of the Biomechanics and Kinesiology discipline has been strengthened. The students' input was often encouraging and, by using Kinovea software alone, they were able to put into reality the ideas accumulated in the course, the notions of biomechanics, kinesiology, and linear kinematics (acceleration, speed, and vertical position).

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