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A Validity and Reliability Study of the K-Muscle Controller Hand-Held Dynamometer in Measuring Shoulder's Internal and External Rotation Force

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Abstract

Purpose: To evaluate the validity and reliability of a new Hand-Held dynamometer, K-Muscle Controller, compared to MicroFET2 on measuring the shoulder's external and internal rotation strength on patients with shoulder impingement syndrome (SIS). **Study sample:** A group of 22 (Group A) and a group of 25 (Group B) SIS patients participated. **Data collection and Analysis:** The isometric force of shoulder internal and external rotation was measured using only K-Muscle Controller (group A, two measurements with K-Muscle Controller) or both instruments (group B, one measurement with each instrument). The Intra-Class Correlation (ICC) test was used to investigate the reliability and validity of the K-Muscle Controller. The Coefficient of Variation (CoV) was also calculated for both shoulders' internal and external rotation of both groups. Furthermore, Bland-Altman plots were used to present the level of

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agreement between the measurements for both groups. **Results:** Intraclass correlation tests revealed high correlation coefficients for validity (ICCs ranging from 0.957 to 0.986) and for reliability (ICCs ranging from 0.944 to 0.986) for both groups and both arms for K-Muscle Controller. Moreover, CoV showcased values ranging from 31.77% up to 48.57%. Bland-Altman plots showed that data were within the limits of agreement indicating strong relationship between measurements without any observed trend. **Conclusions:** K-Muscle Controller was deemed reliable for measuring the shoulder's external and internal strength in both healthy and pathological shoulders.

Keywords

validity, reliability, hand-held dynamometry, shoulder internal rotation, shoulder external rotation

Introduction

Isokinetic dynamometers as force measuring instruments have thoroughly been evaluated (Verdijk et al., 2009), and they are often used as a gold standard to test other muscle strength measurement devices (Johansson et al., 2015; Karabay et al., 2020; Keep et al., 2016; Kellis & Baltzopoulos, 1995; Stark et al., 2011). They can measure the peak and average power, rate of torque development, range of joint motion, strength endurance, angle of maximum force and other variables which possess a crucial role in movement biomechanics (Kellis & Baltzopoulos, 1995; Stark et al., 2011). On the other hand, they are limited in movement variation, costly in initial purchase and maintenance, and due to their mass and large space requirements, they have a lack of portability (Chamorro et al., 2021; Stark et al., 2011; Whiteley et al., 2012).

Oppositely, Hand-Held Dynamometers (HHD) are low-cost, convenient, portable, and efficient for measuring strength at a wide variety of angles and movements. MicroFET2 (Hoggan Scientific LLC, Salt Lake City, UT, USA) is a widely used HHD, the concurrent validity of which is moderate-to-high compared to an isokinetic dynamometer (Deones et al., 1994; Hansen et al., 2015; Johansson et al., 2015; Karabay et al., 2020; Keep et al., 2016; Whiteley et al., 2012). Moreover, MicroFET2 have demonstrated high reliability in assessing peak shoulder force (Coinceicao et al., 2018; Cools et al., 2015; Kilmer et al., 1997). In addition, it has been used as a reference standard in the assessment of the validity and reliability of another HHD (Karagiannopoulos et al., 2022).

The validity and reliability of such devices are commonly assessed by calculating the Intraclass Correlation Coefficient (ICC). Literature also has shown that reliability is even higher, when high values of ICC are combined with high variation in the data (Scholtes et al., 2011). This is an important parameter, as high variations are often presented in pathological populations, where such devices are most used.

The K-Muscle Controller (KINVENT Biomecanique, Montpellier, France) is a relatively new HHD, which can be used for the assessment of muscle strength and torque in a wide variety of joints' movements (Kekelekis et al., 2024; Kellis et al., 2024; Paliouras et al., 2025; Park et al., 2024). This HHD is accompanied by a dedicated application which provides live, wireless feedback of applied force via mobile devices, allowing a more direct way to monitor strength results, access to the entire time series for further analysis, and synchronization with multiple devices, i.e. an electro-goniometer, for comprehensive evaluation of complex movements (Batatolis et al., 2023; Kużdzał et al., 2024). The reliability of the K-Muscle Controller HDD for assessing hip adduction strength in two different testing positions was found to be excellent (Pippas et al., 2024). Regarding the use of this HDD for the assessment of force in various strength tests in all major upper and lower limb joints, past research has reported a good to excellent intra- and inter-rater reliability in young adults (de Almeida et al., 2023). In addition, the reliability of this HDD was found to be good when measuring force and torque at three different positions of shoulder abduction, and moderate for normalized torque (Olds et al., 2023). In the same study, its validity was also found to be good when measuring force and torque and moderate for normalized torque (Olds et al., 2023). Nevertheless, to the best of the authors' knowledge, no reliability study was conducted for the K-Muscle Controller HDD regarding the measurement of the shoulder joint isometric strength in a non-physically active, pathological population, and for the shoulder internal/external rotation force in specific. Thus, there is a need to have this instrument validated against a golden-standard HHD in the internal/external rotation, as well to be checked for its measurement reliability in both healthy and pathological shoulder.

The purpose of the study was to evaluate the intra-rater reliability of K-Muscle Controller and its validity against MicroFET2 on a population with shoulder impingement syndrome (SIS). This group was chosen as this pathology is very common (Urwin et al., 1998; Östör et al., 2005). However, to materialize the aim of the present research, only patients with unilateral SIS were examined. Thus, the opportunity to study the validity and reliability in both healthy and pathological shoulders was provided and, consequently, to fill the gap in the respective literature. It was hypothesized that the K-Muscle Controller would demonstrate adequate reliability and validity in both healthy and pathological shoulders.

Methods

Participants

Volunteers were recruited during their visit to a clinic. Participants were diagnosed with SIS in only one of their shoulders, using the clinical tests of Neer impingement test and Hawkins impingement sign. To further validate the clinical decision, patients underwent an ultrasound check (Sonoline G20, Siemens Medical Solutions USA, Inc, Washington, DC, USA) which was used to exclude joint arthritis, frozen shoulder syndrome, neuromuscular degenerative diseases or any other pathology. The participants also needed to meet the following criteria to participate: (i) were in sub-acute phase (15 days up to 3 months), (ii) had not received any treatment related to their symptoms before the data collection, (iii) no sign of spinal injury or surgery in the cervical and shoulder areas, (iv) no neurological, rheumatic or infectious problems, (v) no psychiatric and cancer history, (vi) no diabetes or thyroid disfunctions. All participants signed an informed consent form. The study was approved by the Institutional Research Ethics Committee (approval number: 260630/2021).

The convenient sample comprised of forty-seven patients with unilateral SIS was divided randomly into two groups (Table 1). Participants of group A were evaluated with K-Muscle Controller twice to assess the test-retest reliability within the same session. Participants of group B were evaluated with both HHD (K-Muscle Controller and MicroFet2) to test the concurrent validity.

Instruments

The HHD under validation was the K-Muscle Controller (Figure 1A). The instrument is portable and wireless and functions with K-Physio application (KINVENT Biomecanique, Montpellier, France) installed in common smartphones, which receives force data via Bluetooth at 75 Hz.

Before the measurements, a mechanical validation process took place for K-Muscle Controller (Figure 2) using a mechanical press (WDW-5L Microcomputer control electronic universal testing machine, Jinan Chuanbai Instrument Equipment Co., Ltd, Jinan, China). The weights which were used with the mechanical press ranged from 0 to 90 kg, and the resultant measurement error by the K-Muscle Controller ranged from 0.02 to 0.09 kg. MicroFet2 (Figure 1B), was used as reference standard with measurement error ranging from 0.04 to 0.09 kg, as specified by the manufacturer.

Experimental Procedure

Strength evaluation consisted of two repetitions of internal and external shoulder rotation for both the shoulder suffering from impingement syndrome (SIS) and the healthy shoulder (HS). All measurements were held in the evening hours by the same

Table 1. Anthropometric Characteristics (Mean ± Standard Deviation) of the Participants.

Parameter	Group A (n = 22)	Group B (n = 25)
Sex (Men:Women)	6:16	7:18
Age (years)	56.73 ± 13.75	54.16 ± 14.17
Body height (m)	1.66 ± 0.08	1.67 ± 0.09
Body mass (kg)	75.77 ± 15.98	74.0 ± 14.34
Body mass index (kg/m^2)	27.26 ± 4.86	26.34 ± 4.30

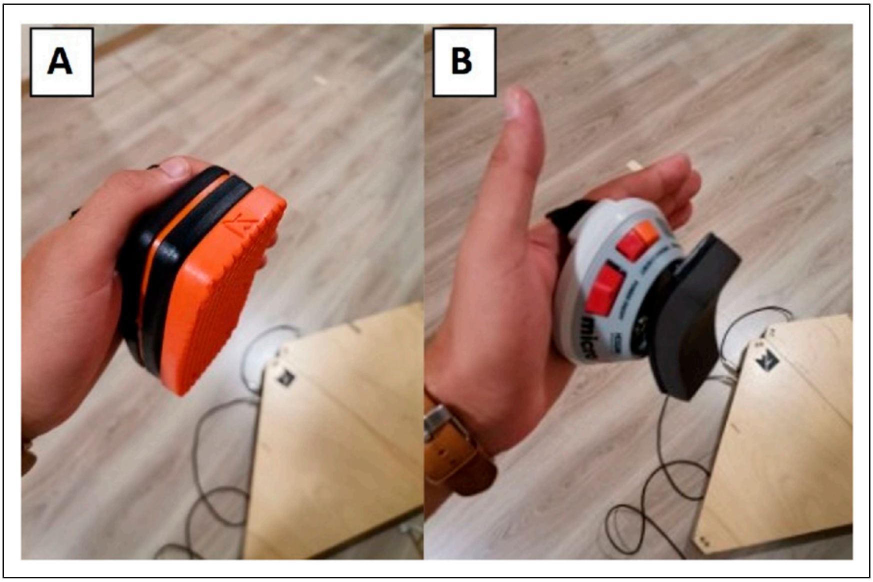

Figure 1. K-Muscle Controller (A), and MicroFET2 (B).

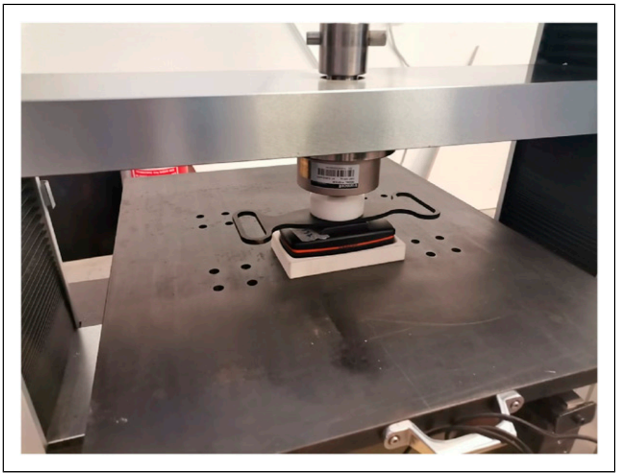

Figure 2. Mechanical validation of K-Muscle Controller using the mechanical press.

experienced tester in an examination room. Both tester and participants were blinded to the results of the measurements during the data collection. The dynamometers were applied on the inner surface of the wrist for the shoulder internal rotation and on the outer surface for the shoulder external rotation. Participants were fixed on a seat with their elbow flexed at 90°. For group B, the instrument of the first repetition was alternately chosen for each participant. A couple of trials were allowed for familiarization before the actual measurements. Each test trial consisted of a 3-s isometric contraction with a 30-s rest between all trials. Peak force was extracted from each trial. The trial with the maximum force recorded was used for further analysis.

Statistical Analysis

Possible group differences were examined with independent samples *t* test following the examination of the anthropometric data with Levene's ($p > .05$) and Shapiro-Wilk ($p > .05$) test, which indicated that homogeneity of variances and normal distribution met the criteria for the implementation of parametric tests. The effect size of the group comparison was evaluated using Hedges' *g*, where the magnitude of $g \geq 0.2$, $g \geq 0.5$, and $g \geq 0.8$, was interpreted as small, medium, and large effect sizes, respectively.

Intra Class Correlation ($ICC_{2,1}$) test (two-way random with absolute agreement) was used to investigate the reliability of the K-Muscle Controller using peak force output from the same instrument (test-retest) derived from two different trials (Group A). The same $ICC_{2,1}$ test was used to investigate the validity of the K-Muscle Controller with respect to the MicroFET2 (Group B). ICC values less than 0.5 were indicative of poor reliability, ICC values between 0.5 and 0.75 were indicative of moderate reliability, ICC values between 0.75 and 0.9 were indicative of good reliability, and ICC values greater than 0.90 were indicative of excellent reliability. The Coefficient of Variation (CoV) was also calculated for the shoulders' internal and external rotation of both groups. Moreover, Bland-Altman plots were used to present the level of agreement between the measurements for both groups. Limits of agreement were set as ±1.96 times the standard deviation of the differences (Bland & Altman, 1986). For the statistical analyses, the IBM SPSS Statistics v.28.0 software (International Business Machines Corp, Armonk, NY, USA) was used, where an $a = 0.05$ level of significance was set.

Results

No differences between groups were observed regarding their anthropometric variables (age: $t_{1,45} = 0.628$, $p = .533$, $g = 0.18$; body mass: $t_{1,45} = 0.401$, $p = .690$, $g = 0.12$; body height: $t_{1,45} = 0.376$, $p = .709$, $g = 0.12$; body mass index: $t_{1,45} = 0.695$, $p = .490$, $g = 0.20$). Intraclass correlation showed excellent reliability (Group A) and validity concerning K-Muscle Controller as shown in Table 2, suggesting that the measurements of K-Muscle Controller and MicroFET2 were comparable. The CoVs are also depicted in Table 2. Bland-Altman plots for reliability and validity are also presented (Figure 3). As shown in the plots, the data are within the limits of agreement, indicating a strong relationship between measurements without any observed trend.

Table 2. Results Concerning the Reliability (Intra-device, Group A) and Validity (Inter-device, Group B) Scores of the Tested K-Muscle Controller Dynamometer.

	Group A (*n* = 22)		Group B (*n* = 25)	
Test	ICC (95 % CI)	CoV	ICC (95 % CI)	CoV
Internal rotation – SIS	0.968 (0.924–0.987)	41.97%	0.968 (0.885–0.988)	48.57%
External rotation – SIS	0.986 (0.966–0.994)	46.01%	0.957 (0.891–0.982)	43.66%
Internal rotation – HS	0.971 (0.931–0.988)	31.77%	0.983 (0.913–0.994)	47.21%
External rotation – HS	0.944 (0.866–0.977)	35.56%	0.986 (0.968–0.994)	38.31%

Note. ICC: intra-class correlation coefficient; CoV: coefficient of variance; CI: confidence interval; SIS: shoulder with shoulder impingement syndrome; HS: healthy shoulder.

Discussion

The current study investigated the K-Muscle Controller' validity compared to MicroFET2 (reference standard), and its reliability as a force measuring device. Intraclass correlation showed excellent reliability concerning K-Muscle Controller. In addition, intra-class correlation referring to K-Muscle Controller's validity was excellent, suggesting that the measurements of K-Muscle Controller and MicroFET2 were comparable. Past research (Olds et al., 2023) suggested that the validity of the K-Muscle Controller compared to Kinvent force plates was good for shoulder abduction force (ICC ≥.79) and torque (ICC ≥.82), and moderate for normalized torque (ICC ≥.71).

Similar reports have been published for devices compared to MicroFET2 concerning their validity and/or their repeatability (Cadogan et al., 2011; Dollings et al., 2012; Karagiannopoulos et al., 2022; McLaine et al., 2016). Karagiannopoulos et al. (2022) compared another HHD with MicroFET2 among three different shoulder movements and found high reliability levels across all shoulder motion. Cadogan et al. (2011), Dollings et al. (2012) and McLaine et al. (2016) measured the intra-examiner reliability of a HHD during various shoulder movements and found high ICC rates (ICC: 0.84 – 0.99). K-Muscle Controller comparatively showcased excellent rates of ICC. This is in partial agreement with past research that reported a good to excellent intra- and inter-rater reliability for the shoulder abduction (ICC: 0.85–0.92, de Almeida et al., 2023; ICC ≥ .79, Olds et al., 2023) and flexion (ICC: 0.71–0.92, de Almeida et al., 2023), as well as excellent test-retest reliability for the hip adduction strength in two different testing positions (ICC: 0.77–0.95, Pippas et al., 2024).

The above findings were observed in the SIS as well as in HS. In fact, the intra-class correlation was excellent despite the high coefficient of variation for peak force which both SIS and HS demonstrated (Table 2). This finding adds to the value of the reliability since Scholtes et al. (2011) mentioned that high variation of data combined with high

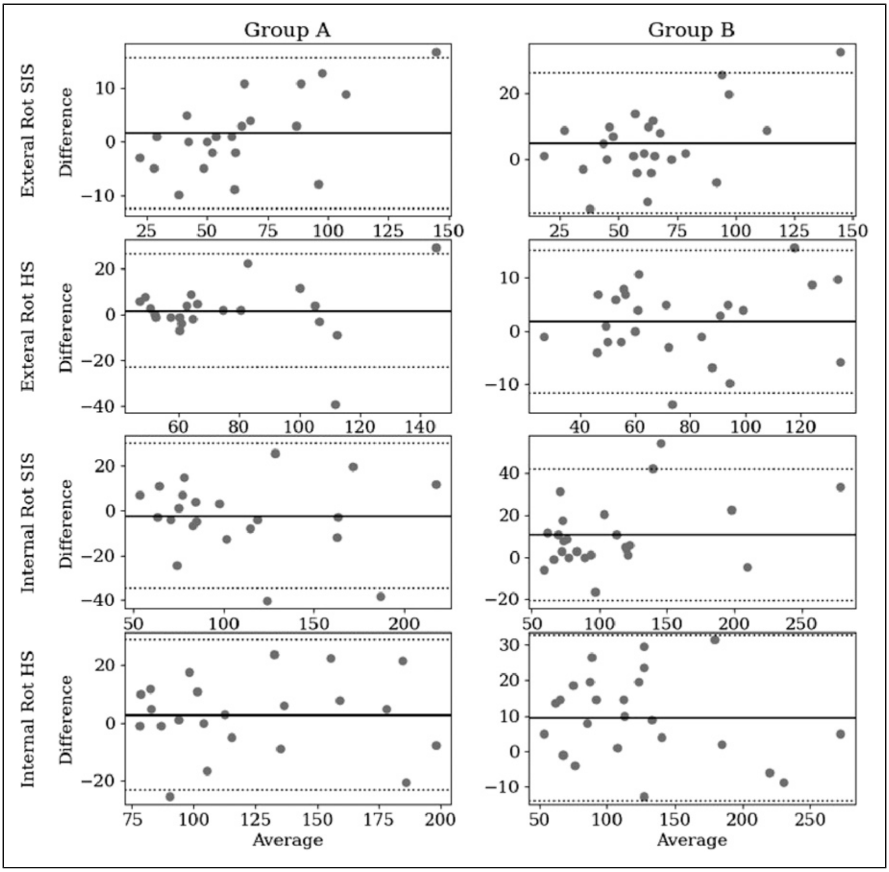

Figure 3. Bland Altman plots for reliability (Group A) and validity (Group B) in internal and external rotation for both upper limbs. HS = healthy shoulder. SIS = shoulder with shoulder impingement syndrome. Values are in Newtons.

intra-class correlation results in much higher reliability, which highlights the repeatability of the K-Muscle Controller measurements.

Despite the high ICC values that were reported both in their present study and in previous research, there are various ways through which the reliability and accuracy of HHDs could be improved. It has been shown that external, rigid, and belt like fixation of HHD can offer results with high reliability and validity (Byrne et al., 2020; Katoh et al., 2011; Martins et al., 2017; Thorborg et al., 2012). Furthermore, live and visual biofeedback of force output, a feature that is included in the assessed HHD, can add value for an experienced clinician who needs to interpret the strength results during assessments.

In the current study, between-rater and between-sessions reliability and validity was not assessed. This limitation should be investigated in future studies to further validate K-Muscle Controller and similar HHD devices.

Conclusion

As a valid and reliable device, K-Muscle Controller is adequate for clinical application on patients for measuring strength deficits. In addition, due to its portability and low-cost, it is a convenient instrument that clinicians can use especially in situations where patients cannot be placed on an isokinetic dynamometer, as the present findings indicated that the K-Muscle Controller is valid and adequate for isometric strength measurements in both the impinged and healthy shoulder of SIS patients.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical Statements

Ethical Approval

The study was approved by the Institutional Research Ethics Committee (approval number: 260630/2021).

Informed Consent

All participants signed an informed consent.

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Data Availability Statement

Data is available upon reasonable request.

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Author Biographies

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Vasileios Mylonas is a PhD student at the University of Nebraska at Omaha. He holds a bachelor's degree in Sport Science and a master's degree in Biomechanics from the Aristotle University of Thessaloniki, where he was actively involved in the Biomechanics Laboratory of the School of Physical Education and Sport Science at Thessaloniki. His research focused on biomechanics, motor control, and human movement variability.

Thomas Nikodelis has a bachelor's degree in Physical Education and Sport Science (1997), and a Ph.D. (2004) in Human Performance and Health, specialized in Swimming Biomechanics. His post-doc was at visual feedback training and Balance in the elderly (2005-2007). He was a Physical Education teacher in the Elementary Education from 2008 until 2017 where he was honored by the Greek Ministry of Education for his innovation and excellence related to the educational program of teaching swimming in the elementary school, which is now applied at a national level. He is also a swimming trainer since 1997. He has worked as a Biomechanics expert is the Gait Analysis Lab of Hellenic Society for Disabled Children (2006-2009), and he is currently (since 2017) working as a laboratory teaching staff in the Biomechanics Laboratory of the School of Physical Education and Sport Science at Thessaloniki, Aristotle University of Thessaloniki (AUTH), Greece. He is a member of the Hellenic Society of Biomechanics and his research focuses on biomechanics of human movement and swimming, postural control, athletic performance, and the application of machine learning in sports science.

Vassilios Panoutsakopoulos received his bachelor's degree in Physical Education and Sport Science from the Aristotle University of Thessaloniki, Greece (AUTH) in 1998, his Master's degree from the Intra-Institutional Graduate Program of the AUTH, the University of Thessaly and the Democritus University of Thrace in 2002, and a PhD from the School of Physical Education and Sports Science, AUTH, in 2014. He is an Assistant Professor for Track and Field Coaching at the School of Physical and Sports

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Theodoros Loizidis, MD, PhD, is Head of Physical and Medical Rehabilitation at Clinic "Agios Loukas" in Thessaloniki, Greece. A graduate (MD in 1992 and PhD in 2002) of the Aristotle University of Thessaloniki, Greece (AUTH). He holds European Board Certification (2000) and a Senior Fellowship from the European College of Physiatrists (2010). He specializes in gait analysis, dry needling, rehabilitation technology, and musculoskeletal pain management. Since 2018, he has pioneered sensor-driven home rehab programs for hemiplegic patients. Dr. Loizidis has held senior clinical roles and contributed extensively to research and patient-centred rehabilitation approaches.

Athanassios Mihailidis is Professor Emeritus. He received his diploma in Mechanical Engineering from the Aristotle University of Thessaloniki, Greece (AUTH) in 1978 and he completed his PhD thesis at Mechanical Engineering Department, AUTH, in 1984. From 2010, he is Full Professor at the Mechanical Engineering Department of AUTH. He was the Director of the Laboratory of Machine Elements and Machine Design at AUTH. His research interests included machine elements, gears and power transmission systems, tribology and thermo-elastohydrodynamic lubrication, and automotive engineering. He is an active member of the Technical Chamber of Greece, the Greek Association of Mechanical Engineers, the Verein Deutscher Ingenieure, the Society of Automotive Engineers. Moreover, he is the Founding Member of the Balkan Tribological Association, and a Founding member of the Balkan Association of Power Transmissions. In addition, he has served as a reviewer of several scientific journals with the scope of mechanics-based design, automation and control. He was the President of the Balkan Association of Power Transmissions from 2006 until 2009, and the Vice President of the Balkan Association of Power Transmissions from 2009 until 2012.