HOW TO VERIFY WHETHER THE SOCCER PLAYER'S KNEE IS FUNCTIONING PROPERLY?

Martyna Michałowska[1,2], Tomasz Walczak[1], Jakub Krzysztof Grabski[1] and Monika Grygorowicz[3,2]

Institute of Applied Mechanics, Faculty of Mechanical Engineering and Management, Poznan University of Technology, Poznań, Poland[1]
Rehasport Clinic FIFA Medical Centre of Excellence, Poznań, Poland[2]
Department of Spondyloorthopaedics and Biomechanics of the Spine, Wiktor Dega Orthopaedic and Rehabilitation Clinical Hospital, University of Medical Sciences, Poznań, Poland[3]

Although isokinetic tests are very widely used as the screening tool in different groups of athletes, there is still very limited number of studies describing proper shape of isokinetic curve for elite soccer players. Isokinetic evaluations are usually restricted to the analysis of only few values, from hundreds of available parameters. That is why the authors decided to investigate and describe the shape of the model isokinetic curve for elite soccer players, based on 126 isokinetic tests performed at isokinetic velocity of 60°/s. The authors proposed and calculated parameters describing the shape of model isokinetic curve designated for mean and standard deviation of all included into analysis isokinetic tests. The resultant curve shape occurred to be very repetitive in every of three tested repetitions. Results of this study might serve as an useful reference model in physiotherapy or clinical practice thanks to its simplicity in interpretation.

KEYWORDS: knee, isokinetic test, soccer, model isokinetic curve shape.

INTRODUCTION: Isokinetic dynamometry is widely used in sport biomechanics, athletes' resistance training, as well as the tool for conducting screening tests or monitoring progress in rehabilitation process (Czaplicki el al., 2015). It is also applied for assessment of the muscle balance in the knee joint, based on hamstring and quadriceps muscles peak torques (PT) calculations (Lee et al., 2017). Most of the studies are focused on analysis only few parameters obtained from this type of evaluation: previously mentioned peak torques, symmetry between PTs between left and right leg or amount of muscle work performed during test. However, these parameters determine only few values from hundreds of parameters recorded during isokinetic test. In authors' opinion, as much attention should be devoted to the analysis of the shape of the curve, as it is devoted to the analysis of various parameters. The shape of the recorded isokinetic curve can be a reflection of knee biomechanical function during flexion-extension movement. Few studies confirm, that shape of isokinetic curve might be a representative for some of the knee dysfunctions (Ayalon et al., 2002). Although, different types of biomechanical and performance knee tests are described in the literature, there is still limited data for soccer players in terms of simultaneous analysis of knee structures and dynamic movement. Therefore, the purpose of this research was to investigate the model shape of the isokinetic curve for elite soccer players, while performing three test repetitions with 60°/s of angular velocity, in order to designate and describe the isokinetic curve shape of a properly functioned knee joint.

METHODS: The analysis was conducted based on data obtained from medical documentation and biomechanical tests gathered for 66 male professional soccer players of one team, previously described in more details (Grygorowicz et al., 2017). Players conducted knee isokinetic tests at the beginning of each soccer season at four different test velocities. However, in this study, only data recorded during the tests with velocity of 60°/s and three extension-flexion repetitions were analysed. Tests were conducted on Biodex System 3 Pro dynamometer (Biodex Corp, 49 Natcon Drive, P. O. Drawer S, Shirley, NY), after warm up consisted of 10-15 minutes of mild pedalling on a stationary Monark cycle ergometer. In order to designate the isokinetic curve shape only for healthy individuals, all data of players with injured knee joint or with a history of recurring injury in the knee joint were rejected. The isokinetic test medical exclusion criteria were as following:

1. injury of the quadriceps, rectus femoris or hamstring muscle in the tested limb before the isokinetic test or in the period of 12 months after isokinetic test,
2. injury or rupture of the tendons and ligaments in the tested knee joint before the isokinetic test or in the period of 12 months after isokinetic test,
3. reconstruction of tendon or ligament in the tested knee joint before the isokinetic test,
4. meniscus lesions or injuries in the tested knee before the isokinetic test or in the period of 12 months after isokinetic test,
5. injury of patellar ligament in the tested knee before the isokinetic test or in the period of 12 months after isokinetic test.

From 340 isokinetic tests gathered between 2010 and 2016 for this soccer team, 209 tests of 44 players (aged 24.12 ± 5.40 at the test day, weight 79.29 ± 6.03, height 183.86 ± 5.27) were not associated with the exclusion criteria described above and were taken into further analysis. Isokinetic tests were analysed in MATLAB software and obtained from the Biodex dynamometer as raw measurement data in the form of text files consisted of recorded torque, position of dynamometer lever, anatomical position of the joint flexion/extension and actual velocity, all of these measured with frequency of 100 Hz. It should be noticed, that in raw measurements files, data with positive torque values are recording during knee extension (so work of the knee extensors is registered with positive values) and negative torque values corresponds to knee flexion movement (work of the knee flexors is registered). To make isokinetic curves comparable with each other, measured torque values were normalized by the body weight (BW) and time was normalized by maximum time of three test repetitions, so the time axis was expressed as percent of test completion (from 0 to 100%).
Due to the fact, that number of time samples was different, depending on test time, it was necessary to equalize number of time samples in all recordings. The authors used *interp1* MATLAB function and interpolated all torque measurements in 1000 evenly distributed time samples with values from 0 to 100%, what corresponds to previously described process of time axis normalization. Subsequently, all isokinetic curves were plotted on one graph and mean as well as standard deviation (SD) were calculated in each time sample (Figure 1).

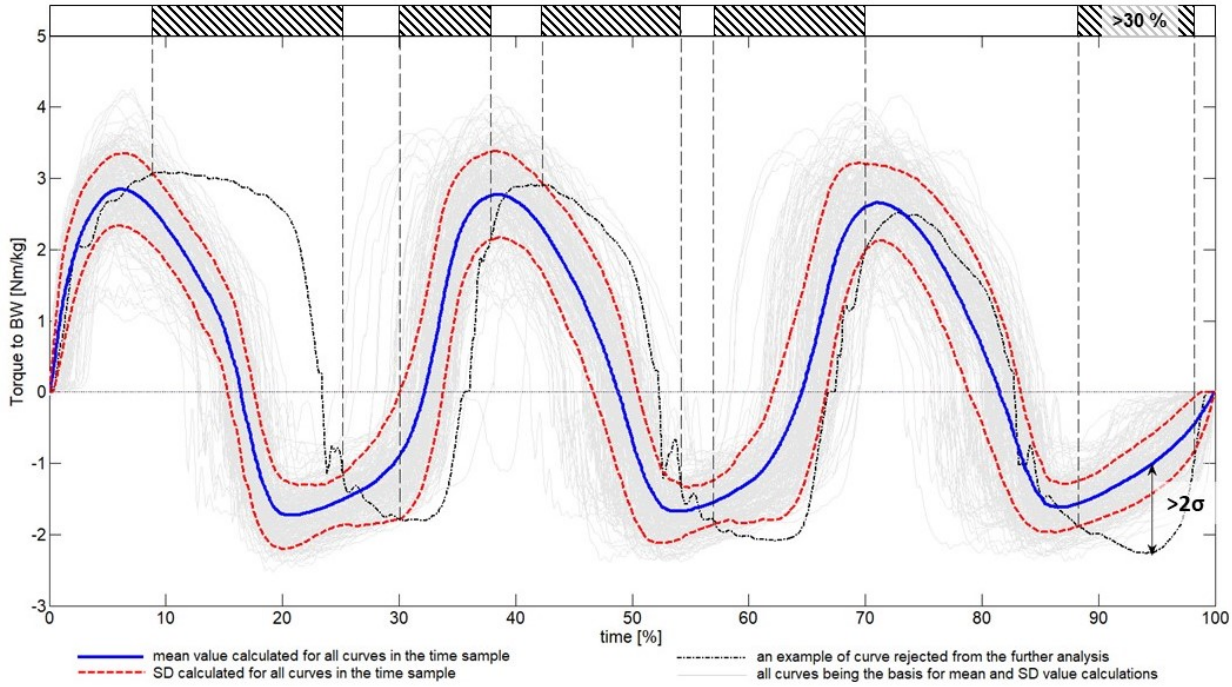

Figure 1: Mean and SD values calculated for each time sample for all 209 curves selected with the use of medical exclusion criteria and graphical representation of shape exclusion criteria used in the further process of data selection.

To obtain more regular shape of the model curve, the authors decided to apply two more exclusion criteria, simultaneously preserving high quantity data making contribution to final calculations. The additional isokinetic curve shape exclusion criteria were as following:

1. value of measured torque in more than 30% of time samples was not inscribed in range of values designated by mean and SD calculated for particular sample,
2. value of measured torque in any of sample was higher/lower than doubled value of mean (calculated for particular time sample) plus or minus σ, accordingly. σ value was constant, calculated as maximum SD for all considered curves and samples (σ = 1.43 Nm/kg).

Application of shape exclusion criteria allowed eliminating tests containing very high values of measured torque caused by artefacts from isokinetic dynamometer. Moreover, very short periods of time where exerted torque was unnaturally very high or very low (criterion no 2), and tests where distribution of at least one repetition in time was very disproportionate in comparison to the other two test repetitions (criterion no 1) were excluded in this way. Based on these two criteria, the authors rejected 83 tests, so 126 isokinetic tests were the basis of final calculations targeted on finding the model, averaged curve shape.

For the model curve presented in the Figure 2, mean normalized torque and SD values were calculated in each time sample. Subsequently, characteristic points of resultant curve were marked on the graph and presented in the Table 1. All curve parameters were calculated for each of three repetitions separately, but for clarity of data presentation characteristics associated with local maxima, minima (their values, SD, occurrence in time) and intersections with the time axis are presented on the 1st and 2nd repetitions and characteristics associated with angles of the curve slopes are presented in the 3rd repetition. In Table 1, values of parameters Mt_1, Mt_2 and t1 as well as ranges being the basis for slopes calculations (described in caption to Figure 2) are presented in regard to time of one repetition (Tr), while t2 is calculated as time with regard to full test time (three repetitions). Slopes were calculated with the use of *LinearModel.fit* MATLAB function.

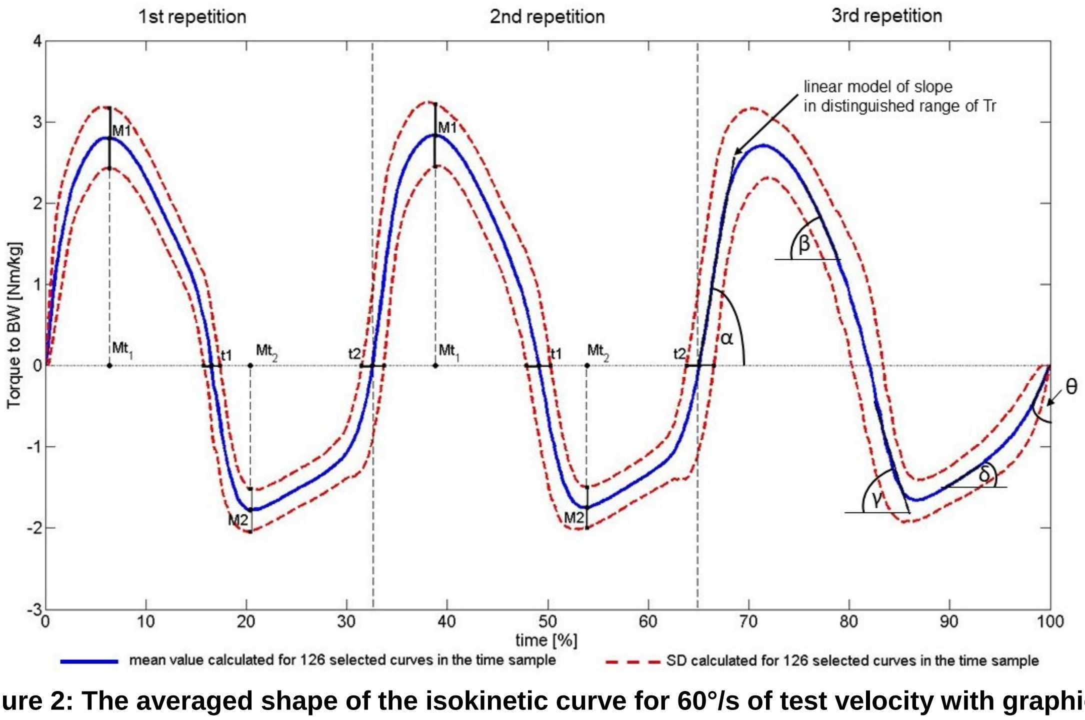

Figure 2: The averaged shape of the isokinetic curve for 60°/s of test velocity with graphical representation of parameters describing curve shape. Tr – time of single repetition, α – calculated for 0 - 10% Tr, β – calculated for 30 - 40% Tr, γ – calculated for 50 - 60% Tr, δ – calculated for 70 - 80% Tr, θ – calculated for 95 - 100% Tr.

RESULTS&DISCUSSION: Values of model isokinetic curve shape parameters presented in Table 1 shows, that each of three repetitions is very similar to each other. Slightly lower values of M1, M2 parameters and wider θ were noted for 3rd repetition, what can be caused by tiredness of tested person at the end of the test.

Table 1: Mean and SD values distinguished as curve shape parameters in the Figure 2.
*** SD calculated for all curves, **SD calculated for linear model of slope in range of analysed Tr.**

Parameter	1st repetition	2nd repetition	3rd repetition	Mean for 3 repetitions
M1 [Nm/kg]	2.79 ± 0.37*	2.83 ± 0.39*	2.71 ± 0.41*	2.78 ± 0.39
Mt_1 [%]	19.66	19.22	18.43	19.10 ± 0.51
M2 [Nm/kg]	-1.78 ± 0.26*	-1.74 ± 0.25*	-1.66 ± 0.25*	-1.73 ± 0.25
Mt_2 [%]	62.67	65.67	61.65	63.33 ± 1.71
t1 [%]	50.69 ± 2.67*	51.00 ± 3.91*	48.48 ± 2.26*	50.06 ± 2.95
t2 [%]	32.55 ± 1.06*	65.06 ± 1.33*	100	-
α [°]	79.84 ± 0.15**	80.58 ± 1.04**	79.02 ± 0.73**	79.81 ± 0.61
β [°]	62.33 ± 0.05**	62.95 ± 0.10**	64.32 ± 0.18**	63.20 ± 0.11
γ [°]	77.95 ± 1.06**	76.76 ± 0.69**	71.33 ± 0.83**	75.35 ± 0.86
δ [°]	28.06 ± 0.02**	28.47 ± 0.03**	31.01 ± 0.02**	29.18 ± 0.02
θ [°]	15.32 ± 1.04**	14.93 ± 0.79**	24.93 ± 0.14**	18.39 ± 0.66

The aim of this study was to identify the model shape of isokinetic knee curve for velocity of 60°/s, intended for elite soccer players. The model was successfully created and its characteristic points and features were calculated and presented sufficiently. In the future, demonstrated model of the curve may serve as the model shape pattern in isokinetic assessment practice. Substantial deviations from the model can be treated as “red flag” by evaluators and may be useful in planning treatment and rehabilitation programs. In further studies the authors plan to create models characteristic for specific types of injuries.
In contrast to previous models presented by Carvalho et al. (Carvalho, 2015), the model presented in this study was build based on relatively larger sample (12 tests in Carvalho study vs.126 tests in current study). Additionally, the model seems to be easy to apply in daily basis, because it is focused on basic statistics describing the curve shape. The model is ready to use after implementation the normalization of vertical axis by BW and time axis by overall test time. In different studies isokinetic curve shape is usually presented as torque in the function of angle position (or extension/flexion stage) (Carvalho, 2015; Czaplicki et al., 2015) but in authors’ opinion it is essential to use muscle torque as a function of time, because only this approach reflects fluency of movement during the test, that is another important factor, which should be taken into isokinetic test qualitative analysis.

CONCLUSION: This study identified a model shape of the curve for the isokinetic test with 60°/s angular velocity in the knee joint, recommended for group of male professional soccer players. Such a model has a high potential to be applied in physiotherapy or clinical practice. Proposed curve model determines desirable and normative values of the characteristic isokinetic curve features, what might be useful in determination of return to sport criteria after injury in the knee joint or in planning treatment and rehabilitation programs.

REFERENCES

Ayalon, M., Barak, Y., & Rubinstein, M. (2002). Qualitative analysis of the isokinetic moment curve of the knee extensors. *Isokinetics and Excercise Science*, 10, 145–151.

Carvalho, H. M. (2015). Multilevel Models for the Analysis of Angle-Specific Torque Curves with Application to Master Athletes. *Journal of Human Kinetics*, 49(1).

Czaplicki, A., Jarocka, M., & Walawski, J. (2015). Isokinetic Identification of Knee Joint Torques before and after Anterior Cruciate Ligament Reconstruction. *PLOS ONE*, 10(12), e0144283.

Grygorowicz, M., Michałowska, M., Walczak, T., Owen, A., Grabski, J. K., Pyda, A., … Kotwicki, T. (2017). Discussion about different cut-off values of conventional hamstring-to-quadriceps ratio used in hamstring injury prediction among professional male football players. *PLOS ONE*, 12(12), 1–17.

Lee, J. W. Y., Mok, K.-M., Chan, H. C. K., Yung, P. S. H., & Chan, K.-M. (2017). Eccentric hamstring strength deficit and poor hamstring-to-quadriceps ratio are risk factors for hamstring strain injury in football: A prospective study of 146 professional players. *Journal of Science and Medicine in Sport*.

ACKNOWLEDGEMENTS: The presented research results were funded with the grant 02/21/DSMK/3499 allocated by the Ministry of Science and Higher Education in Poland.