Artificial neural networks in knee injury risk evaluation among professional football players

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Abstract

Assessment of the risk of injury was based on isokinetic examination that is a part of standard athlete's biomechanical evaluation performed mainly twice a year. Information about non-contact knee injury (or lack of the injury) sustained within twelve months after isokinetic test, confirmed in USG were verified. Three the most common types of football injuries were taken into consideration: anterior cruciate ligament (ACL) rupture, hamstring and quadriceps muscles injuries. 22 parameters, obtained from isokinetic tests were divided into 4 groups and used as input parameters of five feedforward ANNs. The 5th group consisted of all considered parameters. The networks were trained with the use of Levenberg-Marquardt backpropagation algorithm to return value close to 1 for the sets of parameters corresponding injury event and close to 0 for parameters with no injury recorded within 6 - 12 months after isokinetic test.

Keywords: artificial neural network, isokinetic test, knee, injury prediction, conventional H/Q ratio, muscle strength asymmetries

1. Introduction

Sports injury prevention is one of the most important issue of the athlete's career, because serve injury may be one of the main cause for the involuntary and premature termination from competitive sport [1]. Because of that athletes are very often assessed with the use of battery of biomechanical tests conducted as a pre-season evaluation. Isokinetic assessment is widely used in knee joint examination. It provides the information about knee flexors and extensors muscles strength, endurance, power, fatigue, etc. [2].

Values of typical parameters obtained from isokinetic tests differ in relation to the sport discipline, gender and even playing position of the athlete. Typically, two main outcomes are used in determining the risk of injury: the hamstring to quadriceps muscle strength ratio (H/Q), conventional or functional, and asymmetries in the peak torques between corresponding muscles in right and left lower limbs. Many authors claim that conventional H/Q ratio lower than 0,6 with contralateral muscle strength asymmetry higher than 5%, obtained with 60°/s velocity during isokinetic test are indicators of higher risk of the injury among male football players [2].

The aim of the biomechanical evaluation performed among healthy professional athletes is to provide risk injury data and to evaluate the performance profile of tested athlete. Based on the complex biomechanical evaluation it is possible to analyse the current functional status of an athlete and to implement injury prevention exercises if it is needed. Due to the fact that knee isokinetic test provides maximal 80 muscle parameters and their derivatives, the authors of this paper proposed the mathematical tool, based on artificial intelligence methods, which compress many information in one parameter. This parameter might be useful in determination of the knee injury risk. Its simplicity in risk injury interpretation (parameter close to 1 corresponds to higher risk of injury and close to 0 corresponds to lower risk of injury) provides the opportunity to be applied in sport physiotherapy practice.

2. Methods

A special database was created. This database comprised of two aspects: results of the isokinetic test and information whether a player suffered an injury. All of the data were collected in retrospective way.

2.1. Isokinetic tests

Biomechanical data of the 66 athletes played for one elite football team between 2010 and 2016 were collected as pre- and middle season evaluation. All players were monitored and treated by one orthopedic clinic. The authors enrolled the tests with at least 6 month follow-up in medical documentation (171 tests for both lower limbs). Isokinetic knee strength was performed on Biodex System 3 Pro dynamometer. After 10-15min. warm-up on a stationary cycle ergometer and dynamic stretching of the major lower limb muscle groups the concentric quadriceps and hamstrings torque muscles were assessed. The athletes performed three knee extension-flexion movements at the angular velocity of 60°/s, through a knee range of motion of 0° (flexion) to 90° (full extension) [3].

2.2. Medical history and injury registration

Medical history concerning non-contact lower extremities injuries suffered during 6 to 12 months after each isokinetic test was collected. Three types of injuries were analysed: anterior cruciate ligament (ACL) rupture, hamstring and rectus femoris muscle injuries. These structures are considered as having the biggest influence on knee joint function what can be observed in isokinetic test. All injuries were confirmed by ultrasound examination. Injuries caused by collision with another player were excluded. As the result, 33 injuries were recorded.

3. Artificial neural network models

Records from isokinetic tests and medical history were used as input parameters of the artificial neural network models and output values used in training process (information about sustained injury marked as 1, non-injured cases marked as 0). Input parameters were divided by authors to 4 following groups:

1) NN_1 – parameters describing muscle peak torque:
   - BW – body weight,
   - PtQ – quadriceps peak torque,
   - a_PtQ – angle of quadriceps peak torque,
   - PtH – hamstring peak torque,
   - a_PtH – angle of hamstring peak torque.
2) NN_2 – classical parameters used in injury risk assessment:
   - H/Q – hamstring to quadriceps ratio,
   - Q_as – side to side asymmetry between quadriceps muscles,
   - H_as – side to side asymmetry between hamstring muscles.
3) NN_3 – parameters associated with work and power:
   - Total_workQ – quadriceps work,
   - Total_workH – hamstring work,
   - Av_powerQ – quadriceps average power,
   - Av_powerH – hamstring average power,
   - t_PtQ – time to quadriceps peak torque,
   - t_PtH – time to hamstring peak torque,
   - T_0.18sQ – quadriceps torque at 0.18 s,
   - T_0.18sH – hamstring torque at 0.18 s.
4) NN_4 – neuromuscular and functional parameters:
   - Acc_tQ – quadriceps acceleration time,
   - Dcc_tQ – quadriceps deceleration time,
   - T_30dQ – quadriceps torque at 30 degrees,
   - Acc_tH – hamstring acceleration time,
   - Dcc_tH – hamstring deceleration time,
   - T_30dH – hamstring torque at 30 degrees.

Additionally, there was created the 5th group, which contained all above mentioned parameters.

Each ANN was created in Neural Network Toolbox for MATLAB and comprised of six neurons in hidden layer and one neuron in the output layer. Models were trained 50 times with Levenberg-Marquardt backpropagation algorithm and half of the data collected in the database (171 records). The number of maximum train epochs was set at 600 and weights in the neural network models were initialized randomly. For all trained neural networks their performance (Perf.) was recorded. The second half of the data in database was used to validate the prediction of response (validation data). For this purpose the output value of the neural network was compared with expected answer, and calculated as root-mean-square error (RMSE). Furthermore, they have been counted predicted injuries (TP, true positives), predicted non-injuries (TN, true negatives), false predicted injuries (FP, false positives) and non-predicted injuries (FN, false negatives). For each model output value ≥0.5 was classified as predicted injury (1), otherwise the answer was "no injury" (0). Sensitivity (Sens.) and specificity (Spec.) of each trained model were calculated based on TP, TN, FP, FN values for each trained model.

Table 1: Neural networks training and validation - results summarized for 50 training trials.

	Perf.	RMSE	TP	TN	FP	FN	Sens.	Spec.
	NN_1 Peak torque parameters							
Best results	0,017	0,17	3	154	0	14	0,18	1,00
Mean	0,048	0,23	0	145	9	17	0,03	0,94
	NN_2 Classic injury prediction parameters							
Best results	0,030	0,18	3	154	0	14	0,18	1,00
Mean	0,055	0,29	1	146	8	16	0,04	0,95
	NN_3 Work and power parameters							
Best results	0,001	0,18	4	154	0	13	0,24	1,00
Mean	0,045	0,24	1	144	10	16	0,04	0,94
	NN_4 Neuromuscular and functional parameters							
Best results	0,016	0,17	4	154	0	13	0,24	1,00
Mean	0,046	0,23	1	146	8	16	0,04	0,95
	NN_5 All parameters							
Best results	0,001	0,17	8	154	0	9	0,47	1,00
Mean	0,037	0,28	2	138	16	15	0,10	0,90

4. Conclusions

High values of specificity presented in Tab.1 indicates that all described neural network models were able to predict most non-injured cases within validation data. Low values of models sensitivity might be caused by not sufficient amount of data associated with injury, used to train and validate proposed neural network models. Higher effectiveness can be observed in NN_5 model that contains all chosen parameters. It may indicate a greater complexity of the challenge of inclusion the most important parameters from the isokinetic test. Accuracy of this study could be improved by increasing quantity of training data and modification of neural networks architectures. Future studies should be focused on pointing out the most important isokinetic parameters in neural network decisive process. Procedure presented in this study might be a different approach to support medical decision making process, however further studies are needed verifying mathematical tool, based on artificial intelligence methods, in knee injury risk assessment.

References

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