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ORIGINAL ARTICLE

Predicting judo champions and medallists using statistical modelling

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: In the past decade, several studies have convincingly demonstrated that the identification of characteristics in young children can form a solid basis to identify those subjects with the most chance to excel at the international competition level. The present study aims to predict the performance of young male judo athletes with linear and non-linear predictive statistical models. It is hypothesized that a non-sport specific test battery will allocate athletes to their best achievement level at least three years past baseline.

Material and Methods: In this retrospective cross-sectional study, 22 trained male Belgian judo athletes U14 (12.675 ±0.910 years) were tested in 2009-2011 using a generic test battery consisting of five anthropometrical, seven physical performance and three motor coordination tests. In 2016 they were allocated to one of three groups depending on their achievement level between 2013-2015. First, Kruskal-Wallis was used to discover indicators that significantly differ across the three groups sampled by achievements. Second, linear discriminant analysis (LDA) was applied to discriminate the participants and allocate them to their respective achievement level.

Results: The Kruskal-Wallis test showed significant differences for three indicators (sitting height, weight, Body Mass Index). Using all indicators, discriminant analysis correctly classified 95.5% of the participants. Only 36.4% of cross-validated grouped cases were correctly classified based on all indicators. Therefore, a sequential discriminant analysis, containing the significant tests (three indicators) was applied to improve the cross-validated model from 36.4% to 59.1%. Using all indicators makes the model stronger but using a limited number of indicators makes it easier to assign athletes to the right group.

Conclusions: Generic talent characteristics (anthropometry) included in the present study allow for a successful discrimination between drop out, sub-elite and elite judo athletes. In addition to the trainer's opinion and the individual screening of judo specific performance characteristics, this generic test battery provides opportunities for predicting judo performance of young athletes.

Keywords: cross-sectional study • judo achievements • performance characteristics • talent identification

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Performance prediction – the statistical process of estimating an athlete's performance level in the future based upon a given baseline test.

Discriminant analysis – multivariate statistical technique used for classifying a set of observations into predefined groups.

Physical performance test – set of tests to evaluate speed, strength, and flexibility in non-sport specific context.

Motor coordination test – test designed to evaluate the ability to organise one's movements successfully.

Talent scout – *noun* somebody whose job is to search for people who have exceptional abilities and recruit them for professional work. Also called **scout** [28].

Scout – *noun* same as **talent scout** ▯ ***verb*** to look for talented players for a sports team [28].

INTRODUCTION

Today many countries have implied formal talent identification (TI) and talent development (TD) models in the sport to increase their success at the international scene. TI is defined as the process of recognising current participants with the potential to excel in a particular sport, while TD provides the required learning environment to maximise this potential [1, 2]. Efforts to develop TI and TD models stem from the general conviction that gifted youngsters do not automatically end up at the highest performance level in a particular sport. However, returns from investment on current TI and TD models of sport in youth are sub par, meaning that only a few young athletes continue their career to achieve podium positions at the elite sports level in adulthood [3]. Understanding the underlying performance characteristics that relate to international success in judo might help the talent identification (TI) as well as the talent development (TD) process.

In the past decade, several studies have convincingly demonstrated that the identification of characteristics in young children can form a solid basis to identify those subjects with the most chance to excel at the international competition level. Such an approach does not only allow the discrimination between successful and less successful young athletes but also allowed to predict the future performance level to a certain extent. This has been demonstrated in volleyball [4], gymnastics [4, 5] soccer, and many other sports [4].

Studies comparing performance characteristics in judo are scarce and are mostly based on the evaluation of judo specific skills and characteristics. Recently Tavra et al. [6] identified differences between elite and non-elite judo athletes using judo specific tests. The main objective of this study was the discriminant and factorial validity of four judo-specific tests in a sample of high-level junior female judokas. They found that the Special Judo Fitness Test (SJFT) and the Uchi Komi Fitness Test (UFT) better discriminated the elite from the sub elite female judokas. Research using a generic testing battery to reveal performance related characteristics in judo showed that explosive strength, balance, flexibility and agility contribute to faster-executed judo skills [7, 8].

Next, to such sport-specific tests, the importance of general motor coordination has long been neglected in the literature [9, 10]. Given the technical complexity and speed of execution required in judo, it is assumed that motor coordination also plays an important role in this discipline. The importance of motor coordination has been demonstrated for performance prediction [11] as well as for sports orientation. Volleyball players with better results for motor coordination had more chance to reach the podium at international level [11]. The same generic test battery showed that it was possible to orient athletes towards different sports [12] as well as to sports that are to a certain extent similar to each other, like martial arts karate, judo and taekwondo [13]. While performance characteristics in judo have been identified in other studies, the retrospective design of this study allows the comparison between judo achievements and baseline performance characteristics at least three years prior to the status of competition participation at the highest level. The pending question is whether predictive models can reduce the talent development costs in judo. It was investigated to what extent judo achievements can be predicted using linear mathematic methods using discriminant analysis.

The present study aims to predict the performance of young male judo athletes with linear and non-linear predictive statistical models. It is hypothesized that a non-sport specific test battery will allocate athletes to their best achievement level at least three years past baseline.

MATERIAL AND METHODS

Participants and design

A sample of 22 highly trained judo athletes (12.675 ±0.910 years) in Belgium participated in this retrospective, cross-sectional study. They were all selected for the Flemish Top Sport Schools, where they were involved in a talent development program preparing them for international competition. This study has been conducted in accordance with recognised ethical standards [14] and was approved by the local Ethics Committee of the Ghent University Hospital. For all participants, written informed parental consent was obtained. None of the participants refused participation.

Measurements

The participants were measured in 2009, 2010 or 2011 and completed five anthropometrical,

seven physical performance and three motor coordination tests. A team of experienced examiners of the Department of Movement and Sports Sciences assessed the generic test battery. At any given time, instruction and demonstration were standardised according to the test guidelines. The athletes performed all tests barefoot except the sprints, the counter movement jump and the endurance shuttle run test, which were all performed with running shoes. In 2016, the participants were sought through a reliable data source of judo results at www.judoinside.com. The website provides competition results of judo athletes and their current rankings. Achievements throughout 2013, 2014 and 2015 were registered and categorised by level, i.e. elite, sub-elite or drop out. Athletes who had obtained medals at the national level and/or participated in international tournaments (European and World level) were allocated to the elite category. Meanwhile, athletes who had obtained medals at the national level and/or participated in international tournaments were classified in the sub-elite category. Finally, athletes who had not participated in the national/international competition since 2013, were assigned to the drop out the group.

Anthropometry

Height (H) and sitting height (SH) (0.1 cm, Harpenden, portable Stadiometer, Holtain, UK), body weight (BW) and body fat percentage (BF) (0.1 kg, Tanita, BC-420SMA) were assessed according to previously described procedures [15] and manufacturer guidelines. Height and weight values were used to calculate Body Mass Index (BMI).

Physical Performance

Flexibility was assessed by the sit-and-reach test of the Eurofit test battery with an accuracy of 0.5 cm [16]. To estimate explosive leg power, the counter movement jump was performed. The participants performed three single jumps without arm swing recorded with an OptoJump device (MicroGate, Italy). The highest of three jumps was used for further analysis (0.1 cm). Static strength was measured by the handgrip [16] in Nm. Speed was evaluated by two maximal sprints of 30 meters with split time measured at five meters. The recovery time between each sprint was set at two minutes. The fastest time for the 5m sprint and 30m sprint was used for analysis [17]. The sprint tests were recorded with MicroGate Racetime2 chronometry and Polifemo Light photocells at an accuracy of 0.001 s (MicroGate, Italy). Upper body strength was determined by the performance of sit-ups according to the BOT2 procedures [18], requiring the athletes to execute as many repetitions as possible in 30 seconds. The beep test, with the final 30 seconds that persisted (0.5 min), was used for valuing the endurance of the participants.

Motor Coordination

Gross motor coordination was evaluated using three subtests of the "KörperkoordinationsTest für Kinder" (KTK) [19, 20]. The fourth test hoping for height was not performed, due to the risk of injuries to the ankles [21]. First, participants had to walk backwards along balance beams of decreasing width (6 cm; 4.5 cm and 3 cm respectively). Secondly, participants had to jumping sideways with a two-legged, performed over a wooden slat (2 x 15 s), summing the number of jumps over the two trials. Thirdly, participants had to move sideways on wooden platforms (2 x 20 s), summing the number of relocations over two trials.

Performance Level

All competition results were sought by the year 2013, 2014 or 2015 in the database at www.judoinside.com, a trusted source for judo results since 2002.

Athletes classified as 'drop out' have not participated in the national/international competition since 2013. Sub-elite athletes were those who won a medal at national championships or international tournaments in National Cadets Championship (NCAD) and National Juniors Championship (NJUN), or International Cadets Tournament (ITCAD) and International Juniors Tournament (ITJUN).

Elite judo athletes outstand the other ones by participating or winning a medal in European or World Cups and Championships in International Judo Federation (IJF), World Tour for Cadets (IJFCAD), International Judo Federation (IJF) World Tour for Juniors (IJFJUN), European Cadet Championships (ECHCAD) or World Cadet Championships (WCAD). The best achievement of that year was registered and based on their best achievement through all three years (2013, 2014 and 2015) the judo athletes were grouped in their corresponding class.

Statistical analyses

All data were analysed using SPPS for Windows version 23.0. The present study had a cross-sectional design involving three study groups: drop out, sub-elite and elite. The basic descriptive indicators (mean and standard deviation) were calculated for all analysed variables. The Kolmogorov Smirnov test revealed that some of the variables were not normally distributed ($p<0.05$). Consequently, the non-parametric Kruskal-Wallis Test was used to compare all test results across the 3 groups. Second, a discriminant analysis was used to investigate for relevant achievements in this sample of young male judo athletes U14. In this analysis, belonging to either of three levels was the grouping variable, and the independent variables were the test results obtained from the five anthropometrical characteristics, seven physical characteristics and three motor coordination tests. Third, a Sequential Canonical Discriminant Analysis was used to examine the test that showed to be significant across the three groups to improve the cross validated the model.

RESULTS

From the initial 22 judo athletes, six were categorised as **elite** athletes or champions based upon their best achievements at European and world level three years after baseline tests. Ten judo athletes participated in international tournaments in 2013-2015 and were called **sub-elite** athletes or medallists. Six of them were considered as **drop out** since they did not participate in the national/international competition since 2013. The elite group performed better than the sub-elites and dropped outs in most of the physical performances test. They seem to perform better in 5m sprint test, 30m sprint test, sit and reach test, sit up test and beep test compared to the other two groups (Table 1).

Some of the generic performance tests were not normally distributed ($p<0.05$) and therefore, non-parametric tests applied for statistical analysis (based on Kolmogorov Smirnov test of normality with Lilliefors correction normally distributed). The distribution of Z-scores for sitting height ($p = 0.021$), weight ($p = 0.025$) and BMI ($p = 0.020$) was significantly different across the groups. No other significant differences found in this analysis (Table 2).

TA discriminant analysis (DA) applied on all tests as predictor variables revealed two significant functions FD1 and FD2 in the sample of trained male judo athletes U14 athletes. Almost all athletes (95.5%) were correctly classified in their respective achievement level (df = 30;

Table 1. Mean and standard deviations from the descriptive analysis for male judo athletes U14 in three different groups.

Variable (indicator)	Evaluated group		
	elite n = 6	sub-elite n =10	drop-out n = 6
Age (year)	13.0 (±0.5)	12.5 (±1.1)	12.7 (±0.9)
Height (cm)*	153.9 (±6.0)	150.0 (±7.2)	156.6 (±11.8)
Sitting height (cm)	82.5 (±5.4)	77.0 (±3.9)	82.9 (±5.4)
Weight (kg)*	47.5 (±5.9)	39.3 (±5.9)	51.1 (±12.2)
Fat percentage (%)	13.5 (±1.9)	12.2 (±2.9)	16.2 (±4.5)
BMI*	20.0 (±1.3)	17.4 (±1.5)	20.6 (±2.9)
Sprint 5m (s)	1.17 (±0.07)	1.28 (±0.1)	1.23 (±0.14)
Sprint 30m (s)	4.98 (±0.2)	5.34 (±0.29)	5.09 (±0.66)
Hand grip (Nm)	30 (±6)	23 (±7)	30 (±16)
Sit and reach (cm)	24.8 (±8.1)	21.5 (±5.5)	21.1 (±3.4)
Counter movement jump (cm)	27.4 (±1.7)	24.6 (±4.3)	27.5 (±6.7)
Sit up (repetitions/30s)	46 (±7)	41 (±6)	41 (±5)
Beep Test	9.7 (±1.5)	8.9 (±1.7)	8.4 (±2.2)
Balance beam (points)	59 (±11)	56 (±8)	54 (±9)
Jumping sideways (points)	97 (±10)	98 (±14)	96 (±12)
Moving sideways (points)	67 (±8)	61 (±10)	59 (±9)

Table 2. Mean and standard deviations from Z-Score for male judo athletes U14 in three different group.

Variable (indicator)	Evaluated group		
	elite n = 6	sub-elite n =10	drop-out n = 6
Height (cm)*	0.13 (±0.71)	−0.34 (±0.84)	0.44 (±1.39)
Sitting height (cm)	0.44 (±1.00)	−0.58 (±0.72)	0.52 (±1.01)
Weight (kg)*	0.29 (±0.64)	−0.59 (±0.63)	0.68 (±1.31)
Fat percentage (%)	−0.04 (±0.55)	−0.41 (±0.82)	0.73 (±1.30)
BMI*	0.42 (±0.57)	−0.67 (±0.62)	0.70 (±1.21)
Sprint 5m (s)	−0.58 (±0.62)	0.37 (±0.92)	−0.03 (±1.27)
Sprint 30m (s)	−0.46 (±0.48)	0.40 (±0.69)	−0.21 (±1.58)
Hand grip (Nm)	0.33 (±0.59)	−0.40 (±0.67)	0.33 (±1.57)
Sit and reach (cm)	0.43 (±1.40)	−0.13 (±0.94)	−0.21 (±0.58)
Counter movement jump (cm)	0.27 (±0.37)	−0.34 (±0.92)	0.30 (±1.45)
Sit up (repetitions/30s)	0.59 (±1.11)	−0.23 (±0.99)	−0.21 (±0.78)
Beep Test	0.40 (±0.84)	−0.06 (±0.94)	−0.31 (±1.26)
Balance beam (points)	0.33 (±1.20)	−0.02 (±0.91)	−0.30 (±1.01)
Jumping sideways (points)	−0.02 (±0.86)	0.06 (±1.18)	−0.09 (±0.97)
Moving sideways (points)	0.55 (±0.83)	−0.10 (±1.09)	−0.37 (±0.91)

*p<0.03

r_{can} = 0.887; Wilks' Λ = 0.08 and p<0421). However, only 36.4% of cross-validated grouped cases were correctly classified. Figure 1 illustrates the differences between the achievement levels for trained male athletes U14 based on canonical discriminant functions calculated from all the predictor variables.

A way to improve the cross-validation of the model is to take into account the significant indicators and therefore a sequential discriminant analysis (SDA) was applied on the three significant tests, i.e. sitting height, body weight and stature. The SDA classified 72.7% of the judo athletes in the correct group when using the achievement level as a grouping variable (df = 6; r_{can} = 0.690; Wilks' Λ = 0.481 and p<0.04). More important is that 59.1% of cross-validated grouped cases correctly classified with this model.

DISCUSSION

This retrospective cross-sectional study investigated to what extent boys U14 in judo could be predicted as future champions or medallists by means of a generic test battery. The main finding was that the test battery, which contained five anthropometric, seven physical performance and three motor coordination tests allocated 95.5% of the participants in the correct group. However, this model showed to be not strong enough to allocate new participants since the cross-validation using the leave-one-out method classified only 36.4% of the participants in the correct group. Therefore, a sequential discriminant analysis was performed with the significant tests, i.e. sitting height, weight and BMI. Discriminant analysis showed 72.7% successful discrimination in their respective achievement level three years later. Based on the descriptive analysis, this study shows that elite- and sub-elite athletes are much lighter than the drop out. Compared to the sub-elites and drop out, the elite athletes seem to show better results in 5m sprint test, 30m sprint test, sit-and-reach test, sit ups and beep test. Besides the physical characteristics, it can be expected that the better athletes outperform the drop out for motor coordination based on the descriptive analysis.

Nevertheless, the discriminant analysis shows no significant difference between those three groups in motor coordination. One might

conclude that motor coordination might not be an important factor in determining who makes it into an elite level in judo and who does not. However, general motor coordination has been proven a valuable indicator of an athlete's potential for progression and as such an important talent characteristic in skill-based sports such as artistic gymnastics [5] and combat sports [22]. Pion and colleagues applied a generic test battery to discriminate three martial arts and found that the physical and the motor performance tests significantly differed for the three sports and that the anthropometrical indicators were not significantly different between judo, karate and taekwondo [13]. In contrast to our findings, Krstulovic and colleagues reported that motor coordination and balance is better developed in elite judo compared to non-elite [8]. Therefore, specific assessment tests would be of importance for success in judo competitions [23].

The main findings of this study are that judo performance, i.e. the rank in judo competitions, of adult men was negatively related to %fat ($r = -0.829$ and $p \leq 0.05$) and positively related to relative Pmax of the upper body ($r = 0.829$ and $p \leq 0.05$). According to Franchini et al. [24], dynamic grip strength endurance seems to be a discriminating variable between judo athletes, probably because judo combat involves many elbow extensions and flexions to avoid the opponent's grip and to subdue them [24]. The differences in the current study with the literature might be explained on the one hand by the fact that our sample size is limited. On the other hand, compared with the scores in the study of Pion et al. [12] on young, different sports athletes, it is remarkable that the scores of the current sample are much better in general. This indicates that this sample might already have been pre-selected and therefore are more homogeneous with respect to motor coordination.

Considering the specificity of judo, it becomes necessary to evaluate performance using specific methods and characteristics from a certain performance level on. The Special Judo Fitness Test (SJFT) training method [25] is one of the most utilised tests in this context; a considerable number of national teams use the test to evaluate the physical capacity relevant to judo [26]. Franchini and colleagues affirm that the SJFT is valid in relation to the physiological demands imposed by the judo fight [24]. Boguszewski et al. [27] analysed indices of struggle dynamics by male and female (seven each) finalists from European Championships in Rotterdam 2005. They concluded that the gold medallists exhibited a markedly higher struggle dynamics in mean effective offensive actions (EA), effective counter attacks (EC) and global index of struggle dynamics (SDI) values than their opponents [27]. Talent identification is a complex phenomenon and requires a new specialisation – **talent scout** (see glossary) – both from judo coaches, as well as researchers science of martial arts.

Strengths and Limitations

The strengths of this study are the use of a combination of anthropometrical, physical performance characteristics and motor coordination tests. This study applied linear predictive models with generic tests for allocating judo champions. The prediction based on generic tests in a three years retrospective study is a new approach to talent identification and talent development in judo. The limitation of the relatively small sample size is inherent to research in trained athletes, who are not numerous by definition. For further research of this type, a bigger sample size is strongly recommended especially given the difference in weight categories. Only those who managed to participate in international competitions, European or World Championships can belong to the elite class of judo in Belgium. During the talent development phase between testing (2009-2011) and achievement years (2013-2015), there could be other factors than just those anthropometrical and physical characteristics or motor coordination influencing the achievement. In this grey zone, a lot can happen to overestimate or underestimate the young judo athletes, for example, the development of athletes can be influenced by illness or injuries.

CONCLUSIONS

Generic talent characteristics (anthropometry) included in the present study allow for a successful discrimination between drop out, sub-elite and elite judo athletes. In addition to the trainer's opinion and the individual screening of judo specific performance characteristics, this generic test battery provides opportunities for predicting judo performance of young athletes.

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EDITORIAL NOTE

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By the way, success in such complex sport as judo is determined by many factors. For this reason, it is appropriate to embed in the broader context of the newest scientific knowledge both the premises for own research and the discussion of the results obtained.

The following recommended references without two papers directly related to the theme of this article published in 2015, 2016 whose first author is Editor-in-Chief of the *Archives of Budo*.

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