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Original empirical article

THE CANONICAL CORRELATION BETWEEN THE BIOLOGICAL MARKERS OF PERFORMANCE AND PHYSICAL FITNESS IN HIGH LEVEL JUDO ATHLETES

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Abstract. *The objective of this research was to verify the relationship between biological markers of performance of elite judo athletes and performance in different physical fitness tests. Twenty-one judo athletes were involved in the present observational and correlational study. Dermatoglyphic variables and the 2D:4D digit ratio were considered as biological markers, while the physical fitness variables analyzed were body fat, maximal strength, muscular power, the aerobic and anaerobic profile, and performance in specific tests. The statistics involved canonical correlations and a multivariate technique. A high and significant canonical correlation was observed between groups of variables, the first expressed by 1=0.999 (p<0.0001) and the second by 2=0.997 (p<0.001). It appears that, beyond height and body mass, total ridge count, pattern intensity for fingers and 2D:4D had more canonical loading. The physical fitness component of the first canonical variable incorporated, with high intensity were: the sum of skinfold thickness, the bench press one-repetition maximum (1RM), upper and lower body aerobic power. In the second canonical variable, physical fitness was composed of the squat 1RM, suspension time on the bar, the SJFT-index, and mean power during the upper body Wingate test. The data of this investigation showed the interdependence between biological markers of performance and physical fitness in high level judo athletes.*

Key words: *biological markers, dermatoglyphics, 2d:4d ratio, physical fitness.*

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INTRODUCTION

Among the various immutable and highly genetic-determined somatoscopic biological markers of performance that can be used in sport, dermatoglyphics stands out (Ziwan, 1991, Abramova et al., 1996, Del Vecchio & Gonçalves, 2011) and the second to fourth digit ratio, 2D:4D (Manning, 2002). In relation to dermatoglyphics, the following variables are considered relevant: total ridge count (Del Vecchio & Gonçalves, 2011), the pattern intensity for fingers (Abramova et al., 1996), the atd angle, measured by the union of these three palmar triradii, (Liang & Li, 1996, Xiao-Ping, 2005), ulnarity and combined indexes (Borin & Gonçalves, 2004), which have different distributions among elite athletes (Serhiyenko & Lishevskaya, 2010). In relation to the 2D:4D, lower values were associated with better performance in different sports and motor tasks (Anders & Hampson, 2005, Fink et al., 2006, Manning, Morris & Caswell, 2007).

However, most studies adopted descriptive procedures (Oleynik, 2009a) and bivariate associations (Nassau et al., 2006). To increase the use of multivariate analyses in sports science, considering biological markers of performance as the target, studies have applied this method to the study of elite athletes (Verma & Saxena, 1989, Karmakar, Yakovenko & Kobyliansky, 2003, Chen, 2003).

In order to expand the body of knowledge about the relationship between different variables, the canonical correlation could be adopted. This procedure allows us to investigate the association between two sets of variables (Ayres et al., 2005), and was used in other opportunities, with non-athletes (Pasetti, 2007) and fencer elite athletes (Sterkowicz-Przybycień, 2009).

Considering that judo performance is multifactorial, the objective of this research was to verify the relationship between biological markers of performance of elite judo athletes and the performance in different physical fitness tests.

MATERIALS AND METHODS

Study type and casuistic analysis

This is an observational, transversal, and correlational study. The casuistic was composed by 21 judo athletes (12 men and 9 women) members of the Brazilian team selected to participate in the XXVIII Olympic Games, in Athens 2004. The athletes were 24±4 years-old, men and women who practiced judo for 18±3 years and 15±5 years, respectively. In reference to ancestrality, more than 90% have Brazilians parents and grandparents, complemented with a Korean and Japanese minority.

Study Design

The study was approved by the Ethics Committee on Human Research at the University of Campinas (process # 250/2007). The performance tests and body composition evaluations were performed in circuit format. Physical assessments were interspersed with anthropometric ones, during three days, with previously trained evaluators, performing the same procedures, to ensure internal consistency. In reference to the biological markers of performance, dermatoglyphics and 2D:4D measurements were conducted by one researcher in accordance with the competitive calendar and in state and national level competitions.

Procedures of data collection and recording

Measures of biological markers of performance

Body mass was measured in kilograms to the nearest 0.1 kg and height in centimeters to the nearest 0.1 cm, with the participant standing on both feet, without shoes, on a stadiometer.

With respect to the dermatoglyphic variables, the procedures were standardized internationally (Penrose, 1968) and were collected with a dark pigment applied to the palms, following which it was transferred to white paper (Gonçalves & Gonçalves, 1984). The collections were made as many times as needed for the correct visualization of epidermal ridges and triradii. The following variables were quantified: total ridge count (TRC), i.e., the sum of digital pad ridges from right and left hands (Saldanha, 1968), pattern intensity for fingers, determined considering the number of triradii in each pad (PIF, Loesch, 1983), ab and A'd counts, respectively identified by the number of lines between palmar triradius a and b and between the point created by the intersection of the triradius d and line A, made with a compass, atd angle, measured by the intersection of triradius a, t (at the end of the palm) and d, beyond the ulnar and combined index, which are secondary measures from the triradius a, d and t (Moscati, 1975).

The 2D:4D was obtained by measuring the segments between the flexion crease and proximal end of the second (index) and fourth (ring) fingers of both hands, with a digital caliper accurate to 0.1 mm with full extension of all the fingers (Manning et al., 2005).

Physical fitness variables

The following variables were measured: i) six skinfold thickness (Σ6SF: triceps, subscapular, abdominal, suprailiac, front thigh and medial calf) were measured at least three times per site with a Harpenden caliper and summarized (Drinkwater & Ross, 1980), ii) one-repetition maximum (1RM) for the bench press and the 90° Smith Machine squat (Brown & Weir, 2003), iii) the countermovement jump in the *Jump Test* equipment (in cm, HidroFit™, Belo Horizonte, Brazil), iv) suspension time from a fixed bar (Franchini et al., 2011a), v) upper and lower body aerobic power, in Watts (Horswill et al., 1992, Hübner-Wozniak et al., 2004) and maximal oxygen uptake estimated by means of the ACSM equation (in $ml \cdot kg^{-1} \cdot min^{-1}$) based on the lower body test, vi) anaerobic capacity, from relative mean power in the upper body Wingate test, with a load of 0.05 $kg \cdot kg^{-1}$ of the body mass (Franchini, Takito & Bertuzzi, 2005), and vii) the Special Judo Fitness Test (SJFT) index, calculated based on the following equation: (heart rate after test + heart rate 1 min after test) / total throws (Franchini, Del Vecchio & Sterkowicz, 2009).

Data analysis

The statistical study of the relationship between sets of biological markers of performance and physical fitness was performed using the multivariate technique of canonical correlations (Johnson & Wichern, 2002). The tests were conducted using SAS v.8.

RESULTS

The values of the canonical correlations and respective coefficients between the two groups of variables: i) body mass, height and digit-palmar markers, and ii) the physical

fitness variables are shown in Table 1. In table 1 shows that the first, $\hat{\rho}_1$=0.999, and the second canonical correlation, $\hat{\rho}_2$=0.997, had a high significance (p<0.001).

Table 1 Coefficients of the canonical functions for the biological markers of performance and physical fitness and their combinations (canonical loading)

Variables	First Canonical Variable	Second Canonical Variable
Biological markers of performance		
Height	0.499 (0.767)	0.310 (0.421)
TRC	-0.156 (0.725)	-0.151 (0.358)
Body mass	-0.439 (-0.507)	0.759 (0.667)
PIF*	0.346 (0.215)	0.108 (0.235)
2D:4D#	0.262 (0.146)	0.141 (0.147)
a-b count*	-0.135 (-0.117)	0.356 (0.138)
A'd count *	0.346 (0.094)	-0.059 (0.145)
atd angle*	0.271 (0.042)	-0.133 (0.056)
Ulnarity index*	-0.050 (-0.008)	-0.081 (-0.024)
Combined index*	-0.006 (-0.043)	0.265 (0.135)
Physical fitness		
Σ6 Skinfold thickness	-0.598 (-0.641)	-0.026 (-0.203)
1RM Bench press	0.105 (-0.580)	-0.223 (-0.180)
Upper limb aerobic power	-0.061 (0.575)	0.253 (-0.361)
Lower limb aerobic power	0.059 (-0.448)	0.342 (-0.378)
Vertical jump height	-0.522 (-0.441)	-0.254 (-0.235)
VO_2max	0.256 (-0.375)	-0.372 (-0.227)
SJFT-index	0.392 (-0.185)	0.046 (-0.708)
Average power in Wingate test	0.081 (0.130)	-0.149 (-0.504)
1RM in squat	0.272 (-0.123)	0.729 (0.887)
Time of suspension	-0.229 (-0.094)	0.099 (-0.783)
Canonical correlation (p-Value)	0.999 (p<0.0001)	0.997 (p<0.001)

* and # - Referring to the sum and average values from right and left hands, respectively.
TRC - total ridge count of digital pads, PIF - pattern intensity of fingers,
2D:4D - second to fourth digit ratio, 1RM - 1 maximal repetition, SJFT - Special Judo Fitness Test.

It was found that in the first canonical variable (BIOLOGICAL1), height, TRC body mass, PIF and 2D:4D had a great canonical load. The biological variables component for the first canonical correlation is synthesized by the following equation 1:

$$\begin{aligned} \text{BIOLOGICAL1} = {} & 0.499 \cdot \text{height} - 0.156 \cdot \text{TRC} - 0.439 \cdot \text{body mass} + 0.346 \cdot \text{PIF} + \\ & 0{,}262 \cdot \text{2D:4D} - 0.135 \cdot \text{ab count} + 0.346 \cdot \text{A'd count} + 0.271 \cdot \text{atd angle} \\ & - 0.05 \cdot \text{IU} - 0.006 \cdot \text{IC} \end{aligned}$$

In the second canonical correlation (BIOLOGICAL2), the biological component composition had a greater contribution of body mass, height, TRC and PIF. The corresponding linear function is expressed by:

BIOLOGICAL2 = 0.31·height – 0.151·TRC + 0.759·body mass + 0.108·PIF + 0.141·2D:4D + 0.356· ab count – 0.059·A'd count – 0.133·atd angle – 0.081·IU – 0.265·IC

The physical fitness component (FITNESS1) of the first canonical variable incorporated, mainly, the skinfold thicknesses sum, bench press 1RM, upper and lower body aerobic power. FITNESS1 is expressed by:

FITNESS1 = – 0.598·Σ6SF + 0.105·1RM bench press – 0.061·upper limb aerobic power + 0.059·lower limb aerobic power – 0.522·vertical jump height + 0.256·VO_{2max} + 0.392·SJFT-index + 0.081·average power in Wingate test + 0.272·1RM squat – 0.229·time of suspension

Regarding the second canonical variable, physical fitness was determined by the squat performance, suspension time on the bar, the SJFT-index (-0.708), mean power in the upper body Wingate test, lower and upper body aerobic power, denoted in this linear function:

FITNESS2 = – 0.026·Σ6SF – 0.223·1RM bench press + 0.253·upper limb aerobic power + 0.342·lower limb aerobic power – 0.254· vertical jump height – 0.372·VO_{2max} + 0.046· SJFT-index – 0.1495·average power in Wingate test + 0.729·1RM squat + 0.099·time of suspension

In general, it was observed that, for the biological markers of performance, the TRC appeared in two canonical variables, such as height and body mass. Thus, the PIF and 2D:4D were important. In physical fitness, the two following canonical pairs were common: upper and lower body aerobic power and the SJFT-index. Only to the first, add: the sum of skinfold thicknesses, bench press 1RM, vertical jump height, maximal oxygen uptake and squat 1RM, and, to the second: time of suspension on the bar and mean power in the upper body Wingate test.

DISCUSSION

Several previous studies performed measurements of the biological and/or motor profile of judo athletes (Franchini et al., 2011b, Miarka, Del Vecchio & Franchini, 2011), including dermatoglyphics (Mello & Fernandes Filho, 2005, Oleynik, 2009a) and 2D:4D (Oleynik, 2009b), but none of them had considered both sets of information.

The multivariate technique, that has allowed a better understanding of competitive success (Bratić, 1998) and a more efficient process for throwing techniques taught in different combat sports (Krstulovic, Sekulic & Sertic, 2005), shows, in the present study, that biological markers of performance were significantly correlated with the general and specific physical fitness of high level judo athletes. Beyond height and body mass, which are relevant for judo competition (Lech, Sterkowicz & Rukasz, 2007, Artioli et al., 2010), TRC, pattern intensity of fingers and 2D:4D were also important. One limitation of this study was the small size of the sample of the judo athletes involved, that can partly be explained by this high competitive level. Considering the dermatoglyphical variables, although an analysis including men and women together can be complicated, a division based on gender in this case was not possible. On the other hand, is observed that the

2D:4D values from high level female wrestling athletes were similar to those of men, which could minimize this limitation (Oleynik, 2009b).

Athlete's TRC tends to be lower than the normal data among men (Borin & Gonçalves, 2004) and high-level female judo athletes (Mello & Fernandes Filho, 2005) exhibited significantly lower values compared to the reference values (TRC=109±34 and 126±49, respectively, p=0.03) (Penhalber et al., 1994). The pattern of the intensity of the fingers is inversely associated with body fat (Nikitjuk, 1988), and the best competitors of combat and team sports and Olympic weightlifting exhibited high values (Abramova et al., 1996, Oleynik, 2009b). The 2D:4D shows a significant negative correlation with an endurance profile (Manning, Morris & Caswell, 2007), isometric handgrip (Fink et al., 2006) and is positively associated with the ability to perform anaerobic efforts (Manning & Hill, 2009). In sports, small 2D:4D is linked to better skills (Paul et al., 2006, Moffit & Swanik, 2011) and improved competitive performance (Manning, 2002; Bennett et al., 2010; Del Vecchio et al., 2010; Voracek, Reimer & Dressler, 2010).

In judo, low body fat percentage is a prerequisite for success as athletes are divided into weight categories (Artioli et al., 2010). Additionally, they have moderate to high aerobic power, which contributes to a high-intensity intermittent performance, and in the recovery process between the matches (Franchini et al., 2011b). High level judo athletes and wrestlers normally show a high anaerobic capacity (Hübner-Wozniak et al., 2004; Franchini et al., 2011b), which is positively correlated with the number of attacks performed during a match (Franchini, Takito & Bertuzzi, 2005). Maximal strength (bench press and squat 1RM), muscle power (vertical jump height) and isometric endurance-strength (time of suspension from a fixed bar) are essential features of elite judo athletes (Franchini et al., 2011a). The first is related to the ability to block high loads, like when the opponent is trying a certain throw or immobilization (Amtmann & Cotton, 2005). Assuming that all throwing techniques last about 1.4 s (Blais, Trilles & Lacouture, 2007), this means that a judoka needs to develop considerable force in a short time (the rate of force development) to throw his opponent on the ground without reaction. As 50% of the judo match is composed of grip disputes (Marcon et al., 2010, Calmet, Miarka & Franchini, 2010), and the physical component of the judo grip can discriminate judo players at different levels (Franchini et al., 2011b), grip strength endurance is relevant for judo success. Additionally, the SJFT index synthesizes the aerobic and anaerobic fitness and properly discriminates elite and non-elite judo athletes (Franchini, Del Vecchio & Sterkowicz, 2009).

It is known that dermatoglyphics can be used in the process of the detection of sport talents (Serhiyenko & Lishevskaya, 2010), and the results of the present study confirm this, as this variable was associated with a group of physical fitness variables relevant to the competitive performance in judo.

CONCLUSION

The data of this investigation showed the interdependence between biological markers of performance and physical fitness in high level judo athletes, with an elevated contribution of total ridge count, pattern intensity of fingers and 2D:4D. Regarding physical fitness, much of its composition is derived from the low values for skinfold thickness, high load for the bench press and squat, prolonged suspension, high mean power in the upper body Wingate test and a low SJFT index.

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KANONIČKA KORELACIJA IZMEĐU BIOLOŠKIH MARKERA PERFORMANSE I FIZIČKE PRIPREMLJENOSTI KOD ELITNIH DŽUDISTA

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Cilj ovog istraživanja bio je da se potvrdi odnos između bioloških markera performanse eltinih džudista i njihovih rezultata na različitim testovima za određivanje nivoa fizičke pripremljenosti. Ukupno je 21 džudista učestvovao u istraživanju. Dermatoglifijske varijable i odnos 2D:4D smatrani su biološkim markerima, dok su varijable za fizičku pripremljenost koje su analizirane bile telesna masnoća, maksimalna snaga, mišićna snaga, aerobički i anaeorobički profil, i rezultati postignuti na pojedinim testovima. Statistička obrada podataka obuhvatala je kanoničke korelacije i multivarijantnu tehniku. Visoka i značajna kanonička korelacija utvrđena je između grupa varijabli. Prva je izražena kroz 1=0.999 (p<0.0001) a druga kroz 2=0.997 (p<0.001). Čini se da su, pored visine i telesne mase, sveukupni broj brazdi, intenziteta otiska prsta i odnos 2D:4D imali veći kanonički uticaj. Komponenta fizičke pripremljenosti prve kanoničke varijable je obuhvatala, sa visokim intenzitetom: ukupnu sumu debljine nabora kože, duboki pretklon na klupici sa (1RM), aerobičku snagu gornjeg i donjeg dela tela. U drugoj kanoničkoj varijabli, fizička pripremljenost se sastoji od čučnja 1RM, vreme visa u zgibu, SJFT-indeks, i srednje vrednosti snage tokom Wingate testa za gornji deo tela. Podaci prikupljeni tokom ovog istraživanja pokazali su međusobnu vezu između bioloških markera performanse i fizičke pripremljenosti kod elitnih džudoista.

Ključne reči: *biološki markeri, dermatoglifija, odnos 2d:4d, fizička pripremljenost.*