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GENOTYPIC AND ENVIRONMENTAL INFLUENCE ON THE PHYSICAL QUALITIES OBSERVED BY THE METHOD OF TWINS IN MALES

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ABSTRACT

Introduction: The purpose of this study was to assess the genetic and environmental influence on the physical qualities of the static strength of hand prehension (FE), speed of reaction (SR), static balance (SB), agility (AG), motor coordination (MC), speed of displacement (SD), power of lower limbs (PIL) and aerobic endurance (VO_{2max}). **Materials and Methods**: We calculated quantitative indices of heritability (h^2) by intra-pair differences in monozygotic and dizygotics twins. The sample was composed of eight pairs of male twins (five monozygotic pairs and three dizygotic pairs). **Results**: The index of heritability followed the order: SB and FE over 0.90; VO_{2max}, SD and PIL between 0.76 and 0.87; MC equal to 0.45; AG and SR below 0.15. The genotypic influence was significant only in relation to FE (h^2=0.96) and the SB (h^2=0.97). The indices of heritability showed that there was a greater genotypic influence on the SB, FE, VO_{2max}, SD and PIL, and greater environmental influence in MC, AG and SR. This is observed by the values of h^2 that, if are above 0.50 show greater genetic influence, or if below 0.50 show greater environmental influence. **Discussion**: We found correlations between FE, SB, SD and PIL, which were qualities with high heritability, and between AG and SR, which had the lowest values of heritability.

KEYWORDS

Genetics, Genotype, Heredity.

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Influência genotípica e do ambiente sobre as qualidades físicas observadas pelo método de gêmeos em indivíduos do sexo masculino

RESUMO

Introdução: O objetivo da presente estudo foi verificar a influência genotípica e do ambiente sobre as qualidades físicas de força estática de preensão de mão (FE), velocidade de reação (VR), equilíbrio estático (EQ), agilidade (AG), coordenação motora (CM), velocidade de deslocamento (VD), potência de membros inferiores (PMI) e resistência aeróbica ($VO_{2máx}$). **Materiais e Métodos**: Foram calculados índices de herdabilidade quantitativos (h^2) por meio das diferenças intra-par encontradas em gêmeos monozigóticos e dizigóticos. A amostra estudada foi constituída por oito pares de gêmeos do sexo masculino (sendo cinco pares monozigóticos e três pares dizigóticos). **Resultados**: Os índices de herdabilidade seguiram a seguinte ordem: EQ e FE acima de 0,90; $VO_{2máx}$, VD e PMI entre 0,76 e 0,87; CM igual a 0,45; e AG e VR abaixo de 0,15. A influência genotípica foi significativa apenas em relação à FE (h^2=0,96) e ao EQ (h^2=0,97). Os índices de herdabilidade indicaram que houve uma maior influência genotípica no EQ, FE, $VO_{2máx}$, VD e PMI, e uma maior influência ambiental na CM, AG e VR. Isto é observado pelos valores de h^2 que, se forem acima de 0,50, demonstram maior influência genotípica, e, abaixo de 0,50, demonstram maior influência ambiental. **Discussão**: Foram encontradas correlações entre a FE, EQ, VD e PMI, que foram qualidades com elevada herdabilidade, e entre AG e a VR, que apresentaram os valores mais baixos de herdabilidade.

PALAVRAS-CHAVE

Genética, Genótipo, Hereditariedade.

Influencia genotípica y del ambiente sobre las cualidades físicas observadas por el método de gemelos en individuos del sexo masculino

RESUMEN

Introducción: El objetivo del presente estudio fue evaluar la influencia de la genética y el medio ambiente sobre las cualidades físicas de la resistencia de la mano prensión (FE), la rapidez de reacción (VR), equilibrio estático (EQ), agilidad (AG), la coordinación motora (CM), la velocidad de desplazamiento (VD), el poder de las extremidades inferiores (PMI) y de resistencia aeróbica ($VO_{2máx}$). **Materiales y Métodos**: Se calcularon los índices cuantitativos de heredabilidad (h^2) por medio de las diferencias intra-par en gemelos monocigóticos y dizigóticos. La muestra se compone de ocho pares de gemelos de sexo masculino (cinco pares monocigóticos y tres pares dizigóticos). **Resultados**: El índice de heredabilidad seguido el orden: EQ y FE más de 0,90; $VO_{2máx}$, VD y PMI entre 0,76 y 0,87; CM igual a 0,45; AG y VR por debajo de 0,15. El efecto genotípica fue significativa sólo en relación con FE (h^2=0,96) y EQ (h^2=0,97). Los índices de heredabilidad mostraron que hubo una mayor influencia genotípica en EQ, FE, $VO_{2máx}$, VD y PMI, y una mayor influencia del medio ambiente em CM, AG y VR. Esto se observa en los valores de h^2 que, están por encima de 0,50 indican una mayor influencia genética y, por debajo de 0.50, muestran una mayor influencia ambiental. **Discusión**: Se encontraron correlaciones entre FE, EQ, VD y PMI, que son cualidades con alta heredabilidad, y entre AG y VR, con los valores más bajos de heredabilidad.

PALABRAS CLAVE

Genética, Genótipo, Herencia.

INTRODUCTION

Recently, a bigger attention is being given to the genetic approach in relation to the sportive predispositions and to health. It is known that genetic information constitutes the base of the transmitted inheritance from parents to their children (the genetic factor or character) and that it determines, in a considerable degree, the growth, the organism formation, its adaptatives reactions to exterior influences, the development rhythms and the various ontogenic phases[1].

The study of pairs of twins has been traditionally employee, in different research areas of Human Genetics, with the purpose to inquire the relative influence of the genotype and the environment on the normal or pathological phenotypic variation[2].

The use of pairs of twins in studies to evaluate the relative value of the genotype in the determination of phenotype is based, basically, in the fact that the genotypic similarity of the dizygotic pairs is, on average, the one presented by pairs of brothers successively generated because, as these last ones derived from the syngamy of distinct pairs of gametes, produced by the same genitors[2]. They possess, on average, 50% of the similar genes. The monozygotic pairs, for being derived from a single

zygote, are genetically identical, that is, they possess the same genotype[2].

Particularly, in the studies of the interactions of the genetic influence on the *performance* and human physical form, is extremely important to emphasize that the effect of the genes will not always occur in a similar way and in the same magnitude in the two sexes and different age intervals. For example, in the evaluation of the associated physical aptitude to the health, the genetic effects vary from moderate to substantial ones, in the explanation of the inter-individual differences. Translating, there is a strong variability of reply of young and adults to the stimulations from the physical education classes, sportive trainings and of community intervention programs[3].

The study of Maia *et al.*[3] investigated the genetic and ambient components involved in moderate physical activities (such as walking or going up stairs) and intense (such as running, cycling and swimming, for example). Much of the phenotypic variability, for both moderate and intense activities, is the result of the effects from family aggregation. The genes can influence the regular participation in specific intense exercises more than a moderate activity as, for example, the exercise of walking.

This way, there is an increasing number of scientific works that has been evaluating, in quantitative way, the genetic influence on the levels of physical activity and human *performance*, such as studies with family cores[4,5,6] and studies with twins[7,8,9].

However, according to Heck *et al.*[10], even though the studies based on families have provided sustentation to the function of genes in human *performance*, the identification and detection of the genes and of the interactions gene-environment that influence, this *performance* is difficult due to factors such as: the training reply, that is highly heterogeneous and can be influenced by many components, in addition to the genetic factors; the expression of the genetic variation influencing the *performance* can be dependent of the context (the genetic predisposition for muscular hypertrophy can be evident only after a specific type of resistance training); and genes and environments, that can act independently or combined to influence the training results.

This way, the objective of this study was to verify the genotypic and environmental influence on the basic physical qualities through the method of twins, calculating the quantitative indexes of heritability (h^2) using measures carried through in monozygotic and dizygotic twins.

MATERIALS AND METHODS

The study characterized itself for being transversal, descriptive, of the comparative type (used for the comparison of differences between means when the cause of the differences is isolated and known) and correlational[9]. To meet the established objectives, the sample was constituted of eight pairs of twins (five monozygotic pairs and three dizygotic pairs), in the age group of 11 to 27 years-old, males. The present work met the Norms for the Accomplishment of Research in Human Beings, Resolution 196/96, of the National Advice of Health of 10/10/1996 [12], having been approved by the Ethics Committee from the Castelo Branco University - UCB.

The collection was held in the following sequence:

1. Anamnesis
2. Realization of the battery of tests of the physical qualities:
   1. Static strength of hand prehension (FE), test of manual dynamometry (Grip) - Johnson and Nelson (1979)[13];
   2. Speed of reaction (SR), also called test of time of reaction (TTR)[14];
   3. Static balance (SB), flamingo test[13];
   4. Agility (AG), Shuttle Run test[14];
   5. Motor coordination (MC), Burpee test[13];
   6. Speed of displacement (SD), 30m running test1[3];
   7. Power of inferior limbs (PIL), Sargent Jump Test - slew, indirectly measures the muscular force of the inferior limbs[15];
   8. Aerobic resistance (VO_{2max}), 1000m test for the evaluated with age between eight and 13 years-old15 and the 2400m test for the evaluated ones with age between 13 and 60 years-old[15].

Descriptive statistics

The presented descriptive analysis is composed by a set of measures that have for objective to define the profile of the studied group, obtaining representative values of the obtained data, through the measures of central trend (mean and median), characterizing the variation of these data through measure of dispersion (standard deviation).

Estimate of heritability of quantitative data

The most used process to get estimates of heritability (h^2) consists of the comparison of differences of a character data, observed in monozygotic (MZ) and dizygotic (DZ) twins[16]. To characters of quantitative variation, the differences between pairs of MZ twins and pairs of DZ twins are taken, using the following formula[17]:

$$h^2 = (S^2_{DZ} - S^2_{MZ})/S^2_{DZ}$$

where S^2 represents the variance of each series of differences.

When $h^2=1$, the variance of the character is attributable exclusively to genetic causes, since MZ twins are concordant: $S^2=0$, and the character presents in each pair a constant expression. When $h^2=0$, the variation is entirely explained by the environmental effects. In both cases, we estimate that measure errors are random and tend, therefore, to nullify themselves.

Inferencial statistics

Any way the formula is applied to the estimate of heritability of quantitative variables, the demonstration from which it differs significantly from zero will be made by means of an *F*, obtained by the division of the variance inside the dizygotic pairs through the variance inside the monozygotic pairs[2]. This way, to compare between the variances of pairs of monozygotic and dizygotic twins, the *F* distribution was used, as it has been applied in earlier studies[18,19,20], using the table of critical values for this distribution presented by Triola[21], to evaluate the level of significance of each test.

RESULTS

In Table 1 the means, medians, and the standard deviations of age, stature, corporal mass and body mass index of the evaluated ones, to characterize the sample. It was observed a low difference between the age averages of the monozygotic and dizygotic pairs (with a value 15.5% greater in the monozygotic group), as well as in relation to the median ones (with a value 13.3% greater in the dizygotic group).

In response to the applied questionnaire to obtain anamnesis, it was characterized that, in general way, there are no intra-pair differences when it comes to the creation and practice of physical activities that can be considered as limitation for the application of the method of twins. The integrants of each pair of twins were raised together, probably suffering environmental influences in common.

In relation to the practice of physical activity, it was observed that, in the monozygotic group, 80% of the pairs practice regular physical activity and, in the dizygotic group, 67% of the pairs practice regular physical activity. This indicates that also exists differences in frequency of the practice of physical activity between the twins' types.

None of the interviewed ones declared being professional or amateur athlete. However, 33% of the dizygotic pairs indicated that they had already been amateur athletes; however, they only participated in local competitions (pertaining to school and between city counties). All the interviewed individuals indicated that they did not take part in different regular physical activities than its brother.

These informations served, then, as base for the evaluation of the applicability of the method of twins to the present study.

According to Beiguelman[2], the investigation of the method of twins demands the acceptance of various premises, such as:

1. The twins are a sample of the general population;
2. The twins are a sample of all the twins;
3. The components of each pair of twins are subject to the same influences of the environment;
4. The twins' environment is, on average, equal to the one of the elements of the general population;
5. The variables that act on the monozygotic twins, provoking intra-pair phenotypical differences, are the same ones that act on the dizygotic twins.

There are possible limitations for the use of these premises, as cited by Beiguelman2. For example, the differences in the intrauterine development and the diversifications of the twins' environment (that grows with the age) can affect the intra-pair variability of the monozygotic twins, while a more similar treatment, given more to the monozygotic twins than to the dizygotic ones (observed mainly in infancy), can contribute for a bigger similarity between the monozygotic twins than between the dizygotic twins. This way, the limitations for the method of twins application can be reduced if the pointed factors of distortion (that go against the indicated premises) are counterbalanced by others.

In this context, although the showed groups present heterogeneity in relation to the place of residence and the age of the individuals, to this group could be applied the method of twins, as it will be argued to follow.

The results obtained to the measures of static strength of hand prehension, power of inferior limbs, speed of displacement, speed of reaction, static balance, coordination, agility and VO_{2max} of the monozygotic groups and dizygotic members are presented in Table 2, while the indexes of

Table 1 – Mean, median and standard deviation (sd) of age, stature, body mass (BM) and body mass index (BMI)

	monozygotic			dizygotic		
	mean	median	sd	mean	median	sd
age (years)	17.4	13.0	6.3	14.7	15.0	3.1
stature (cm)	160.8	160.3	10.2	161.5	162.8	16.1
BM (kg)	47.7	42.5	10.3	48.1	47.5	13.8
BMI ($kg.m^{-2}$)	18.2	17.8	1.80	18.0	18.1	1.80

quantitative heritabilities (h^2), are demonstrated in Table 3. It is distinguished that a similarity occurred between the measures of the observed physical qualities in the monozygotic and dizygotic groups.

There was a variation between the heritability indexes of h^2 from 0.01 to 0.97, that followed the following order: balance and force above 0.90; VO_{2max}, speed of displacement and power of inferior limbs between 0.76 and 0.87; motor coordination, 0.45; and agility and speed of reaction below 0.15. The balance presented the biggest index of heritability and the reaction speed presented the lesser index.

The results from the comparisons of the variances of the data from the physical qualities demonstrated that only for the strength variable of hand hold and balance were found statistically significant differences between the monozygotic and dizygotic twins ($p<0.05$).

In accordance with studies compiled by Frederiksen & Christensen[22], the heritability of the strength of hand hold varied from 22% to 65%, while the heritability of the VO_{2max} varied from 20% to 66%. The results demonstrated in Table 3, in relation to the strength of hand hold and the VO_{2max}, were bigger than the ones reported by Frederiksen & Christensen[22].

DISCUSSION

Tiainen *et al.*[9] indicated that studies of genetic effects in elderly points out a variation of the genetic influence from 22% to 52% in relation to the strength of hand hold. Arden & Spector[8] found an index of heritability of strength of hand hold of 0.30 in elderly twins. This result corroborates the results demonstrated in the study of Tiainen *et al.*[9]. However, when analyzing the index of heritability in younger people, the value found can be higher than the presented by those authors, as, for example, in the present study an index of heritability for the strength of hand hold of $h2=0.96$ was found. That is an indicative of that, the bigger the age, greater can be the environmental influence in relation to the strength of hand hold.

Studies reported by Malina & Bouchard[23], showed the intra-pair correlations to the VO_{2max} of mozygotic and dizygotic twins, that made possible to calculate the heritability index (h^2), using the equation presented by Holzinger[17]. This calculation indicated an $h^2=0.39$ index, that was inferior to the one found in this study. However, the result of this study was inferior to the value of 0.94 presented by Venerando & Milani-Comparetti[16]. Klissouras[16] pointed out that the heritability estimates of the VO_{2max} are generally high. This is confirmed by the values revised by Rupert[24].

Table 2 - Mean, median, standard deviation (sd) of the static strength of hand prehension (SS), agility (AG), speed of reaction (SR), static balance (SB), speed of displacement (SD), power of inferior limbs (PIL), motor coordination (MC), and aerobic resistance (VO_{2max})

	monozygotic			dizygotic		
	mean	median	sd	mean	median	sd
SS (kgf)	69.7	52.8	30.5	65.1	60.5	31.0
AG (s)	11.7	11.8	1.15	12.8	11.9	1.88
SR (s)	0.73	0.72	0.10	0.91	0.80	0.22
SB (tries in 1 min)	5.6	5.00	3.89	5.50	5.50	4.59
SD (0.1s)	5.98	6.01	0.64	6.08	6.07	0.71
PIL ($kgm.s^{-1}$)	649.3	567.8	212.5	642.0	599.4	268.7
MC (number of executed parts in 10s)	15.5	15.0	1.84	18.2	19.0	3.60
VO_{2max}	38.8	39.4	3.04	35.7	36.7	4.32

Table 3 - Variance of each series of differences between pairs of monozygotic twins (S^2_{MZ}) and between pairs of dizygotic twins (S^2_{DZ}), *F* Test and quantitative heritability indexes (h^2) of the static strength of hand prehension (SS), agility (AG), speed of reaction (SR), static balance (SB), speed of displacement (SD), power of inferior limbs (PIL), motor coordination (MC) and aerobic resistance (VO_{2max})

	S^2_{MZ}	S^2_{DZ}	F	h^2
FE	5.10	119.7	23.5*	0.96
AG	0.10	0.11	1.13	0.12
SR	0.004	0.004	1.01	0.01
SB	1.00	28.8	28.8*	0.97
SD	0.02	0.10	4.14	0.76
PIL	2240.7	13721.1	6.12	0.84
MC	2.30	4.17	1.81	0.45
VO_{2max}	2.06	15.6	7.57	0.87

**statistically significant difference ($p\leq0.05$)*

Table 4 - Coefficients of correlation between static strength of hand hold (SS), agility (AG), speed of reaction (SR), static balance (SB), speed of displacement (SD), power of inferior limbs (PIL), motor coordination (MC) and aerobic resistance (VO_{2max})

	FE	AG	SR	SB	SD	PIL	MC
AG	-0.43						
SR	-0.38	0.90*					
SB	-0.59*	0.32	0.32				
SD	-0.81*	0.47	0.39	0.59*			
PIL	0.96*	-0.41	-0.35	-0.53*	-0.83*		
MC	0.28	-0.48	-0.42	-0.26	-0.26	0.33	
VO_{2max}	0.48	-0.29	-0.39	-0.30	-0.44	0.40	0.08

**statistically significant difference ($p \leq 0.05$)*

According to studies cited by Bouchard *et al.*[6], the maximum aerobic strength is characterized by limited trainability in children with less than 10 years-old, but the VO_{2max} is clearly a trainable phenotype, on average, in older children, adolescents and adults from both sexes. The present study found an index of heritability for the VO_{2max} ($h^2=0.87$) bigger than the presented in the study of Bouchard *et al.*[6] (0.47). This way, it becomes important to identify the level of genotypic and environmental influence on the VO_{2max}, so that a better training can be planned.

The estimates of heritability are generally low and non-consistent when the analysis happens on traces such as dexterity, balance and coordination[16]. The results obtained in the present study corroborate this, in relation to agility and coordination; however the balance presented a high heritability, disagreeing with this trend.

A bigger heritability for the increase of the isokinetic strength in adolescents, compared to female preadolescents, can be explained by differences in the maturation of the neuromuscular activation metabolism[25]. The present study was carried through without separating the sample by maturation level, representing a heterogeneous sample in relation to the metabolism of the neuromuscular activation, that it may have caused a bigger variation in relation to the mean.

In Table 4 correlations between the variables analyzed are presented. Two groups of variables presented significant correlations. One of these groups was formed by strength, balance, speed of displacement and power of inferior limbs that were qualities with high heritability index ($h^2 \geq 0.76$). It can be pointed out that there were positive and negative correlations between these variables that always meant that a good performance in a variable was correlated to a good performance in the other variable.

The other group of variables that correlated was formed by agility and speed of reaction. It was presented a positive and significant correlation between these two physical qualities that presented the lowest values of heritability indexes. The coordination and the VO_{2max} did not present any correlation with the analyzed variables.

Probably, the main limitations of the present study were: a low number of showed individuals; the age differences of the individuals inside of each group of twins; and possible environmental differences between the places of origin of the individuals, that may cause some variability between the pairs of twins. The anamnesis indicated that other factors that could be limitations (such as intra-pair differences when it comes to the creation and the practice of physical activities), were probably not so important.

Among the reached objectives and the limitations found for the accomplishment of this study, the results can contribute for the advance of the scientific knowledge in the identification of the genotypic and environmental influence, so that it can, in the future, accomplish and develop more specific and adequate works to an individual or group of individuals.

From the observations made throughout this study, the following recommendations for the continuity of this research line can be made:

1. The accomplishment of studies of comparison between sexes that considered the different age/maturational level classes would be fundamental to extend the knowledge on the genetic and environmental influence;
2. The development of studies with a bigger number of twin pairs is clearly necessary for a more including evaluation; and
3. Psychological, nutritional and socioeconomic evaluations could contribute to characterize and clarify possible differences between the studied individuals.

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