The Spanish Journal of Psychology
2012, Vol. 15, No. 1, 29-34
http://dx.doi.org/10.5209/rev_SJOP.2012.v15.n1.37281

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ISSN 1138-7416

Relationship between Physical Prowess and Cognitive Function

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There is some evidence about the low relationship between physical prowess and cognitive function (Posthuma, Mulder, Boomsma & de Geus, 2002). The aim of this paper is to investigate the relationship between cognitive variables (spatial ability, reasoning, numerical ability, inductive reasoning, and reasoning and verbal comprehension) and physical prowess in sport performance (agility circuit, coordination circuit, horizontal jump, swimming and sprint racing). Two studies were performance. In the first one we applied a battery of standardized cognitive tests and a battery of physical grading tests to 400 subjects. When we applied factor analysis to the physical prowess and the cognitive variables, we found one general factor in cognitive variables and one general factor in physical prowess. We found a low relationship between both factors (.21). In the second study we compare the cognitive abilities in elite and amateur sport people. Results show that elite gymnastics people present higher cognitive abilities than amateur sportspeople. It should be relevant in order to clarify the total set of variables involved in sport performance.
Keywords: physical prowess, cognition, spatial ability, reasoning.

Existen ciertas evidencias sobre la relación existente entre destreza física y capacidad cognitiva (Posthuma, Mulder, Boomsma y de Geus, 2002). El objetivo de este trabajo es investigar la relación entre variables cognitivas (capacidad espacial, razonamiento, capacidad numérica, razonamiento inductivo y comprensión verbal) y destreza física asociada al rendimiento deportivo (circuito de agilidad, circuito de coordinación, natación, salto horizontal y carrera de velocidad). Para ello se llevaron a cabo dos estudios. En el primero se administró una batería de test cognitivos estandarizados y una batería de pruebas de condición física a 400 sujetos. Se aplicó un análisis factorial para las pruebas de destreza física y otro para las variables cognitivas. Encontramos un factor general asociado a las variables cognitivas y un factor general asociado a la destreza física. La correlación encontrada entre ambos factores fue baja pero significativa (0,21). En el segundo estudio se compararon las capacidades cognitivas en deportistas de élite y amateurs. Los resultados muestran que los deportistas de elite presentan mayores puntuaciones en los test cognitivos que los deportistas amateurs. Estos resultados son relevantes para establecer el conjunto de variables que se asocian al rendimiento deportivo.
Palabras clave: destreza física, cognición, capacidad espacial, razonamiento.

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https://doi.org/10.5209/rev_SJOP.2012.v15.n1.37281 Published online by Cambridge University Press

The study of individual differences in sport is foremost associated with personality. However, the findings drawn from research about intelligence were inconclusive. Intelligence is a complex cognitive construct, particularly when applied to a physical prowess, but the question is whether or not motor performance requires intelligence.

Several authors show the importance of the predictive factor of intelligence in different contexts (Gottfredson, 1997; Gottfredson & Deary, 2004; Hunter & Schmidt, 1996; De Juan-Espinosa, 1997; Hunt, 1995a; Hunt, 1995b; McHenry, Hought, Toquam, Hanson & Ashworth, 1990; Sternberg & Grigorenko, 1997). However, when analyzing the relationship between physical prowess and cognitive function there is some controversy. We found some studies than reject this relationship (Hillman, Weiss, Hagberg & Hatfield, 2002). Some studies have indicated a small and positive relationship (Posthuma, Mulder, Boomsma & de Geus, 2002; Yaffe, Barnes, Nevitt, Lui & Covinsky, 2001).

We assume that an individual with a high level of physical capacity could carry out a physical task better than another with low capacity. Sports practice involves several factors: the number of decisions and diversity of intentions, the decision making time, the number of elements to remember, the level of uncertainty about the decision, the order and sequence of decisions and the risk level of the decision, etc. (Sanchez Bañuelos, 1996). We consider that people who have better cognitive capacities will have an advantage in physical prowess performance. This idea is supported by Kramer et al. (1999). Their results show that physical activity is related to cognitive performance.

Therefore, the relationship between physical condition (physiological, biological capacity) and cognitive capacity could be the key to success in the execution of specific motor tasks. This idea is supported by Neisser et al. (1996) when they point out that the practical advantage in people with high intelligence increases for new situations or when the situations become more complex, changeable, unpredictable or have many alternatives. Recently, Gale, Batty, Cooper and Deary (2009) found that psychomotor coordination scores were higher in participants with a higher IQ in two different cohorts.

The aim of this study is analyze the relationship between cognitive factors and physical prowess in sport performance in two different samples and two different studies. The first sample comprised undergraduate sports science students and the second elite gymnasts. We were of the opinion that the effect of the cognitive variables could be different in these groups, so we compared the results obtained in both studies.

Study 1

Method

Subjects

The sample comprised 400 subjects (378 males and 22 females). The average age was 21.7 (*SD* = 2.8). The average age for males was 22.3 *(SD* = 2.9) and for females was 20.3 (*SD* = 2.0). All were students who wanted to study sports sciences in the Universidad Europea de Madrid. The proportion is the usual proportion between male and female sports science university students.

Measures

The psychometric instruments applied in this work were the following: Spatial (PMA E), Reasoning (PMA R) and Verbal (PMA V) scales of the PMA (Primary Mental Abilities Test, Thurstone, 1938); Verbal Scale of the DAT (Differential Aptitude Test, Bennett, Seashore & Wesman, 1972); Monedas-2 test (Seisdedos, 1980), a Spanish test that we applied in order to obtain a measure of the numerical ability, and finally, TIG-2 test (Seisdedos, 1982), another Spanish test that we applied in order to obtain inductive reasoning ability. All tests were applied to the entire sample in groups of 30 people.

In addition, we applied the following physical grading tests in order to obtain a measure of the physical condition of the subjects. On the agility circuit subjects have to run around a 28 meter circuit and jump under and over a 0.72 meter hurdle. On the coordination circuit subjects have to bounce and dribble a ball around a 10.5 meter circuit. We assessed again the time spent doing the circuit.. In the swimming task subjects swim 50 meters. Subjects dive to 2.5 meters to a ring at the bottom of the swimming pool and then in back crawl style swim 25 meters. The last 25 meters are swum in crawl style.. In the sprinting race task, the subjects run 50 meters. In all this tasks, we assessed the time spent by subjects doing the task. Finally, in the horizontal jump task subjects jump with feet together starting from a stop position. In this case we assessed the distance reached by subjects.

Results

Descriptives

Table 1 shows the means, standard deviations, kurtosis, skewness and alpha coefficients in physical grading tests and cognitive tests. The skewness and kurtosis are usually considered as a normality test. Values outside the -1 to +1 interval have been suggested as indicators of normality violation (Muthén & Kaplan, 1985). In the cognitive test, the kurtosis and skewness values indicate that all scales have a normal and symmetrical distribution. All the values are positioned in this range. However, in the case of Physical condition test, all the values are outside of this range, probably due to the characteristics of the task. Nonetheless, all the values oscillated in the normal range of these kinds of tasks.

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T test

Table 2 show means, standard deviations and t-test by gender in physical grading tests and cognitive test. As we can see there are significant differences between males and females in all the physical condition tests. In all of them males obtained better scores than females. In the case of cognitive tests, we found significant differences in PMAR, DAT VR and Monedas. In this test the males obtained better scores than females. There were no significant differences in TIG-2, PMAE and PMAR.

Correlations

Correlations between cognitive and psychical condition scales are shown in Table 3. PMA E shows significant correlations in all the psychical condition scales.

TIG-2 and Monedas show similar results, with significant correlations in all the psychical condition scales except swimming. PMA R shows low but significant relationship with the agility circuit, coordination circuit and sprinting race. Finally, DAT VR shows low but significant

Table 1
Descriptive statistics in physical grading tests and cognitive test

	Mean	S.D.	Min.	Max.	Kurtosis	Skewness	Alpha
Agility Circuit	13.42	0.90	10.93	18.30	5.46	1.59	
Coordination Circuit	18.67	2.63	15.23	37.80	12.03	2.67	
Swimming	42.75	5.74	28.38	69.00	2.23	0.95	
Horizontal Jump	2.34	0.22	1.00	2.90	5.87	–1.39	
Sprint Race	6.87	0.44	6.08	9.14	4.15	1.49	
TIG	26.38	5.13	12.00	41.00	0.09	–0.15	0.92
PMA E	29.96	10.42	0.00	54.00	0.27	–0.04	0.73
PMA R	19.17	4.33	4.00	30.00	0.25	–0.40	0.92
PMA V	28.42	6.72	12.00	48.00	–0.29	0.22	0.91
DAT VR	28.50	6.78	12.00	50.00	–0.23	0.13	0.84
Monedas	25.69	6.31	4.00	39.00	–0.02	–0.47	0.94

Table 2
Means, standard deviations and t-test by gender in physical grading tests and cognitive test

	Mean (Male)	Mean (Female)	T	Gl	Sig. (bilateral)
Agility Circuit	13.37	14.65	–11.38	135.27	.000
Coordination Circuit	18.45	22.87	–9.49	120.76	.000
Swimming	42.82	48.65	–7.91	145.65	.000
Horizontal Jump	2.37	1.95	20.58	614.00	.000
Sprint Race	6.82	7.86	18.73	128.03	.000
TIG	25.84	25.31	.97	621.00	.332
PMA E	26.47	23.73	2.27	621.00	.024
PMA R	18.57	18.87	–.63	620.00	.527
PMA V	27.96	25.50	3.50	621.00	.000
DAT VR	28.02	25.03	4.23	621.00	.000
Monedas	25.46	20.63	7.63	621.00	.000

Table 3
Correlations between physical condition and cognitive test

	Agility Circuit	Coordination Circuit	Swimming	Horizontal Jump	Sprint Race
TIG	–.17**	–.18**	–.09	.13**	–.15**
PMA E	–.24**	–.25**	–.18**	.35**	–.36**
PMA R	–.12*	–.15**	–.05	–.08	–.15*
PMA V	–.00	–.06	.00	.10*	–.10*
DAT VR	–.11	–.12*	.03	.12*	–.13**
Monedas	–.19**	–.17**	–.09**	.17**	–.19**

** Sig. 0.01
* Sig. 0.05

https://doi.org/10.5209/rev_SJOP.2012.v15.n1.37281 Published online by Cambridge University Press

correlation with the coordination circuit, horizontal jump and sprinting race, as well as PMAV.

Exploratory Factor Analysis

In our study we use several measures for cognitive and physical prowess variables. In order to obtain a unique measurement for each dimension, we applied a principal components factor analysis to the cognitive variables and we obtained just one factor. The same procedure was applied to physical prowess variables and we obtained one factor, as with the cognitive test. Table 4 shows the principal components factor solution when the cognitive tests were analyzed. We obtained a Kaiser-Meyer-Olkin (*KMO*) measure of sampling adequacy: 0.835, and the Bartlett's Test of Sphericity (*BTS*): Approx. Chi-Square: 844.91; $df = 15$ ($p < .001$). The factor analysis shows one factor that explains 47.64% of the variance. All the tests show loadings over 0.6. Table 4 also shows the factor solution when the physical activities tests were analyzed. We obtained a *KMO* measure of sampling adequacy: 0.79, and the (BTS): Approx. Chi-Square: 1192.79; $df = 10$ ($p < .001$). We obtained only one factor that explains 59.31% of the variance. The correlation between the cognitive factor and the physical factor was .21.

Discussion

In the correct execution of motor tasks, it is necessary to take several decisions that follow adequate reasoning and decision making with regards to the nature of the task (Yaffe et al., 2001). In our case, the results show several significant correlations between cognitive tasks and physical condition.

Table 4
Cognitive test and physical condition test principal components factor analysis

	FI		FI
TIG	0.72	Agility Circuit	.84
PMA E	0.63	Coordination Circuit	.70
PMA R	0.75	Swimming	–.59
PMA V	0.62	Horizontal Jump	.79
DAT VR	0.65	Sprint Race	.87
Monedas	0.73		

We found significant correlations between PMA E and Monedas with all the physical condition tests. As we comment further on, the PMA E reflects a measure of spatial ability, and the Monedas test shows a measure of the numerical ability. Consequently, the subjects have to use spatial ability in order to solve various aspects of the tests. In the correct execution of motor tasks it is necessary to take decisions that involve spatial abilities. These relationships are reflected in the changes that we found in time and spatial measures of the motor tasks.

When we applied a factor analysis in the physical condition test, they were grouped in one factor, as well as the cognitive test. The correlation between both factors is .21, a low but significant correlation, so the cognitive task shows a significant impact on the correct execution of motor task. The aim of our next study is to analyze if these relationships are consistent with different kinds of sportspeople, like elite gymnasts.

Study 2

Method

Subjects

The sample comprised 40 members of the Spanish National Gymnastics Team. The average age was 18.1 (*SD* = 4.1). They belong to different gymnastic modalities, 12 men's artistic gymnasts (MAG), 9 women's artistic gymnasts (WAG), 9 rhythmic gymnasts (RG) and 10 trampoline (TRA).

Measures

We applied two psychometric instruments that we had used in the previous study, ie the Spatial and Reasoning Scales of the PMA (Primary Mental Abilities Test).

Results

Descriptives

Table 5 shows means, standard deviations, kurtosis, skewness and alpha coefficients. Regarding skewness and kurtosis, all the values are positioned between –1 and 1.

Table 5
Descriptive statistics of the PMA E and PMA R

	Mean	*SD*	Min.	Max.	Alpha
PMA E	30.15	7.22	19	51	0.73
PMA R	16.78	4.76	7	27	0.92 **

https://doi.org/10.5209/rev_SJOP.2012.v15.n1.37281 Published online by Cambridge University Press

However, in the case of the physical condition test, all the values are outside of this range, probably due to the characteristics of the space-time measure.

T Test

In both studies we applied the same tests. We were interested in analyzing if there were significant differences in the tests when we considered the expertise of the sportspeople. In this way we compared elite sportspeople with general sportspeople, so we compared the results of both samples.

As we can see, table 6 shows the significant differences between the sample of study 1 and the sample of study 2 in PMA E. The elite sportspeople show higher scores than general sportspeople, so that means that the elite sportspeople have more spatial aptitude. With the reasoning ability (PMA R) we did not find any differences between the two samples.

Discussion

Our results support the idea that in the correct execution of physical tasks the gymnasts must use cognitive abilities. For example, they carry out complex movements in the air, they move, turn and coordinate different parts of the body in different axis, they need to established spatial and time relationships, etc. In the execution of these extremely complicated movements, we considered that spatial ability represents a very important factor, associated to the best execution of movements as in the complex items of a spatial test.

When we compared the results of both studies, the T test shows that the elite gymnasts obtained a higher score in spatial ability, but there are no differences in reasoning ability. We considered that this difference can be due to the following factors: a) training that the sportspeople have carried out over the years, in which they have learned to fit the movement of the body to external conditions of space and time; b) prior selection occurs in developing gymnasts. That means that only those with high abilities can carry out elite gymnastics, so it is normal to find such a profile in this kind of people.

To test both factors, it is necessary to realize a longitudinal study and observe if the aptitude of the gymnasts for establishing spatial relations improves over the years with training, but this kind of study is not yet developed.

General Discussion

We can consider that the influence of physical prowess on cognitive performance is small but relevant (Hillman el at., 1997). In general, research in this area is associated with the preservation of cognitive health in older adults (Lytle, Vander Bilt, Pandav, Dodge, & Ganguli, 2004; Yaffe et al., 2001), suggesting that physical prowess may be beneficial to some aspects of cognition during various periods of the human life span.

There are few studies showing relationships between physical activity and cognition in young people. Richards, Hardy, and Wadsworth (2003) analyze the relationship between physical activity and cognition (verbal memory) in people aged 36-53, showing that there is an association between physical activity and cognitive decrease. However, in our case, we are interested in elite sportspeople and general sportspeople. In both studies we verified how the best execution of physical prowess (in terms of time, distance, etc.) is followed by the best scores in cognitive ability test. Probably, the best execution depends on the characteristics of the physical prowess. There are sports in which cognitive ability is more important than others and there are some sport modalities in which subjects must analyze the context and take decisions concerning physical execution, whereas in others there are not as many variables in the decision process and in the characteristics of the execution.

The correct execution of sports prowess depends on the various perceptions processed during execution time, because tasks have different requirements at different times. Intelligence motor behavior could be considered as a perceptual style that requires attention to process information efficiently (Smith & Bar-Eli, 2007). Elite sportspeople must execute complicated corporal movements in which a small modification in the perception of the external points of reference could cause an execution error. In this way, elite sportspeople could show a higher spatial capacity than other sportspeople.

Results found in our studies allow us to consider that a relationship exists between cognitive abilities and physical condition. Our data support the idea that intelligence, a useful variable in sports performance, could be useful in different contexts,, like training, education or in the process of selecting the best sportspeople.

Table 6
PMA-E and PMA-R compare means (T-test) between study 1 and study 2 samples

	T	Gl	Sig. (bilateral)	Mean Study 1	Mean Study 2
PMA E	–3.388	53.021	.001	25.97	30.15
PMA R	1.702	638.00	.089	18.63	16.78

https://doi.org/10.5209/rev_SJOP.2012.v15.n1.37281 Published online by Cambridge University Press

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Received December 16, 2009
Revision received February 28, 2011
Accepted April 11, 2011

https://doi.org/10.5209/rev_SJOP.2012.v15.n1.37281 Published online by Cambridge University Press