Advances in Physical Education
2013. Vol.3, No.1, 15-19
Published Online February 2013 in SciRes (http://www.scirp.org/journal/ape)
http://dx.doi.org/10.4236/ape.2013.31003

Relationships of Various Coordination Tests

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Received October 1st, 2012; revised November 5th, 2012; accepted November 17th, 2012

This study aimed to examine the relationships among four coordination tests with different movement styles according to gender difference and hand dominance. The subjects performed the coordinated force exertion test, the moving beans with tweezers test and the Purdue pegboard test for three trials as well as the pursuit rotor test for seven trials with the dominant and non-dominant hands. Significant and low correlations were found between the moving beans with tweezers test and the Purdue pegboard test for both hands in females but not among the other tests. Significant correlations were found for both hands in males and females in all tests, showing a significant gender difference between correlations only in the pursuit rotor test. In conclusion, relationships among the four tests for both hands were low, and each test is highly unique. In addition, females have higher relationships between dominant and non-dominant hands, and the tendency is marked, particularly in tests that involve pursuing a moving target.

Keywords: Coordination Tests; Relationships; Gender Difference; Hand Dominance

Introduction

Until now, many coordination tests that mimic the various coordinated movements of the upper limbs in daily life activities have been developed. For example, the Pegboard test and the moving beans with tweezers test are tests that involve using the hand and fingers skillfully and moving objects quickly (Buddenberg & Davis, 2000; Shigematsu et al., 2001). The former has been used to evaluate lateralized brain damage (Mack, 1969; Vega, 1969; Desrosiers et al., 1995; Lehoux et al., 2003), and the latter to evaluate activity levels of the elderly (Shigematsu et al., 2001). The pursuit rotor test and the coordinated force exertion test are tests that involve pursuing a moving target (Ferslew et al., 1982; Nakafuji & Tsuji, 2001; Nagasawa & Demura, 2002, 2004). The tests requiring coordination ability of the hand and fingers, like those mentioned above, have been mainly used for screening autonomic nerve function and for the rehabilitation of cooperated movement in patients with disorders of the cerebellum (Chen & Chang, 1999). These are the useful tests to evaluate motor control function, which coordinates movements according to each task. To smoothly exert motor control function, information from the central and peripheral nervous systems is integrated in the cerebrum and is necessary to properly control movements in each motor organ. Motor control function is interpreted to be superior when contraction and relaxation of muscles are performed smoothly according to the movement of a target, and variability decreases and accuracy increases (Brown & Bennett, 2002). The ability to control this motor function is frequently acquired postnatally through learning based on motor experiences. It was also reported that the above stated 4 coordination tests have laterality and that the degree differs by tests (Noguchi et al., 2006). The dominant hand preferably used in daily life is superior in tests that require skillful, accurate, and quick movement or coordinated muscle strength exertion. In addition, according to Noguchi et al. (2006), a significant gender difference was not found in tests that involve quickly carrying objects to specified locations by skillfully using the hands and fingers but was in tests that involve chasing a moving target. From these reports, it is also assumed that the pegboard test, the moving beans with tweezers test, the pursuit rotor test and the coordinated force exertion test differ in their relationships between the dominant and non-dominant hands or between males and females. The above four coordination tests of the upper limbs have respective similarity and uniqueness, and the coordination abilities (quickness, dexterity and spatial perception, etc.) related to each test may differ subtly. When considering the practicality and efficiency of tests that similarly test the coordination ability of the upper limbs, the uniqueness and similarity of movement evaluated by each test are made clearer by examining the relationships among tests. As the result, we will be able to rationally select coordination tests according to each research purpose. The laterality (Noguchi et al., 2006) and practice effect (Gallus & Mathiowetz, 2003; Haward & Griffin, 2002) of human dexterity have been studied. However, few studies have compared laterality among different movement tasks (Butki, 1994).

Methods

Subjects

The subjects were 20 male (age 20.1 ± 2.1 yrs; height 173.3 ± 4.5 cm; weight 68.9 ± 11.1 kg) and 20 female adults (age 19.6 ± 1.3 yrs; height 161.4 ± 5.0 cm; weight 52.2 ± 4.9 kg) without previous wrist injuries or nerve damage of the upper limbs. Prior to measurement, the purpose and procedure of this study were explained in detail, and informed written consent was obtained from all subjects. Eighteen males and all females

were regarded as right-handed based on Oldfield's inventory (1971). Their height and weight were similar to Japanese normative values (Laboratory Physical Education in Tokyo Metropolitan University, 1989) for this age.

Coordination Tests

This study selected the moving beans with tweezers test, the Purdue pegboard test, the pursuit rotor test and the coordinated strength exertion test as representative coordination tests of the upper limbs. Shigematsu et al. (2000) reported that the moving bean with tweezers test is effective as a test to evaluate the operative ability of the hands and fingers. This test requires grasping and transporting objects as quickly as possible with a tool. The accuracy, agility and dexterity of the hands and fingers relate to achievement in the test.

The Purdue pegboard test has been mainly used for the rehabilitation of cerebellar disorders. This test requires basic movements which are important in daily life, such as grasping objects and accurately inserting them into the holes. Agility, dexterity and spatial cognitive ability relate to achievement in the test. The pursuit rotor test can evaluate a decrease of coordination caused by disorders of the central and peripheral nervous systems as a decrease of performance and requires the exertion of hand-eye coordination and space cognitive ability.

The coordinated strength exertion test developed by Nagasawa and Demura (2002, 2004) uses the exertion of sub-maximal grip strength while matching a target shown on a monitor to evaluate muscle strength, coordination, and processing of visual information.

Experimental Equipment, Procedure, and Evaluation Methods

The Purdue Pegboard Test (Gallus & Mathiowetz, 2003)

The Purdue pegboard device (PC-7473, SAKAI) was used for this test. This device consists of a white board with a container and steel pins (3 mm × 25 mm) in a container above the board. Subjects were instructed to put pins at fixed position into holes on the board as accurately and quickly as possible for 30 sec. They alternately performed three trials each with their dominant and non-dominant hands. Subjects who could put more pins into fixed holes were interpreted to be superior in the test.

Moving Beans with Tweezers Test (Shigematsu et al., 2001; Noguchi et al., 2006)

An open container A (20 cm in diameter, 2 cm in depth) containing 60 beans (about 6 mm in diameter) was put in front of the hand and an open container B (5 cm in diameter, 3.5 cm in depth) was put in front of the other hand 20 cm apart (Kim et al., 2001). Subjects were instructed to sit in front of the containers and to transport each bean using tweezers from container A to B as rapidly and accurately as possible for 30 sec. Subjects alternately performed three trials each with their dominant and non-dominant hands. Subjects who transported more beans were interpreted to be superior in the test (Shigematsu et al., 2001; Noguchi et al., 2006).

Coordinated Strength Exertion Test (Nagasawa & Demura, 2002, 2004)

In this test, subjects performed a grip exertion, attempting to minimize the differences between the grip strength and the demand value presented with a waveform on a computer display. The digital grip measurement system (EG-100, SAKAI) was used for this test. The demand value (5% - 25% of maximal grip strength) varied over a period of 40 sec at a frequency of 0.3 Hz (Nagasawa et al., 2002). Subjects alternately performed three trials each with their dominant and non-dominant hands. The sum of the above differences (%) for 25 sec excluding the first 15 sec of each trial was used as an estimate according to a previous study (Nagasawa et al., 2002). Subjects with smaller values (%) were interpreted to have better coordinated strength exertion ability.

Pursuit Rotor Test (Nagasawa & Demura, 2004; Noguchi et al., 2005)

An apparatus was used for the pursuit rotor test (Takei, TKK2110, Tokyo, Japan). The subjects pursued a 10 mm diameter concave target placed 100 mm from the center of the circular board turning at 50 rpm clockwise when they used the right hand and counterclockwise when they used the left hand with a 3 mm diameter L-type steel pin. A practice time of about 5 min with the dominant and non-dominant hands was performed before the test. Subjects performed seven trials each with the dominant and non-dominant hands. Contact time between the steel pin and the target for 1 min was used as an evaluation parameter for the test. Subjects with longer contact times were interpreted to be superior in the test.

Data Analysis

To assess the reliability of each test, the intra-class correlation coefficient (ICC) was calculated. When significant differences were found, Tukey's honest significant difference (HSD) was used for pair-wise comparisons. The relationships between tests of dominant and non-dominant hands were examined by Pearson's correlation coefficient. The test based on the normal distribution was performed to examine the gender difference of correlations. The statistical significance (α) was set at $p < 0.05$ in this study.

Results

Table 1 shows the ICCs of the moving beans with tweezers test, the Purdue pegboard test and the coordinated strength exertion test. Nagasawa et al. (2002) used the mean of the second and third trials as a representative value of the last test. The ICC of the second and third trials was high (ICC = 0.72) for both hand dominances in males and females. Because the former two tests showed a significant difference between the second and third trials, we selected values of the two high-ranking trials and calculated their ICCs again. As a result, they showed an insignificant difference, and their ICCs ranged from 0.54 - 0.82 in the moving beans with tweezers test and from 0.50 - 0.82 in the Purdue pegboard test.

Table 2 shows the ICCs of the pursuit rotor test. Noguchi et al. (2005) reported that measurements after the seven trials in this test were stable. The ICC of trials six and seven was high (0.73 - 0.88).

Table 3 shows the significant correlations between tests according to both hand dominance and gender. Significant correlations between the moving beans with tweezers test and the Purdue pegboard test were found only between both hands in females (r = 0.48, 0.53).

Table 1.
The ICCs between trials for coordination strength exertion, moving beens with tweezers and pegboard tests.

			1 trial		2 trial		3 trial		1 - 3 trials		2 - 3 trials		2 high-ranking trials	
			Mean	SD	Mean	SD	Mean	SD	F	ICC	F	ICC	F	ICC
Male (n = 20)	Dominant hand	Coordinated strength exertion test	746.5	191.9	709.1	178.1	680.5	167.5	3.68*	0.80	1.29	0.80		
		Moving beans with tweezers test	21.1	2.9	22.7	2.9	22.7	3.2	5.09*	0.61	0.01	0.63	0.94	0.71
		Pegboard test	17.4	1.4	17.7	1.3	18.2	1.3	2.07	0.24	3.27*	0.52	0.70	0.50
	Non-dominant hand	Coordinated strength exertion test	899.6	216.6	819.4	142.4	807.9	158.8	4.34*	0.61	0.32	0.83		
		Moving beans with tweezers test	17.8	1.9	18.1	2.2	17.8	2.6	0.19	0.49	0.30	0.59	0.03	0.82
		Pegboard test	15.0	1.7	16.1	1.5	16.0	1.2	5.87*	0.34	0.13	0.62	0.04	0.72
Female (n = 20)	Dominant hand	Coordinated strength exertion test	867.5	177.3	775.5	197.9	775.2	158.0	7.32*	0.71	0.00	0.85		
		Moving beans with tweezers test	21.8	3.3	22.0	2.5	23.3	2.2	3.67	0.50	5.84*	0.46	2.75	0.54
		Pegboard test	16.9	1.6	17.6	1.5	17.9	1.5	3.79*	0.44	1.41	0.72	0.00	0.72
	Non-dominant hand	Coordinated strength exertion test	1005.7	252.7	956.4	195.6	935.3	223.5	2.15	0.76	0.33	0.72		
		Moving beans with tweezers test	18.4	2.8	19.1	2.4	20.1	3.1	5.61*	0.63	2.93	0.59	0.49	0.80
		Pegboard test	15.6	1.8	15.9	1.5	16.4	1.7	4.83*	0.69	3.52	0.70	0.41	0.82

Note: $^{*}p < 0.05$.

Table 2.
The ICCs for the pursuit rotor test.

		Dominant hand						Non-dominant hand					
		6 trial		7 trial				6 trial		7 trial			
		Mean	SD	Mean	SD	F	ICC	Mean	SD	Mean	SD	F	ICC
Male	(n = 20)	47.2	11.41	47.5	13.37	0.02	0.78	40.9	11.76	44	13.03	2.35	0.73
Female	(n = 20)	38.4	17.76	40.5	20.21	0.91	0.87	29.3	18.93	32.3	17.95	2.27	0.88

Table 3.
The significant correlation for both hands of males and females.

		Non-dominant hand			
	Male (n = 20)	Moving beans with tweezers test	Pegboard test	Coordinated strength exertion test	Pursuit rotor test
Dominant Hand	Moving beans with tweezers test		0.22	−0.17	0.07
	Pegboard test	0.23		−0.25	0.32
	Coordinated strength exertion test	−0.24	0.01		−0.19
	Pursuit rotor test	0.18	0.24	−0.23	
	Female (n = 20)	Moving beans with tweezers test	Pegboard test	Coordinated strength exertion test	Pursuit rotor test
Dominant Hand	Moving beans with tweezers test		0.53*	0.18	0.15
	Pegboard test	0.48*		−0.02	0.21
	Coordinated strength exertion test	0.02	0.16		−0.21
	Pursuit rotor test	−0.03	0.14	−0.22	

Note: $^{*}p < 0.05$.

Table 4 shows the correlations between both hands based on gender. Significant correlations were found in all tests in males and females (r = 0.44, 0.85), and a female's value was higher in the pursuit rotor test.

Discussions

Significant correlations were not found between the pursuit rotor test and the coordinated force exertion test in males and females, and both tests showed insignificant correlations with the moving beans with tweezers test and the Purdue pegboard test. It was assumed that the former tests have a significant relationship because of similar tests that involve the pursuit of a moving object. The coordinated force exertion test is related mainly to grip muscle strength, because it involves chasing a target displayed on a personal computer screen while controlling the exertion of grip strength (Nagasawa & Demura, 2004). The pursuit rotor test involves chasing the target while matching arms and hands to the movement of the rotating plate. This test is related to visual sensation and special cognitive ability because of accurate visual assessment of the spatial position of a target and pursuing a moving target with eye movement. From the present results, it is suggested that the ability evaluated by both tests differs in spite of involving chasing the target in both tests, and each test has high uniqueness. In addition, it is inferred that both tests evaluate different abilities from the Pegboard test and the moving beans with tweezers test, which evaluate the skillful use of the fingers and quick movement of objects.

On the other hand, the moving beans with tweezers test and the Purdue pegboard test showed significant correlations only in the hand dominance of females, but they were moderate or low (r = 0.48, 0.53). It was assumed that their relationships are high because the tests involve using the hand and fingers skillfully and moving objects quickly. However, the present hypothesis was not always supported, because correlations were not high. Chen and Chang (1999) reported that the test of chopsticks manipulation using chopsticks for physiotherapy showed significant correlations with the tweezers dexterity test but not with the pegboard test. Also, the present results showed insignificant correlations between the Purdue pegboard test and the moving beans with tweezers test for both hands in males, and their relationships were also low in females. As reported in a previous study (Chen & Chang, 1999), the relationship between both tests may be low.

Although both tests evaluate the skillful use of the fingers and the quick transport of objects, the former involves grasping objects directly with the fingers, but the latter uses tools (Buddenberg & Davis, 2000; Sigematsu et al., 2001). In short, in spite of the same transport movement by the hand, the test content differs in the use or not of a tool. In addition, because the Pegboard test requires the insertion of pegs into the holes on the board as quickly and accurately as possible, the dexterity required may be more than that for the moving beans with tweezers test. Hence, it is inferred that the ability evaluated by both tests differs and that they have high uniqueness. From the above, the relationships between the pursuit rotor test and the coordinated force exertion test, which involve pursuing a moving target, and between the moving beans with tweezers test and the Purdue pegboard test, which use the fingers to skillfully transport objects quickly, are low. In short, they may each evaluate unique coordination abilities.

Hence, when evaluating the coordination ability of the hands and fingers, it will be important that we use tests corresponding to the research purpose or plural tests and synthetically evaluate the results of each test by paying attention to the origin of movements in each test.

When examining the correlations between both hands in the tests according to gender, they showed high relationships in the moving beans with tweezers test and moderate relationships in the Purdue pegboard test in males and females. Both tests are related to the dexterity and quickness of arm and fingers, and similar operations are used in daily life regardless of the dominant or non-dominant hands in males and females. Hence, it is inferred that both tests showed a high relationship between dominant and non-dominant hands.

On the other hand, the pursuit rotor test and the coordinated force exertion test showed a different tendency in relationships between dominant and non-dominant hands in males and females. Noguchi et al. (2006) reported that a significant gender difference was found in these tests. The present results showed a significant gender difference in the correlation between dominant and non-dominant hands in the pursuit rotor test, being higher in females. Both tests are similar in that they involve chasing a moving target. However, grip muscle strength relates mainly to the coordinated force exertion test, because the test involves chasing a target displayed on a personal computer screen while controlling the exertion of grip strength. In contrast, visual sensation and spatial cognitive ability relates mainly to the pursuit rotor test. Although abilities related to both tests differ somewhat, they both require coordination ability which a person matches to the movement of the object. Haward et al. (2002) reported that the superiority of the dominant hand is strongly influenced by an acquired factor. Females use both hands in many basic operations in daily life, such as cooking, cleaning, and sewing. In short, because females frequently use the non-dominant hand as well as the dominant hand, the dexterity of their non-dominant hand develops more. Hence, the difference between both hands may not have been marked in females. From the above, it is inferred that the moving beans with tweezers test and the Purdue pegboard test have a high relationship between the dominant and non-dominant hands regardless of gender, and the relationship between the pursuit rotor test and the coordinated force exertion test differs in males and females, being higher in females.

In conclusion, the relationships among the four tests for both hands are low, and each test has respective high uniqueness. In addition, females have higher relationships between the dominant and non-dominant hands, and the tendency is marked, particularly in tests involving pursuing a moving target.

Table 4.
The correlation coefficients between both hands.

	Male (n = 20)	Female (n = 20)	Result
Moving beans with tweezers test	0.76*	0.69*	0.43
Pegboard test	0.55*	0.58*	−0.13
Coordinated strength exertion test	0.44*	0.72*	−1.27
Pursuit rotor test	0.44*	0.85*	−2.29*

Note: $^{*}p < 0.05$.

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