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The Influence of Gender, Athletic Events, and Athletic Experience on the Subjective Dominant Hand and the Determination of the Dominant Hand Based on the Laterality Quotient (LQ) and the Validity of the LQ

Shinichi Demura[1)], Nobuhiko Tada[2)], Jinzaburo Matsuzawa[3)], Hajime Mikami[4)], Tetsuhiko Ohuchi[5)], Hiroya Shirane[6)], Yoshinori Nagasawa[7)] and Masanobu Uchiyama[1)]

1) Kanazawa University, Graduate School of Natural Science & Technology
2) Fukui Prefectural University
3) Fukui Institute of Technology
4) Fukui University, Faculty of Education and Regional Studies
5) Nippon Sports Science University, Graduate School, Field of Training Science
6) Akita National College of Technology, Faculty of Natural Science
7) Akita Prefectural University, Research and Education Center for Comprehensive Science

Abstract This study aimed to reveal the influence of gender, athletic events and athletic experience on the subjective dominant hand and the dominant hand based on the laterality quotient (LQ). It also aimed to examine the validity of the Edinburgh Inventory (Oldfield, 1971). Males and females (n=3,726) living in 7 prefectures in Japan (age: 16–45 yrs) participated in this survey. Analysis was performed on 3,557 separate datasets with high reliability. The reliability of the survey was examined using a test-retest method consisting of 100 people selected randomly from all participants. All participants provided the same answers for each question. The influence of gender, event and experience was examined for the subjective and LQ-based dominant hands. In addition, concordance rates of the subjective dominant hand and the LQ-based dominant hand and both dominant hands were examined. Differences of concordance rates between hands used in the 10 movement questions of the Inventory and the subjective dominant hand were tested using the χ^2 test. The frequency differences among items were tested using Ryan's method (multiple comparisons). Significant gender differences were found between rates of the LQ-based dominant hand (males: 94.4%; females: 96.6%) and the subjective dominant hand (males: 91.6%; females: 94.0%), but the degree was only 2.0–4.0%. Insignificant differences were found among athletic events, two groups of different athletic experience, and gender according to each athletic event. The subjective dominant hand almost always agreed with the LQ-based dominant hand (complete concordance rate=0.96, κ=0.67). Of the 10 question items, inexperienced answers were found only in the item "Knife (without fork)". The "Toothbrush", "Broom (upper hand)", and "Opening box (lid)" items had significantly lower correspondence with the subjective dominant hand (79.7–87.0%) than the other items (92.1–95.7%).

In conclusion, athletic experience appears to have little influence on handedness, although there is a slight gender difference. The subjective dominant hand almost always agrees with the dominant hand based on the Inventory. A more efficient handedness inventory may be constructed by excluding the above 4 items. *J Physiol Anthropol 25(5): 321–329, 2006* http://jstage.jst.go.jp/browse/jpa2
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Introduction

People tend to prefer one hand over another, a so-called a functional "laterality", in many everyday-life settings or in various physical activities unless there are special demands. The functional dominant hand is formed due to the influence of various factors such as lifestyle, culture, and genetic information (McGlone, 1980; Fumoto, 1982; Yorozui et al., 1971). In addition, some studies reported that there are gender differences in the rate of dominant hands, and left-handedness is greater in male than female (Oldfield, 1971; Hildreth, 1950). Currently, due to increasing popularity in various sports morphological laterality, which depends on the characteristics of each athletic event, has been reported (Bissell and Johnson, 1940). The hand or leg most frequently used during exercise differs among sports because of their respective movement

Table 1 Questionnaire items for handedness assessment in this study (interpolation of Oldfield, 1971)

Question: Which hand do you use for doing the following movements:				
1 Writing	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
2 Drawing	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
3 Throwing	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
4 Scissors	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
5 Toothbrush	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
6 Knife (without fork)	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
7 Spoon	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
8 Broom (upper hand)	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
9 Bat (lower hand)	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
10 Striking a match	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
11 Opening box (lid)	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced
12 Bat (upper hand)	1. Right hand	2. Left hand	3. Both hands	4. Inexperienced

Questionnaire items 9 and 12 were included as lie scales. If a contradiction between both items was found, the subject was excluded from further analysis.

styles. Therefore, each sport may influence functional and morphological characteristics of each extremity. For example, Kimura (1989) reported that muscle strength and boundary length increased to a greater extent in the dominant hand versus the non-dominant hand, due to athletic experiences and that the upper arm, forearm, and femur circumferences are larger on the right side of Kendo athletes, while little lateral difference is found in the morphological characteristics of gymnasts. However, there are few prior reports on functional laterality in athletes.

Moreover, the handedness inventory developed by Oldfield (1971) or Chapman and Chapman (1987) has been widely used to judge the functional dominance of upper limbs. They judge the dominant hand based on the hand used in various movements in daily life such as "writing" and "throwing a ball". However, the above representative inventories were made 20–30 years ago. Cultural backgrounds since then have changed significantly. Therefore, they are not necessarily valid for assessing handedness today. By including inappropriate questions, a laterality quotient may be less accurate in judging handedness. Meanwhile, the hand actually used for each movement in the above Inventory may differ from the conscious dominant hand.

This study aimed to reveal the effects of differences in gender, athletic-event, and athletic experience on the determination of the subjective dominant hand and the dominant hand based on the laterality quotient (LQ) and to examine the validity of the Edinburgh Inventory (Oldfield, 1971).

Methods

Subjects

People aged 16–45 yrs from 7 prefectures in Japan were asked to answer a survey. Informed consent was obtained from each participant. The handedness inventory was delivered and 3,726 responses were obtained. The responses were checked for lie scales and blank or unknown forms about base attributes. Analysis was performed on 3,557 reliable and valid responses. One hundred subjects selected randomly from all subjects were surveyed again to examine reliability using a test-retest method.

Surveying methods

The survey was conducted between October 2004 and the following August. The objectivity of the survey was explained to all participants. In addition, they were instructed that it was not necessary to provide a name and that the obtained data was statistically processed with no possibility of privacy invasion.

The questionnaire was composed of questions about base attributes (school, grade, full name or anonymous name, years, gender, etc.), athletic event experiences, years of athletic experience, subjective dominant hand, and the Edinburgh Inventory by Oldfield (1971) (Table 1). The inventory consisted of 10 items and two lie-scale items added in this study regarding daily activities. The form instructed participants to select one of the following 4 choices: 1. Right hand, 2. Left hand, 3. Both hands, and 4. Inexperienced with respect to the hand used in each movement question. Subjects were asked to choose 3. Both hands when they use both hands with the same frequency or both hands were equally easy to use.

Highly reliable data were obtained by excluding 139 questionnaires with conflicting responses on the lie scales, e.g. by answering when holding a bat, the upper hand is the right hand, but also answering the right hand for the lower hand elsewhere in the same question. Highly reliable data were also obtained by excluding 169 nonresponders on basic attributes or subjective dominant hand items.

Statistical analysis

The dominant hand of each subject was judged by laterality quotients (LQ) calculated using the Oldfield (1971) handedness test with the following equation (Oldfield, 1971);

$$LQ = ((\text{total number of right hand}) - (\text{total number of left hand})) / ((\text{right}) + (\text{left}))$$

The concordance rate of the LQ-based and subjective dominant hands was examined using the complete concordance rate and Cohen's kappa (κ). Gender differences in the concordance rate between both dominant hands and differences between groups with different years of athletic experience (two groups of up to 5 yrs and 6 yrs or more) in the rates of each dominant hand were examined by a test of the ratio difference between the two groups with Yates's continuity correction using the ratio of right handedness. Differences between athletic events and the frequency of both dominant hands and their concordance rate in the integrated data of males and females were examined by a test of independence with Yates's continuity correction (13: events×2: consistency or discrepancy) or (13: events×2: handedness).

Concordance frequencies between the actually used hand in each question item and the subjective dominant hand were examined by a test of independence. A multiple comparison test based on Ryan's method was used to indicate a significant difference. The significance level was set at 0.05 in this study. The frequency of the dominant hand in each athletic event and

Table 2-1 Gender differences in the frequency of the subjective dominant hand in each athletic event

			Left-handed		Right-handed		Ambidextrous		Gender difference	
			Frequency	Rate	Frequency	Rate	Frequency	Rate	χ^2	two-sided p-value
Baseball	Male	n=523	36	(6.9%)	474	(90.6%)	13	(2.5%)	0.22	0.64 ns
	Female	n=11	2	(18.2%)	9	(81.8%)	0	(0.0%)		
	Total	n=534	38	(7.1%)	483	(90.4%)	13	(2.4%)		
Football	Male	n=327	19	(5.8%)	300	(91.7%)	8	(2.4%)	1.47	0.23 ns
	Female	n=7	1	(14.3%)	5	(71.4%)	1	(14.3%)		
	Total	n=334	20	(6.0%)	305	(91.3%)	9	(2.7%)		
Basketball	Male	n=223	18	(8.1%)	204	(91.5%)	1	(0.4%)	0.00	1.00 ns
	Female	n=164	9	(5.5%)	150	(91.5%)	5	(3.0%)		
	Total	n=387	27	(7.0%)	354	(91.5%)	6	(1.6%		
Volleyball	Male	n=107	5	(4.7%)	99	(92.5%)	3	(2.8%)	2.00	0.16 ns
	Female	n=143	2	(1.4%)	139	(97.2%)	2	(1.4%)		
	Total	n=250	7	(2.8%)	238	(95.2%)	5	(2.0%)		
Tennis	Male	n=70	2	(2.9%)	65	(92.9%)	3	(4.3%)	0.00	0.94 ns
	Female	n=41	2	(4.9%)	39	(95.1%)	0	(0.0%)		
	Total	n=111	4	(3.6%)	104	(93.7%)	3	(2.7%)		
Soft Tennis	Male	n=149	14	(9.4%)	134	(89.9%)	1	(0.7%)	0.21	0.65 ns
	Female	n=82	2	(2.4%)	76	(92.7%)	4	(4.9%)		
	Total	n=231	16	(6.9%)	210	(90.9%)	5	(2.2%)		
Badminton	Male	n=50	6	(12.0%)	44	(88.0%)	0	(0.0%)	0.04	0.83 ns
	Female	n=96	3	(3.1%)	87	(90.6%)	6	(6.3%)		
	Total	n=146	9	(6.2%)	131	(89.7%)	6	(4.1%)		
Table Tennis	Male	n=168	7	(4.2%)	157	(93.5%)	4	(2.4%)	0.00	1.00 ns
	Female	n=55	2	(3.6%)	52	(94.5%)	1	(1.8%)		
	Total	n=223	9	(4.0%)	209	(93.7%)	5	(2.2%)		
Swimming	Male	n=165	15	(9.1%)	147	(89.1%)	3	(1.8%)	3.12	0.08 ns
	Female	n=131	2	(1.5%)	125	(95.4%)	4	(3.1%)		
	Total	n=296	17	(5.7%)	272	(91.9%)	7	(2.4%)		
Track and Field	Male	n=161	9	(5.6%)	150	(93.2%)	2	(1.2%)	0.00	1.00 ns
	Female	n=61	2	(3.3%)	57	(93.4%)	2	(3.3%)		
	Total	n=222	11	(5.0%)	207	(93.2%)	4	(1.8%)		
Kendo	Male	n=135	8	(5.9%)	124	(91.9%)	3	(2.2%)	0.55	0.46 ns
	Female	n=53	0	(0.0%)	51	(96.2%)	2	(3.8%)		
	Total	n=188	8	(4.3%)	175	(93.1%)	5	(2.7%)		
Others	Male	n=241	14	(5.8%)	225	(93.4%)	2	(0.8%)	0.00	1.00 ns
	Female	n=132	5	(3.8%)	123	(93.2%)	4	(3.0%)		
	Total	n=373	19	(5.1%)	348	(93.3%)	6	(1.6%)		
Inexperienced	Male	n=110	6	(5.5%)	103	(93.6%)	1	(0.9%)	0.77	0.38 ns
	Female	n=152	4	(2.6%)	147	(96.7%)	1	(0.7%)		
	Total	n=262	10	(3.8%)	250	(95.4%)	2	(0.8%)		
Total of all events	Male	n=2429	159	(6.5%)	2226	(91.6%)	44	(1.8%)	5.61	0.02 *
	Female	n=1128	36	(3.2%)	1060	(94.0%)	32	(2.8%)		
	Total	n=3557	195	(5.5%)	3286	(92.4%)	76	(2.1%)		

Others: Group including subjects who have technical athletic experiences in the other events. Inexperienced: Subjects who have had no technical athletic experience. *: $p>0.05$; ns: $p<\alpha'$ ($\alpha'=0.05/13$)

the frequency of concordance between the actually used hand and the subjective dominant hand were tested according to Bonferroni's method.

Results

Two answers for the LQ-based dominant hand and the subjective dominant hand in the test-retest method were concordant in all participants (complete concordance rate=1.0 and κ=1.0).

Table 2-1 shows the frequencies of the subjective dominant hand according to gender and each athletic-event, and Table 2-2 shows the frequencies of the dominant hand based on the LQ of the Edinburgh Inventory. The rates of the subjective dominant hand in males were 6.5% in left-handed individuals, 91.6% for right-handed individuals, and 1.8% for ambidextrous individuals and were respectively 3.2, 94.0 and 2.8% in females (gender difference: χ^2=5.61, p=0.01). The rates of the LQ-based dominant hand were 5.2, 94.4 and 0.4% in males, and 3.1, 96.6 and 0.3% in females (gender difference:

Table 2-2 Gender differences in the frequency of the LQ-based dominant hand in each athletic event

			Left-handed		Right-handed		Ambidextrous		Gender difference	
			Frequency	Rate	Frequency	Rate	Frequency	Rate	χ^2	two-sided p-value
Baseball	Male	n=523	24	(4.6%)	496	(94.8%)	3	(0.6%)	1.47	0.23 ns
	Female	n=11	2	(18.2%)	9	(81.8%)	0	(0.0%)		
	Total	n=534	26	(4.9%)	505	(94.6%)	3	(0.6%)		
Football	Male	n=327	15	(4.6%)	310	(94.8%)	2	(0.6%)	0.00	1.00 ns
	Female	n=7	0	(0.0%)	7	(100.0%)	0	(0.0%)		
	Total	n=334	15	(4.5%)	317	(94.9%)	2	(0.6%)		
Basketball	Male	n=223	15	(6.7%)	208	(93.3%)	0	(0.0%)	0.66	0.42 ns
	Female	n=164	7	(4.3%)	157	(95.7%)	0	(0.0%)		
	Total	n=387	22	(5.7%)	365	(94.3%)	0	(0.0%)		
Volleyball	Male	n=107	7	(6.5%)	100	(93.5%)	0	(0.0%)	1.25	0.26 ns
	Female	n=143	3	(2.1%)	139	(97.2%)	1	(0.7%)		
	Total	n=250	10	(4.0%)	239	(95.6%)	1	(0.4%)		
Tennis	Male	n=70	3	(4.3%)	66	(94.3%)	1	(1.4%)	0.00	1.00 ns
	Female	n=41	2	(4.9%)	39	(95.1%)	0	(0.0%)		
	Total	n=111	5	(4.5%)	105	(94.6%)	1	(0.9%)		
Soft Tennis	Male	n=149	10	(6.7%)	139	(93.3%)	0	(0.0%)	0.44	0.51 ns
	Female	n=82	3	(3.7%)	79	(96.3%)	0	(0.0%)		
	Total	n=231	13	(5.6%)	218	(94.4%)	0	(0.0%)		
Badminton	Male	n=50	4	(8.0%)	46	(92.0%)	0	(0.0%)	0.00	0.96 ns
	Female	n=96	5	(5.2%)	90	(93.8%)	1	(1.0%)		
	Total	n=146	9	(6.2%)	136	(93.2%)	1	(0.7%)		
Table Tennis	Male	n=168	7	(4.2%)	160	(95.2%)	1	(0.6%)	0.00	1.00 ns
	Female	n=55	2	(3.6%)	53	(96.4%)	0	(0.0%)		
	Total	n=223	9	(4.0%)	213	(95.5%)	1	(0.4%)		
Swimming	Male	n=165	12	(7.3%)	153	(92.7%)	0	(0.0%)	2.80	0.09 ns
	Female	n=131	3	(2.3%)	128	(97.7%)	0	(0.0%)		
	Total	n=296	15	(5.1%)	281	(94.9%)	0	(0.0%)		
Track and Field	Male	n=161	5	(3.1%)	156	(96.9%)	0	(0.0%)	0.00	1.00 ns
	Female	n=61	2	(3.3%)	59	(96.7%)	0	(0.0%)		
	Total	n=222	7	(3.2%)	215	(96.8%)	0	(0.0%)		
Kendo	Male	n=135	7	(5.2%)	128	(94.8%)	0	(0.0%)	1.59	0.21 ns
	Female	n=53	0	(0.0%)	53	(100.0%)	0	(0.0%)		
	Total	n=188	7	(3.7%)	181	(96.3%)	0	(0.0%)		
Others	Male	n=241	12	(5.0%)	228	(94.6%)	1	(0.4%)	0.62	0.43 ns
	Female	n=132	3	(2.3%)	128	(97.0%)	1	(0.8%)		
	Total	n=373	15	(4.0%)	356	(95.4%)	2	(0.5%)		
Inexperienced	Male	n=110	5	(4.5%)	104	(94.5%)	1	(0.9%)	0.62	0.43 ns
	Female	n=152	3	(2.0%)	149	(98.0%)	0	(0.0%)		
	Total	n=262	8	(3.1%)	253	(96.6%)	1	(0.4%)		
Total of all events	Male	n=2429	126	(5.2%)	2294	(94.4%)	9	(0.4%)	7.51	0.01 *
	Female	n=1128	35	(3.1%)	1090	(96.6%)	3	(0.3%)		
	Total	n=3557	161	(4.5%)	3384	(95.1%)	12	(0.3%)		

Others: Group including subjects who have technical athletic experiences in the other events. Inexperienced: Subjects who have had no technical athletic experience. *: $p>0.05$; ns: $p<\alpha'$ (α'=0.05/13)

χ^2=7.51, p=0.00). Although significant gender differences were found in the subjective and LQ-based dominant hands in all participants, the size difference was only 2–4%.

Differences in dominant hand rates between athletic events were examined using integrated data of males and females since there was no significant gender difference in the rates in all events. There was no significant difference between athletic events (subjective dominant hand: χ^2=20.76, p=0.65; The LQ-based dominant hand: χ^2=14.25, p=0.94).

The test results of dominant hand rates between two groups with different years of athletic experience were not significantly different in any athletic event (Table 2-3). Similar findings were also obtained in the LQ-based dominant hand rates.

Table 3-1 shows the frequency of the subjective and LQ-based dominant hands. The complete concordance rate (P0) was 0.96 (3418/3557). There were more people with a subjective left dominant hand in spite of a right dominant hand on the LQ (n=107) than the number of people with a subjective right dominant hand despite a left dominant on the LQ (n=9). Furthermore, a significant coefficient of κ (0.67, $Z_{\kappa 0}$=14.66>Z (p=0.05)=1.65) was found. Thus, the LQ-based and the subjective dominant hands are judged to be almost identical. Additionally, the results by gender were almost the same.

Table 3-2 (below) shows the concordance frequencies

Table 2-3 Differences of the subjective dominant hand between years of athletic experience in each event (the integrated data of males and females)

			Left-handed		Right-handed		The ratio difference	
			Frequency	Rate	Frequency	Rate	χ^2	Two-sided p-value
Baseball	Long term	n=361	27	(7.5%)	324	(89.8%)	0.40	0.52 ns
	Short term	n=173	11	(6.4%)	159	(91.9%)		
Football	Long term	n=219	14	(6.4%)	200	(91.3%)	0.00	1.00 ns
	Short term	n=115	6	(5.2%)	105	(91.3%)		
Basketball	Long term	n=201	16	(8.0%)	181	(90.0%)	0.74	0.39 ns
	Short term	n=186	11	(5.9%)	173	(93.0%)		
Volleyball	Long term	n=118	4	(3.4%)	113	(95.8%)	0.00	1.00 ns
	Short term	n=131	3	(2.3%)	126	(96.2%)		
Tennis	Long term	n=25	0	(0.0%)	25	(100.0%)	1.01	0.31 ns
	Short term	n=86	4	(4.7%)	79	(91.9%)		
Soft Tennis	Long term	n=90	6	(6.7%)	80	(88.9%)	0.38	0.54 ns
	Short term	n=141	10	(7.1%)	130	(92.2%)		
Badminton	Long term	n=46	1	(2.2%)	44	(95.7%)	1.71	0.19 ns
	Short term	n=100	8	(8.0%)	87	(87.0%)		
Table Tennis	Long term	n=87	4	(4.6%)	81	(93.1%)	0.00	0.98 ns
	Short term	n=136	5	(3.7%)	128	(94.1%)		
Swimming	Long term	n=186	12	(6.5%)	168	(90.3%)	2.78	0.10 ns
	Short term	n=109	5	(4.6%)	105	(96.3%)		
Track and field	Long term	n=106	4	(3.8%)	99	(93.4%)	0.00	1.00 ns
	Short term	n=116	7	(6.0%)	108	(93.1%)		
Kendo	Long term	n=111	6	(5.4%)	103	(92.8%)	0.00	1.00 ns
	Short term	n=77	2	(2.6%)	72	(93.5%)		
Others	Long term	n=161	5	(3.1%)	154	(95.7%)	1.14	0.29 ns
	Short term	n=211	14	(6.6%)	195	(92.4%)		

Long-term: Subjects who experience athletic activities over 6 years or more.
Short-term: Subjects who experience athletic activities for up to 5 years.
Others: A group includeng subjects who has a technical athletic experiences in the other events.
(Subjects without experiences of athletic activities were excluded from this analysis.)
ns: $p<\alpha'$ (α'=0.05/12)

Table 3-1 Frequency of concordance between the LQ-based and subjective dominant hands in the integrated data of males and females

		Subjective dominant hand				Complete concordance rate	
		Right	Left	Ambidextrous	Sum	P_0	κ
LQ-based dominant hand	Right	3277	52	55	3384	0.96	0.67
	Left	7	137	17	161		
	Ambidextrous	2	6	4	12		
	Sum	3286	195	76	3557		

between the subjective and the LQ-based dominant hands according to gender and Table 3-2 (above) shows them in each athletic event. No significant differences were noted for different genders (χ^2=0.024, p=0.88) and athletic events (χ^2=16.30, p=0.18). Results based on each athletic event similarly showed no significant difference (χ^2=0.00–1.39, upper probability: p=0.12–50).

Table 4-1 shows the frequencies of the hand actually used in each question item of the Edinburgh Inventory. There were 35 participants who did not answer the question about using a knife (to be more exact, use of a knife when not using a fork; the original sentence is "Knife (without fork)"). Table 4-2 shows the concordance rate between the subjective dominant hand and the hand actually used in each question movement. The frequencies of concordance and discrepancy differed for each movement (χ^2=1305.73, p=0.00: χ^2=1079.68, p=0.00: χ^2=256.10, p=0.00). The above frequencies were significantly lower for the 5th item "Toothbrush", the 8th item "Broom (upper hand)", and the 10th item "Opening box (lid)".

Table 5 is a matrix of the required difference (RD) with significant differences of concordance rates between each movement question. Significant differences between the above three movement questions were found.

Table 3-2 Frequency of concordance between the subjective and LQ-based dominant hands in each athletic event (the integrated data of males and females)

		Concordance		Discrepancy	
		Frequency	Rate	Frequency	Rate
Baseball	n=534	504	(94.4%)	30	(5.6%)
Football	n=334	318	(95.2%)	16	(4.8%)
Basketball	n=387	374	(96.6%)	13	(3.4%)
Volleyball	n=250	239	(95.6%)	11	(4.4%)
Tennis	n=111	109	(98.2%)	2	(1.8%)
Soft Tennis	n=231	222	(96.1%)	9	(3.9%)
Badminton	n=146	137	(93.8%)	9	(6.2%)
Table Tennis	n=223	219	(98.2%)	4	(1.8%)
Swimming	n=296	282	(95.3%)	14	(4.7%)
Track and field	n=222	214	(96.4%)	8	(3.6%)
Kendo	n=188	181	(96.3%)	7	(3.7%)
Others	n=373	361	(96.8%)	12	(3.2%)
Inexperienced	n=262	258	(98.5%)	4	(1.5%)
Total	n=3557	3414	(96.0%)	143	(4.0%)
(Male)	n=2429	2330	(95.9%)	99	(4.1%)
(Female)	n=1128	1084	(96.1%)	44	(3.9%)

Others: Subjects who are involved in athletic events other than the above events.
Inexperienced: Subjects who have had no technical athletic experience.

Table 4-1 Hands actually used in each movement questionnaire (interpolation of Oldfield, 1971)

	Left hand		Right hand		Both hands		Inexperienced	
	Frequency	Rate	Frequency	Rate	Frequency	Rate	Frequency	Rate
Males and females (n=3557)								
1 Writing	110	(3.1%)	3430	(96.4%)	17	(0.5%)	0	(0.0%)
2 Drawing	122	(3.4%)	3403	(95.7%)	29	(0.8%)	3	(0.1%)
3 Throwing	189	(5.3%)	3300	(92.8%)	68	(1.9%)	0	(0.0%)
4 Scissors	159	(4.5%)	3317	(93.3%)	81	(2.3%)	0	(0.0%)
5 Toothbrush	248	(7.0%)	2992	(84.1%)	317	(8.9%)	0	(0.0%)
6 Knife (without fork)	168	(4.7%)	3323	(93.4%)	31	(0.9%)	35	(1.0%)
7 Spoon	168	(4.7%)	3294	(92.6%)	95	(2.7%)	0	(0.0%)
8 Broom (upper hand)	445	(12.5%)	2898	(81.5%)	214	(6.0%)	0	(0.0%)
9 Striking a match	166	(4.7%)	3291	(92.5%)	91	(2.6%)	9	(0.3%)
10 Opening box (lid)	339	(9.5%)	2784	(78.3%)	434	(12.2%)	0	(0.0%)

Table 4-2 Concordance rate between the subjective dominant hand and the actually used hand for each movement in the questionnaire

	Concordance		Discrepancy		Inexperienced	
	Frequency	Rate	Frequency	Rate	Frequency	Rate
Males and females (n=3557)						
1 Writing	3384	(95.1%)	173	(4.9%)	0	(0.0%)
2 Drawing	3387	(95.2%)	167	(4.7%)	3	(0.1%)
3 Throwing	3375	(94.9%)	182	(5.1%)	0	(0.0%)
4 Scissors	3350	(94.2%)	207	(5.8%)	0	(0.0%)
5 Toothbrush	3094	(87.0%)	463	(13.0%)	0	(0.0%)
6 Knife (without fork)	3296	(92.7%)	226	(6.4%)	35	(1.0%)
7 Spoon	3347	(94.1%)	210	(5.9%)	0	(0.0%)
8 Broom (upper hand)	2932	(82.4%)	625	(17.6%)	0	(0.0%)
9 Striking a match	3319	(93.3%)	229	(6.4%)	9	(0.3%)
10 Opening box (lid)	2834	(79.7%)	723	(20.3%)	0	(0.0%)

Table 5 Differences in the concordance rate between the subjective dominant hand and the actual used hand in each movement and the RD (required difference) in a multiple comparison test by Ryan's method using the integrated data of males and females

Item	1	2	3	4	5	6	7	8	9	10
1										
2	0.013									
3	0.013	0.014								
4	0.015	0.015	0.014							
5	0.019	0.019	0.019	0.019						
6	0.017	0.017	0.016	0.016	0.019					
7	0.016	0.016	0.015	0.014	0.019	0.015				
8	0.021	0.020	0.021	0.021	0.022	0.022	0.021			
9	0.017	0.017	0.017	0.017	0.018	0.015	0.016	0.022		
10	0.022	0.022	0.023	0.023	0.025	0.024	0.023	0.024	0.024	

RD: required difference=SE×Zα′/2. If the difference of rate (Pi–Pj) is greater or equal to RD, the null hypothesis is rejected. Shaded cell: $p<0.05$

Discussion

The functional laterality of the upper limbs, called the handedness, is determined by various factors such as genetics, culture, living environment, etc (Hildreth, 1950). Furthermore, a few previous studies reported gender differences in handedness (Oldfield, 1971; Hildreth, 1950). Currently, various sports have become popular throughout many countries, and have seen participation from athletes across multiple age-levels. It has been reported that these acquisition factors in physical activities affect morphological laterality (Bissell and Johnson, 1940).

To date, many studies have examined hand laterality (Shimizu and Endo, 1983; Bryden, 1977; Hardyck et al., 1975) but very few large-scale surveys have been conducted to determine the influence of athletic activities on functional laterality. This study aimed to examine the influence of athletic events and athletic experience on the dominant hand and the reliability of the inventory (Oldfield, 1971) generally used to judge the dominant hand. It was determined that all subjects gave the same answer when resurveyed. Thus, it was suggested that the reliability of the present survey is very high. The inventory used in this study was a very simple one in which participants state which hand was actually used for each movement question. Since the hand used does not change over the short term, the participants should provide the same answer in both surveys.

Significant gender differences in the dominant hands (left, right, and ambidextrous) were clarified by subjective judgment and the laterality quotient (LQ) (Oldfield, 1971). Bryden (1977), Hardyck et al. (1975), and Oldfield (1971) also reported that there is a gender difference in the rate of the dominant hands. It has been widely reported in Europe, the United States, and Japan that left-handedness occurs more often in males than in females. Shimizu and Endo (1983) also reported a left-handedness ratio of 4.03% in males and 2.36% in females in 4,445 high school students. The rates of ambidextrousness were 4.59% in males and 3.39% in females. The results in the present study show almost the same values (subjective left-handedness: 6.5% in males and 3.2% in females; LQ based left-handedness: 5.2% in males, 3.1% in females). No significant gender differences in the dominant hand rate were found in any athletic event. There have been few studies on gender differences in handedness based on athletic events. Itoh and Hatta (2002) investigated the laterality in upper and lower limbs using 233 males and 595 females (86 male university students, 131 female university students, and 147 males and 464 females who participated in the general physical checkup) and reported that there were no gender differences in which hand was dominant. In the present study, the lack of gender differences in the resulting analyses of each athletic event may relate to the small sample size for each event (range of total frequency by athletic events: n=111–534). However, despite showing a gender difference in an analysis of the total sample, the differences were still very slight (2–4%).

Physical activities influence physical fitness elements (strength, endurance, dexterity, etc.). Kimura (1980) reported that muscle strength and the circumference of certain body parts of people with athletic experience is greater in the dominant arm than in the nondominant arm because athletes have superior physical fitness. Recently, significant relationships between strength or activity of the dominant hand and bone density have been elucidated (Ducher et al., 2000). In contrast, few studies have been conducted on the influence of athletic activities on the functional lateral dominance of upper or lower limbs. When demanding pronounced use of a particular upper limb due to the competitive characteristics of a given athletic event, the biased usage may influence the formation of the dominant hand. It is hypothesized that left-handed people have superior functions in physical exercise, attention, and special functions because of a more developed right hemisphere (Geschwind, 1984; Geschwind and Galaburda, 1985; Nass and Gazzaniga, 1987). Many studies (Annett, 1985; Azemar et al., 1983; Wood and Aggleton, 1989) have examined the superiority of left-handed tennis players based on the above hypothesis and concluded that they are superior in recognition, visio-spatial, and visio-gross motor

tasks. However, the present findings showed that athletic experience had no influence on handedness, across all athletic-events; in other words, there was no significant difference in the handedness ratio between athletic events (Tables 2-1, 2). In particular, it is noteworthy that no significant difference was observed between a general student group without athletic experience and athletic groups. From these findings, it is inferred that the influence of athletic experience on handedness is slight. Furthermore, previous studies reported that left-handed athletes are at an advantage in tactical aspects of fighting sport events (i.e., boxing, fencing etc.) (Grouios, 2004). The above-stated tactical advantage may relate to the high incidence of left-handers in high level athletes. Thus, in future studies, examination of athletic ability will also need to be considered.

In this study, the subjective dominant hand specified by each participant was surveyed in addition to the dominant hand based on the Edinburgh Inventory (Oldfield, 1971). The former is, generally, determined by each subject as the dominant hand for reasons such as "easy to use", "easy to maneuver", "easy to exert", "instantaneously used" etc. The laterality quotient (LQ) based on the Inventory is negative when using the left hand in over 5 of 10 question movements but positive when using the right hand in over 5 movements. If the LQ equals 0, subjects are determined to be ambidextrous (Oldfield, 1971). Namely, participants are never determined to be ambidextrous unless he or she uses both hands equally in 10 movement questions. The present findings clarified that there are several people whose subjective and LQ-based dominant hands are not identical, and the number of people with a subjective left dominant hand in spite of an LQ determined right dominant hand was greater than people matching the inverse criteria. However, the subjective and LQ-based dominant hands corresponded to each other with very high agreement (Table 3-1). Thus, the dominant hand determined by the handedness inventory is suggested to determine people's dominant hand with very high accuracy even after a quarter century has passed. The present findings also suggested that the dominant hand is independent of influences due to gender or athletic experiences.

However, when examining each question item, the subjective dominant hand does not necessarily correspond to the hand actually used in each movement question. People that are naturally considered to be left-handed are often forced to use their right hand for some specific movements such as writing or eating due to cultural influences, as in Japan where right-handedness is predominant (Nakao et al., 1997). Hence, many participants may have chosen the correct hand as an answer to each question of the Inventory. In addition, there are differences in historical and cultural backgrounds for the following movements: striking a match (the 9th item of the Inventory), which is less used today due to the spread of small, personal gas lighters; and a broom (a bamboo broom with a long broomstick or a short broom used with one hand) with different sizes (length of broomstick etc.) based on country. The concordance rates between the subjective dominant hand and the actually used hand in each question movement were significantly lower in the three movements of "Toothbrush", "Broom (upper hand)", and "Opening box (lid)". These movements (both hands; 6.0–12.2%) may require both hands or the non-dominant hand more often (both hands: 0.5–2.7%) (Table 4-1). A representative item, "Writing", in which a person who is naturally left-handed is corrected to use the right hand, had a similar discrepancy rate to the other movement questions. Due to the very low rate of people that were originally left-handed, correcting the dominant hand (left to right hand) may have little influence on the present results in all participants. Furthermore, a relatively large number of answers (n=35) without experience were found in the "Knife (without fork)" question in this study. Since people were designated to be ambidextrous only when ten question movements were divided in half based on the formula of LQ, the rate is considered to decrease when including the above item. When excluding the above-stated four movement questions from the inventory, it may become more useful.

Conclusion

There is a slight gender difference in the dominant hand rates, but athletic experiences have little influence on hand dominance. The subjective dominant hand and the dominant hand based on the Edinburgh Inventory are almost identical, but the concordance rate is low in motions involving a toothbrush, a broom (upper hand), and opening a box (lid)). There are a relatively large number of people that did not provide an answer to the question "knife (without fork)". By excluding certain movement questions, one may devise a more useful handedness test.

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Correspondence to: Masanobu Uchiyama, Kanazawa University, Graduate School of Natural Science & Technology, Kakuma, Kanazawa, Ishikawa 920–1164, Japan
Phone: +81–76–264–5610
e-mail: masanobu@ed.kanazawa-u.ac.jp