Material

Characteristics of Center-of-gravity Sway in Middle-aged Females Playing Badminton as a Lifelong Sport

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With the aim of providing a basis for the improvement of physical functions needed to perform lifelong sports, this study examined center-of-gravity (CoG) sway in middle-aged females playing badminton on a regular basis. Thirty middle-aged females with experience of playing badminton were divided into 2 groups based on the volume of training per week: high- (HV) and low (LV)-volume groups. The mean ages of the groups were similar (47.7±4.9 and 47.9±4.2, respectively). To record the CoG sway path, each subject stood on a stabilometer (Anima GP-5000) for 30 seconds, adopting 3 positions: standing on two legs; and standing on one leg on the same side as the hand holding (racket) and not holding (non-racket leg) the racket. Significant differences were observed in the total trace length and outer peripheral area when standing on two legs with the eyes open or closed, as the HV showed lower values than the LV ($p<0.05$). These results support the effectiveness of badminton to reduce CoG sway even when played as a recreational sport by individuals in their forties or fifties, as well as the feasibility of improving the balance ability by increasing the volume of training per week.

Key words : Badminton, Center of gravity, Balance ability, Middle-aged, Female

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1. Introduction

With recent improvements in health-related areas, such as nutrition and medical services, the mean life expectancy in Japan has reached approximately 80 for males and 86 for females, and is continuing to increase annually (Subcommittee for Community-based Health Promotion; 2002). However, the mean healthy life expectancy remains at approximately 70 for males and 73 for females; there is a difference of nearly 10 years between the 2 categories, indicating a prolonged period during which individuals lead an unhealthy life due to difficulty in maintaining their health. In the near future, Japan's aging society is likely to face increased financial burdens to support extensive social insurance service systems. As maintenance of the elderly's health for a longer period reduces the burden on social insurance, increasing the duration of their healthy lives is an important challenge.

Lifestyle-related diseases negatively affect health and are associated with the development of various disorders, such as diabetes, cancer, and obesity (Bouchard et al., 1999; Doll et al., 1981). In order to address them, it is important to develop exercise habits at appropriate intensity levels, and such exercise is expected to contribute to physical and mental health promotion (Paffenbarger et al., 1984; Sesso et al., 2000). Furthermore, in the elderly, it has been shown that age-related decreases in the muscle volume (Visser et al., 1998) increase the risk of falls. Impaired balance is regarded as a factor increasing such risks (Maki et al., 1996). The balance ability is influenced by various human body systems, including: the visual, vestibular, and somatosensory systems. For example, the visual system plays an important role in maintaining a stable balance by continuously transmitting information regarding the position and movements of the body interacting with environments to the nervous system (Lord, 2006). Muscle strength is an important factor to maintain balance, and it has been demonstrated that decreases in the muscle strength are associated with a decreased balance ability (Lin, 2005). In line with this, improvement of the balance ability, which is subject to the influences of various factors, reduces the risk of falls.

The development of appropriate exercise habits is essential to maintain physical and mental health and lead a healthy daily life, and, therefore, it is important for the middle-aged to start performing exercise on a regular basis and maintain physical functions, such as the muscle strength and balance ability. In modern society, the role of sports to lead an active life is being increasingly focused on, and lifelong sports are considered to be key. In fact, various types of exercise, such as walking, swimming, golf, and badminton, are being performed and enjoyed by a broad range of age groups as lifelong sports today. Badminton is a particularly enjoyable sport for all people, regardless of the age or sex. Masu et al. (2014) compared sway in the center of gravity (CoG) between university students belonging to national top-level university badminton teams (high-level) and those playing this sport as a recreation (low-level players), and reported that there were significant differences in the total trace length when standing on the non-dominant leg with the eyes closed between them, as the former showed lower values. In this study, the leg on the same side as the hand holding the racket and that on the other were defined as the racket and non-racket legs, respectively. In another study, the soleus H-reflex when receiving shuttlecocks was compared between individuals with and without experience of playing badminton (Masu et al., 2015). The H-wave was suppressed in the former, while it was promoted in the latter. The H-reflex has been used as an index to evaluate the activity of the stretch reflex arc in a large number of studies (Michael et al., 2008, Nakazawa et al., 2004), revealing that the soleus H-reflex is promoted in sports in which the same patterns of motion are continuously performed (Ogawa et al., 2009), and suppressed in those involving complex movements (Nielsen et al., 1993). It was also noted that when receiving a shuttlecock, the stretch reflex is suppressed to execute movements accurately reflecting motor commands derived from the cerebral cortex, without the influences of such a reflex (Masu et al., 2015). Based on the findings of these studies, we focused on the possibility of badminton improving the balance ability, and facilitating movements that accurately reflect motor commands derived from the cerebral cortex. However, the effect of badminton to improve these abilities has been examined mainly involving university students with high-level central nervous system plasticity and focusing on functional improvements in this system. The question of whether or not badminton also improves the abilities of middle-aged females playing it only as a lifelong sport, in whom central nervous system plasticity is decreasing with age, has not been fully clarified, although it may be possible to reveal the training effect of badminton from different perspectives by targeting such subjects. As prolonging the healthy life expectancy is a crucial challenge in Japan, it is necessary to promote lifelong sports in order to develop appropriate exercise habits. It is also important to develop effective exercise methods by examining physical functions possibly improved through such sports.

The aim of the present study was to examine CoG sway in middle-aged females regularly playing badminton, with the aim of obtaining findings on the effect of lifelong sports to improve physical functions.

2. Methods

2.1. Subjects

Thirty middle-aged females with experience of playing badminton were divided into 2 groups based on the volume of training per week: high- (HV; training 7 hours or more per week) and low (LV; training 6 hours or less per week)-volume groups (Table 1). The mean ages of the groups were similar (47.7±4.9 and 47.9±4.2, respectively). The objective and safety of measurement were explained to all subjects to obtain their consent to voluntarily participate. This study was conducted with the approval of the Ethics Committee of Health Science University (approval number: 20).

2.2. Measurement of CoG sway

To record the CoG sway path, each subject stood on a stabilometer (ANIMA GP-5000) for 30 seconds, adopting 3 positions: standing on two legs; and standing on one leg on the same side as the hand holding (racket) and not holding (non-racket leg) the racket. The first task was performed with the eyes open and closed, while the second and third tasks were only performed with the eyes

Table 1. Age, Physical Characteristics, Experience of Playing Badminton, and Training status of subjects

Item	High-volume of training group (n=15)	Low-volume of training group (n=15)	t-value	cohen's d
Age (years)	47.7±4.9	47.9±4.2	0.154	0.1
Height (cm)	157.7±4.5	156.8±4.2	-0.572	-0.2
Weight (kg)	52.2±5.5	53.3±7.3	0.445	0.2
Experience of playing badminton (years)	14.6±12.3	10.4±7.8	-1.087	-0.4
Frequency of training (sessions/week)	3.0±0.5	2.0±0.5	-5.123*	-1.9
volume of training (hours/week)	9.0±3.2	4.4±1.0	-5.092*	-2.2

*: p<0.05

Frequency of training: the number of training days per week
Volume of training: the training duration (hr) per week

open, as it was difficult for the subjects to maintain their posture for 30 seconds when standing on one leg with their eyes closed. A 2-minute rest period was inserted between measurements. The subjects were also instructed to fix their eyes on a target placed 2 m ahead at their eye level as a method of postural maintenance. On comparison of the CoG sway path between the HV and LV, the possible influence of the body height on CoG sway was considered non-significant, as there were no marked differences between them in this point.

2.3. Data analysis and statistical processing

While referring to previous studies (Masu et al., 2014), CoG sway in each position was recorded at a sampling frequency of 100 Hz for 30 seconds, and the total path length, outer peripheral area, path length per unit area, and mean CoG displacements in the lateral and anteroposterior directions were calculated. The total path length represents the total length of a shift of the CoG during measurement. The path length per unit area is obtained by dividing the total path length by the outer peripheral area. The outer peripheral area refers to the internal area surrounded by the outermost line of the CoG trace. The lateral and anteroposterior path lengths represent the path length in the lateral and anteroposterior directions, respectively. Furthermore, positive and negative values in the lateral direction represent CoG displacements in the directions of the racket- and non-racket legs, respectively, while those in the anteroposterior direction represent CoG displacements in the ventral and dorsal directions, respectively.

All measurements are shown as the mean±standard deviation. For comparison between the HV and LV, Student's t-test was conducted. Furthermore, to extract factors associated with the total path length when standing on the racket leg, multiple regression analysis was performed with the age, number of years of badminton experience, and amount of training as explanatory variables; independent variables were entered using the stepwise method. For statistical processing, Stat View and Microsoft Excel were used. The significance level was set at less than 5% of the risk rate.

3. Results

Table 2-1 and 2-2 shows a comparison of CoG sway in each direction between the HV and LV. When standing on two legs with the eyes open, the HV showed significantly lower values, representing the total trace length and outer peripheral area, and higher values, representing the trace length per unit area, than the LV ($p<0.05$ in both cases). Concerning the mean lateral and anteroposterior displacements, the CoG was displaced more markedly in the LV ($p<0.05$). Similarly, with the eyes closed, the HV showed significantly lower values, representing the total trace length and outer peripheral area ($p<0.05$), while anteroposterior CoG displacement was more marked in the LV ($p<0.05$). There were no significant differences between the groups in any item when standing on the racket leg. In contrast, when standing on the non-racket leg, the HV showed significantly lower values,

Table 2-1. Comparison of CoG Sway in standing on two legs (HV ; n=15, LV ; n=15)

Standing on two legs	With eyes open				With eyes closed			
	HV	LV	t-value	cohen's d	HV	LV	t-value	cohen's d
Total trace length (cm)	36.3±8.1	46.1±9.8	2.897*	1.1	43.0±10.1	55.5±15.0	2.594*	1.0
Outer peripheral area (cm²)	1.7±0.7	2.7±0.9	3.160*	1.2	2.1±1.0	3.2±1.7	2.071*	0.8
Trace length per unit area (1/cm)	23.2±6.3	18.3±4.2	-2.411*	-0.9	24.6±9.2	21.8±9.3	-0.808	-0.3
Mean lateral displacement (cm)	-0.1±0.4	-0.3±0.5	2.131*	0.8	-0.2±0.6	0.1±0.6	1.398	0.5
Mean anteroposterior displacement (cm)	-1.2±1.0	-2.6±1.7	-2.564*	-1.0	-1.0±1.0	-2.1±1.8	-2.116*	-0.8

*: $p<0.05$

Table 2-2. Comparison of CoG Sway in standing on the leg (HV ; n=15, LV ; n=15)

Standing on the leg	Racket-leg				Non-racket leg			
	HV	LV	t-value	cohen's d	HV	LV	t-value	cohen's d
Total trace length (cm)	149.7±41.0	171.4±35.1	1.499	0.6	140.8±26.1	179.5±55.7	2.354*	0.9
Outer peripheral area (cm²)	10.2±6.6	10.3±4.8	0.032	0.01	8.2±5.0	10.1±4.2	1.104	0.4
Trace length per unit area (1/cm)	17.1±5.2	18.6±4.9	0.778	0.3	20.2±5.9	18.8±4.4	-0.697	-0.3
Mean lateral displacement (cm)	4.8±1.6	5.3±0.6	1.090	0.5	-4.6±1.6	-5.3±0.6	-1.504	-0.6
Mean anteroposterior displacement (cm)	0.5±1.2	0.1±1.7	-0.643	-0.2	0.5±1.6	-0.2±1.9	0.270	-0.4

*: $p<0.05$

Table 3. Correlations of age, badminton experience, and volume of training with total trace length on multiple regression in non-racket leg standing (All subj. ; n=30)

Objective variable	Selected variable	Regressor	Standard error	Standard regression coefficient	F-statistic for exclusion	R^2 for degree-of-freedom adjustment	P-value
Total trace length	Age	6.994	1.419	0.672	24.238	0.504	0.0001
	volume of training	-4.632	1.973	-0.320	5.510		

representing the total trace length ($p<0.05$).

Table 3 shows the results of multiple regression analysis with the total path length as an objective variable and the age, number of years of badminton experience, and volume of training as explanatory variables, focusing on standing on the non-racket leg, on which significant differences were observed between the HV and LV. As factors associated with the total path length, the age (x) and volume of training (y) were extracted ($p<0.05$). The multiple regression equation was as follows: the total path length=-143.024+6.994x-4.632y.

4. Discussion

4.1. Comparison between the badminton and control groups

Complex interactions among the vestibular, visual, and somatosensory systems, as well as the muscle strength, are considered to support postural maintenance in a standing position (Orr et al., 2008). For example, the otolith and semicircular canals (the vestibular system) as sensory organs perceiving the positions of the head and body are involved in postural maintenance (Choy et al., 2006). Furthermore, it has been demonstrated that decreases in the lower-limb muscle strength are strongly correlated with increased CoG sway (Lord et al., 1991), and CoG sway improve with increases in the lower-limb muscle strength (Rooks et al., 1997). In the present study, significant differences were observed in the total trace length and outer peripheral area when standing on two legs with the eyes open or closed, as the HV showed lower values than the LV. Furthermore, the lateral displacement of the CoG when standing with the eyes open and its anteroposterior displacement when standing with them open or closed were more marked in the LV, confirming HV members' higher balance ability. In the LV, a tendency of the CoG to be displaced toward the non-racket leg and backwards when standing with the eyes open was also observed. The difference between the 2 groups was particularly marked when standing on the non-racket leg, as the HV showed significantly lower values. At this point, there may have been functional differences between the 2 groups in the non-racket leg associated with the balance ability. As a characteristic of badminton, a greater burden is generally placed on the racket compared with non-racket leg, as the former is placed forward to deliver or receive shuttlecocks. On the other hand, the non-racket leg plays an important role in stabilizing the posture as the support leg. In a previous study examining CoG sway in young badminton players, the total trace length markedly varied when standing on the non-racket leg, similarly to the results of the present study, as high-level players showed lower values than low-level players (Masu et al., 2014). Based on these findings, badminton training may be effective to improve the balance ability on the side of the non-racket leg.

4.2. Effect of badminton to improve physical functions

The variations in CoG sway and displacements among the subjects may have represented the differences among them in various balance-related functions. However, as none of the previous studies involving badminton players compared the vision and sensory organs of those with different performance levels, it is difficult to discuss whether such functional differences led to the variations in CoG sway between the 2 groups in the present study. On the other hand, considering that badminton players with high performance levels have been reported to exhibit greater lower-limb muscle strength (Lars et al., 2007), it is possible that differences in the muscle strength influenced the variations in CoG sway between them; however, as some researchers regard the association between the muscle strength and balance ability as questionable (Wolfson et al., 1996), the degree of such contribution may be relatively low, and the influence of other factors, rather than the muscle strength, is likely to be more marked. Therefore, the variations in CoG sway among badminton players with different performance levels may reflect those in the functions of the central nervous system integrating various types of sensory information and issuing of motor commands. In previous studies examining individuals with experience of playing badminton, even the spinal cord with reportedly poor plasticity was shown to functionally change through such experience. The H-reflex is frequently used as an index to evaluate the positive effects of the stretch reflex as a spinal reflex (Masu et al., 2015). Masu et al. (2015) compared the soleus H-wave between badminton players and those without experience of playing this sport in the receiving position immediately before making a return, and reported that values significantly decreased when gripping a racket with the dominant hand than when just standing in the badminton group, while they increased in the control group. In short, the number of years of badminton experience or long-term physical training leads to changes in the central nervous system related to postural reflexes. However, such changes were observed in previous studies involving young athletes, and the question of whether or not similar influences are also observed among middle-aged females playing badminton only as a lifelong sport has not been clarified. It should particularly be noted that the influence of aging may have been more marked on the subjects of the present study compared with young individuals. As the age (x) and volume of training (y) were selected as factors related to the total path length when standing on the non-racket leg, it may be possible to reduce CoG sway, which is increased with age, by increasing the volume of training. In this respect, the amount of physical activity is likely to be a more important factor associated with the balance ability of middle-aged females playing badminton as a lifelong sport, and players' technical skills may not markedly influence such ability.

4.3. Badminton as a lifelong sport

As the middle-aged females were not compared to those not playing badminton, the effect of badminton to prevent the balance ability from decreasing remained unclear. However, to the present, there have been a large number of reports supporting the effect of exercise to prevent age-related functional declines (Suzuki et al., 2004; Carter et al., 2002). As previously mentioned, it is necessary to increase the volume of training, in order to improve the balance ability. As an excessive volume of training may lead to overwork, consequently increasing the risk of injury, the setting of an appropriate amount is likely to be essential. However, it is unclear which is more effective: to increase the number of training days per week, or volume of training per session. A prolonged volume of training per session increases the exercise intensity level, consequently accumulating fatigue, or the frequency of training possibly remains low after developing a sense of satisfaction through a single training session. Considering such a tendency, it may be possible to increase the frequency of training by limiting the volume of training per session to an appropriate extent and maintaining the motivation to continue training; consequently, the volume of training per week increases. The results of this study support the effectiveness of badminton to reduce CoG sway even when played as a recreational sport by individuals in their forties or fifties, as well as the feasibility of improving the balance ability by increasing the volume of training per week.

5. Conclusion

This study examined CoG sway in middle-aged females regularly playing badminton. It was suggested that badminton remains effective to suppress CoG sway even when played as an enjoyable sport by individuals in their forties or fifties, and possibly improves the balance ability when played at increased volume of training.

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