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Balance control, agility, eye–hand coordination, and sport performance of amateur badminton players

A cross-sectional study

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Abstract

In this study, balance performance, agility, eye–hand coordination, and sports performance were compared between amateur badminton players and active controls.

Thirty young adult badminton players and 33 active controls participated in the study. Static single-leg standing balance (with eyes closed) was measured using a force platform, and dynamic balance was measured using the Y Balance Test (lower quarter). Agility was measured using a hexagon agility test, and eye–hand coordination was measured using a computerized finger-pointing task. Sports performance was quantified by the number of times a shuttlecock fell in a designated area following a badminton serve.

The badminton players had superior accuracy in badminton serving ($P < .001$) relative to the active controls. However, no significant between-group differences were noted in all other outcome variables ($P > .05$).

Amateur badminton players had more favorable sports performance, but not balance performance, agility, or eye–hand coordination, than controls.

Abbreviations: COP = center of pressure, IPAQ = International physical activity questionnaire.

Keywords: performance, physical fitness, postural control, racket sports, visual motor

1. Introduction

Badminton is a popular sport worldwide that requires fast and powerful shots and agile footwork. It is one of the fastest racket sports in the world; the speed of badminton smashes can be as high as 30 m/s.[1] In addition, badminton players must react to the moving shuttlecock and adjust their body position rapidly and continuously throughout the game.[2] They must maintain their center of gravity within the base of support while performing very rapid and asymmetrical upper limb movements.[3] Therefore, superior body balance is crucial for badminton skill advancement, sports performance,[3] and injury prevention.[4] However, badminton players' balance ability has not yet been fully examined. Masu, Muramatsu, and Hayashi[5] reported that when standing on the nondominant leg with their eyes closed, high-level badminton players swayed less than low-level players. Furthermore, Yuksel, Cengiz, Zorba, and Gokdemir[6] revealed that 8 weeks of badminton training can improve dynamic functional balance performance in children. Therefore, we hypothesized that trained young badminton players may demonstrate superior static single-leg standing balance and dynamic functional balance than their untrained counterparts.

Agile footwork such as the ability to change direction over short distances is essential in both defending and attacking maneuvers during badminton training and competitions.[7,8] Agility, which is defined as a rapid whole-body movement with a change of velocity or direction in response to a stimulus,[9] is a crucial variable for outstanding performance in badminton competitions.[8] A previous study reported that elite national badminton players exhibited superior agility relative to amateur badminton players.[10] However, to the best of our knowledge, no study has compared the agility performance between amateur badminton players and active controls. Based on the existing evidence, we postulated that amateur badminton players have more favorable agility performance than nonplayers.

Eye–hand coordination is the ability of the central nervous system to coordinate the information received from the eyes to control, guide, and direct the hands in the accomplishment of a

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given task such as catching a ball.[11] To date, only 3 studies have investigated the eye–hand coordination of badminton players. Dane, Hazar, and Tan[12] suggested that participation in badminton training was associated with superior eye–hand visual reaction time and visuospatial intelligence. Dube, Mungal, and Kulkarni[13] reported that the required visual reaction time of badminton players was shorter than that of sedentary controls. A recent neuroimaging study confirmed that badminton practice, including high-capacity visuospatial processing and eye–hand coordination training, is associated with neuroplastic changes (eg, enlarged gray matter density) in the cerebellum and functional alterations in the frontoparietal connectivity.[14] Therefore, we hypothesized that badminton players' eye–hand coordination is superior to that of non–badminton players.

The aim of this study was to compare the static and dynamic balance performance, agility, eye–hand coordination, and sports performance between amateur badminton players and physically active controls. The results provide a clearer understanding of the sports-specific physical fitness profiles of amateur badminton players. Moreover, these results can be used to develop an evidence-based training strategy to improve physical fitness and sports performance among badminton players.

2. Methods

2.1. Study design

This was a cross-sectional and exploratory study.

2.2. Sample size calculation

Based on the results of previous studies,[5,6,10,13] we conservatively assumed a medium effect size of 0.75, an alpha level of 0.05 (2-tailed), and a power of 0.80 in this study. Therefore, a minimum of 29 participants per group were required (ie, 58 participants in total).

2.3. Participants

Between October and November 2017, a convenience sample of amateur badminton players was recruited from the KaiSeng Badminton Club, Hong Kong, and other local badminton clubs through personal invitations and by electronic means. Healthy active controls (ie, performed general physical activities weekly) were recruited from the university community using the same methods. All volunteers were screened by the principal investigator based on the following criteria. Inclusion criteria – be aged 18 to 30, had more than 5 years of singles or doubles badminton experience and regularly participated in badminton training (>4 h/week) (for badminton group)/received no formal badminton training (for control group). Exclusion criteria – any recent injury that required medical attention; had significant musculoskeletal, neurological, visual, vestibular, cardiorespiratory, or cognitive disorders; were pregnant; or regularly participated in a particular sports other than badminton. Written informed consent was obtained from each participant. The study was approved by the University of Hong Kong and the Hospital Authority of Hong Kong West Cluster Institutional Review Board, and was conducted according to the Declaration of Helsinki guidelines.

2.4. Outcome measurements

All measurements were performed by the principal investigator and 3 trained assistants. The assessments were conducted in the Physical Activity Laboratory of the University of Hong Kong. The participants were asked to provide their demographic information and medical history, if any. Through questionnaires, the badminton training experience of each participant including the number of years of badminton training received, time spent in training each week, and competition records were determined. Their physical activity level was estimated using the International Physical Activity Questionnaire (IPAQ) short form. In addition, body weight and height were measured using a bathroom scale and a cloth measuring tape fixed to the wall, respectively. The body mass index of the participants was then calculated using the following formula: body weight/body height^2. The lengths of the dominant arm and leg were measured using a cloth measuring tape. After collection of the basic demographic data, each participant underwent the following physical tests in a random order within the same day in our laboratory.

2.4.1. Static single-leg standing balance performance. A previous study has reported that postural sway in static single-leg standing could be used to differentiate badminton players of different skill levels.[5] Therefore, static single-leg standing balance performance was selected as an outcome measure in the present study. Static standing balance was measured by asking the participant to stand on their nondominant leg with the eyes closed and arms by the side of the torso on a force platform (FDM-SX, Zebris Medical GmbH, Isny, Germany) for 10 s.[5] The center of pressure (COP) sway path length and average COP sway velocity were recorded and calculated using the Zebris FDM 1.12 software (Zebris Medical GmbH, Isny, Germany). A longer COP sway path length or higher COP sway velocity indicated poorer static standing balance performance.[15]

2.4.2. Dynamic balance performance. Since scientific evidence has suggested that short-term badminton training can improve dynamic functional balance performance of young people,[6] a Y Balance Test (lower quarter) was performed under the supervision of the principal investigator and assistants following standardized procedures as described in the Functional Movement Systems manual.[16] The Y Balance Test is a dynamic test performed in the single-leg standing position. It examines how the core and each leg function under body weight loads. Adequate leg muscle strength, flexibility, core control, and proprioception are required to achieve optimal postural stability.[16] This test has demonstrated good interrater test–retest reliability (intraclass correlation coefficients = 0.80–0.85) and minimal measurement errors among young healthy individuals.[17] Before the test, the participants removed their footwear and stood on the foot plate in the center of the Y Balance Test instrument. Then, the participants were instructed to maintain a single-leg stance while reaching as far as possible with the contralateral leg, and to return to the starting position on the center platform without losing balance. The test required the participant to reach in 3 directions —anterior, posteromedial, and posterolateral—with 3 trials allowed for each leg. The maximum reach distance for each successive trial was recorded. A composite score for each leg was derived using the following equation: composite score = [(sum of the greatest reach in each direction)/(3 × limb length)] × 100.[16]

2.4.3. Agility. Agility is a crucial variable for outstanding performance in badminton competitions[8] and hence was selected as an outcome measure. Agility was measured using the well-known hexagon agility test, which has excellent test–retest reliability (intraclass correlation coefficients = 0.938–0.924).[18] A hexagon with 24-inch sides and 120° angles was marked using tape on the floor, with a 12-inch tape strip in the middle to mark the starting position. At the beginning of the test, the participant stood barefoot on the tape strip in the middle of the hexagon facing the front line. On the command "go," they jumped ahead across the line and then back over the same line into the middle of the hexagon. While maintaining a forward-facing position with the feet together, the participant jumped outside the hexagon and back into it. Each participant was required to complete 3 full revolutions (trials) in both clockwise and anticlockwise directions. A stopwatch was used to record the time of each revolution. Data were not recorded if the participant failed to completely jump over each line demarcating the hexagon, and they were required to repeat the trial.[19] The average completion times of the 3 trials in both the clockwise and anticlockwise directions were used for analysis. A shorter completion time indicated superior agility.[19]

2.4.4. Eye–hand coordination. Eye–hand coordination is a crucial visual motor function that facilitates goal-directed use of the arm, hand, and fingers to produce controlled, accurate, and rapid movements, especially during sporting activities such as badminton.[20] A computerized eye–hand coordination test (a finger-pointing test) was used to test the eye–hand coordination of the participants as it is a valid and reliable test for measuring eye-hand coordination of adults. The test–retest reliability of the eye–hand coordination test was moderate, with intraclass correlation coefficients ranging from 0.68 to 0.71 in adults.[21] The assessment procedures were described in detail in our previous study.[22] In brief, each participant sat on a chair so that the upper edge of the computer screen was at eye level. The participant's hips, knees, and ankles were at 90° of flexion with both feet flat on the floor. The participant's dominant hand (ie, the hand used for writing) was placed on a touchpad at the beginning of the test. Visual targets in the form of a ball appeared in a random order on the left, right, or center of the screen. The visual target appeared 5 times at each location. The participant was instructed to point to each target on the screen with the index finger of their dominant hand as quickly and accurately as possible. After touching the target, the participant immediately placed their hand back in the designated starting position (the touchpad). Each participant repeated this finger-pointing task 15 times (ie, 15 targets in total).[22]

The following outcomes were documented and used for analysis: endpoint accuracy, which was defined as the absolute value of the deviation (linear distance) of the participant's touch location from the center of the visual target; reaction time, which was the duration between the appearance of the visual target and the moment when the hand left the touchpad; and movement time, which was the duration between the hand leaving the touchpad and the moment when the index finger touched the visual target. The average values from the 15 trials were calculated;[22] for the endpoint accuracy, a lower value indicated less deviation and thus higher accuracy, whereas shorter reaction and movement times reflected superior eye–hand coordination.[21]

2.4.5. Sport performance. As badminton players are required to perform a serve with a distance of not less than 396 cm to start the game,[23] the traveling distance of the shuttlecock and accuracy of a serve are critical indicators of sports performance. In this study, badminton performance was quantified by the number of times a shuttlecock fell in a designated area on the floor (400–420 cm away from the standing position of the player) following a badminton serve. Each participant was given the same badminton racket and 10 shuttlecocks. Then, the participant stood on the starting point and performed 10 serves toward the target area (400–420 cm away). The number of times a shuttlecock fell in the target area was recorded and used for analysis.

2.5. Statistical analyses

Statistical analyses were performed using SPSS 20.0 software (IBM, Armonk, NY). Descriptive statistics was used to analyze all the demographic and outcome variables. Given the relatively small sample size, both Kolmogorov–Smirnov tests and histograms were used to evaluate the normality of the continuous data. Independent t tests and chi-square tests were employed to compare the continuous and categorical demographic variables, respectively, between the badminton group and control groups. To compare the outcome variables between the 2 groups while controlling for an inflation of type I error associated with performing multiple t tests, a multivariate analysis of variance was performed for each category of outcomes:

(1) Y Balance Test,
(2) single-leg standing balance test,
(3) hexagon agility test, and
(4) eye–hand coordination test.

Badminton performance was compared between the 2 groups using a Mann–Whitney U test. The alpha was set at 5% (2-tailed). Effect sizes (partial eta squared) of the outcome variables were also reported. By convention, 0.01, 0.06, and 0.14 represent small, medium, and large effect sizes, respectively.

3. Results

In November 2017, a total of 68 healthy adults volunteered to participate in the study, and 63 participants were deemed eligible; 5 participants were excluded as they exceeded the maximum age limit. The characteristics of the participants are presented in Table 1. Thirty badminton players with an average of 11.9 years of badminton training experience and 33 healthy active controls underwent the assessments. No significant differences were evident in the demographic variables and IPAQ physical activity level between the 2 groups ($P > .05$).

All outcome variables are presented in Table 2. For the sports performance outcome (ie., the number of times a shuttlecock fell in the designated area), a significant difference was observed between the 2 groups. Badminton players outperformed the active controls by 80% ($P < .001$). However, no significant between-group differences were noted in the Y Balance Test, single-leg standing balance test, hexagon agility test, and eye–hand coordination test outcomes ($P > .05$), and all the effect sizes were small (<0.001–0.029).

4. Discussion

The major finding of this study was that the experienced amateur badminton players achieved performance accuracy in badminton serves superior to that of the healthy active controls. This result was expected, and may be explained by the unique training methods and repeated practice of badminton serves among the badminton players; badminton players' sense of distance and neuromuscular control in their upper limbs could have improved through regular training. Indeed, a previous study reported that skilled badminton players had greater control of their forearm

Table 1

Characteristics of participants.

	Badminton group (n=30)	Control group (n=33)	*P*
Age, years	24.57±3.47	23.15±2.50	.071
Sex, n	Male=18 & female=12	Male=18 & female=15	.662
Height, cm	166.50±9.78	168.76±7.80	.318
Weight, kg	59.74±9.89	60.48±9.18	.757
Body mass index, kg/m^2	21.45±2.39	21.17±2.29	.636
Physical activity level, MET minutes per week	6454.00±17336.62	3271.27±2653.84	.301
Badminton experience, years	7.93±3.30	—	—
Time spent on playing badminton, hours per week	2.03±0.72	—	—
Age onset of badminton training, years	11.93±4.09	—	—

Values are means±standard deviations, unless otherwise specified.
MET=metabolic equivalent.

muscles, and this enabled greater accuracy of performance.[24] In addition, during data collection, we observed that badminton players preferred backhand serves while the controls preferred forehand serves. The backhand serve is a special short-serve technique commonly used in doubles badminton competitions.[25] It requires fine movement control,[26] which means that the experienced badminton players selected a superior and more appropriate serve technique that improved their performance accuracy. This may explain why badminton players outperformed the healthy controls in serving the shuttlecocks to the target area.

We observed that both dynamic and static standing balance performance were similar between the badminton players and the control group participants. These findings are somewhat different from other studies indicating that badminton training could improve dynamic and functional balance performance[6] and may improve static single-leg standing balance when the players' eyes are closed.[5] The discrepancy in these findings could be explained by the different onset times of badminton training. In the study of Yuksel et al,[6] child participants received badminton training at the age of 9 years, and in the study of Masu et al,[5] high-level badminton players started training at 7.5 years of age. In the present study, the amateur badminton players started badminton training during their teenage years (average 12 years). As the postural control system matures at approximately 14 to 16 years of age,[27–29] the time for improvement may be shorter in our participants. Even if badminton training could improve balance performance, the balance system of our participants was almost mature, and the potential for further dramatic improvement may have been limited. In addition, we recruited an active control group and balance performance could be influenced by physical activity/sports participation, irrespective of the type of physical activity/sports.[30] These reasons may explain why there were no differences in balance performances between the badminton players and controls in this study.

It is widely acknowledged that agility (eg, sprinting, jumping, leaping, lunging, changing direction rapidly, and stopping and starting suddenly) is an essential training element among badminton players.[7,8] Our results revealed that the hexagon agility test performance was similar between the badminton players and controls, indicating that regular badminton training might not improve agility. Our findings may be explained by the participant characteristics; our active control group comprised recreational soccer players, table tennis players, and lacrosse

Table 2

Comparison of Y Balance Test scores, single-leg standing balance test outcomes, hexagon test outcomes, eye–hand coordination test outcomes, and sport performance between badminton players and controls.

	Badminton group (n=30)	Control group (n=33)	*P*	Effect size
Y Balance Test (lower quarter)				
Right composite score	95.70±8.67	98.53±7.93	.182	0.029
Left composite score	98.43±8.65	99.19±8.25	.722	0.002
Single-leg standing balance test (with eyes closed)				
COP sway path length, mm	966.67±294.00	954.55±327.96	.878	<0.001
COP sway velocity, mm/s	499.63±2175.86	100.30±32.55	.296	0.018
Hexagon agility test				
Completion time (clockwise), s	26.86±8.04	26.64±10.66	.927	<0.001
Completion time (anti-clockwise), s	25.42±5.67	24.50±9.23	.639	0.004
Eye hand coordination test				
Reaction time, ms	319.69±45.07	329.18±27.75	.313	0.017
Movement time, ms	415.61±102.02	412.91±86.81	.910	<0.001
Accuracy, mm	4.71±1.83	4.52±1.13	.607	0.004
Sport performance				
Average number of times a shuttlecock hit the target, n	3.33	1.85	<.001*	

Values are means±standard deviations, unless otherwise specified.
COP=center of pressure.
* $P<.05$.

players. Soccer,[31] table tennis,[32] and lacrosse training[33] may also improve agility. This may explain why we could not identify any significant difference in agility performance between the amateur badminton players and active controls. Another plausible reason is that the hexagon agility test may not be sufficiently sensitive to evaluate badminton-specific agility performance. The Illinois agility test could be a superior instrument for assessing the agility of badminton players.[34]

Our results also revealed that eye–hand coordination was similar between the badminton players and controls. This finding was in contrast to our postulation and previous studies demonstrating that badminton players had superior eye–hand reaction time,[13] visuospatial processing, and eye–hand coordination[14] relative to those who do not play badminton. This may be because the finger-pointing task we used in this study was too static and required fine motor control. However, dynamic eye–hand coordination ability and gross motor control are applied during badminton practice. Our participants may not have been able to carry over the effects of badminton training to the static finger-pointing eye–hand coordination test.[22] Future studies should assess eye–hand coordination using badminton-specific functional tasks instead.

This study has several limitations apart from those stated previously. First, a cross-sectional study design was employed, and the causal relationship between badminton training and all physical fitness and performance outcomes could not be established. Second, lower limb kinematics are known to affect Y Balance Test performance,[35] but we did not account for this confounding factor when analyzing the data. Third, the static balance ability being measured by postural sway in single-leg standing and dynamic balance ability being measured by Y Balance Test may not give a comprehensive measure of balance ability of amateur badminton players. Further study may explore the anticipatory or reactive balance ability of these players.[28] Fourth, although we followed standardized and well-established procedures in measuring static and dynamic balance performance, agility and eye-hand coordination, some of the assessments have not been well validated in previous literature. Fifth, we included an active control group in the present study. Since fitness or performance characteristics such as balance, agility and eye-hand coordination could be influenced by physical activity/sports participation, irrespective of the type of physical activity/sports,[30,36] future studies should engage inactive individuals as controls. Finally, our results were obtained from a sample of amateur badminton players. Therefore, they could not be generalized to badminton players at other training levels (eg, elite badminton players). Future studies can adopt a randomized controlled study design to investigate the effects of badminton training on eye–hand coordination, body balance, agility, and sports performance among amateur badminton players while controlling for the effects of all known confounding variables. Nevertheless, the results of this study may benefit athletes and coaches seeking to identify the sport-specific physical fitness profile and performance of amateur badminton players.

5. Conclusions

Amateur badminton players had superior performance accuracy in badminton serving, but not static and dynamic balance performance, agility, or eye–hand coordination, relative to healthy active controls. Further studies may adopt a randomized controlled study design to confirm the effects of badminton training on these outcome measures. Nevertheless, the results of this study may benefit athletes and coaches seeking to identify the physical fitness profile and performance of amateur badminton players. Moreover, these results can be used to develop an evidence-based training strategy to improve sports performance of amateur badminton players.

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