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Correlation between core muscle strength and hand-eye coordination in badminton players

Vidhi Rajani and Dr. Chintan Solanki

Abstract
Badminton players need to have certain physical characteristics such as balance, coordination, agility, muscle strength. They also need specific movement patterns such as twists, hops and swings. The core acts as a muscle corset stabilizing the body and spine both with and without limb movement. Weak core is thought to disrupt energy transfer, reducing athletic performance and increasing chance of damage to the muscle area. Eye-hand coordination is a critical visual motor function allowing goal-directed use of the arm, hand and fingers to create quick movement.
Method: 45 participants were selected based on the inclusion criteria using convenient sampling. Subjects were evaluated for core muscle strength using plank test. Participants were evaluated for hand-eye coordination using alternate wall toss test on the same day.
Result: Statistical analysis was done using Karl-Pearson Correlational analysis. Correlation coefficient r-value for plank test and alternate wall toss test has been recorded as 0.979 which is statistically highly significant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other.
Conclusion: There is a strong positive correlation between core muscle strength and hand-eye coordination in badminton players. More the core muscle strength, more fine is the hand-eye coordination in badminton players.

Keywords: Alternate wall toss test, badminton players, core muscle strength, eye-hand coordination, plank test

Introduction
Badminton is one of the most popular and widely practiced sports in India and the world today [3]. A shuttlecock is hit across a net while playing the racquet sport of badminton [3]. This sport has five events: men’s and women’s singles, men’s and women’s doubles, and mixed doubles, each requiring specific preparation in terms of technique, control and physical fitness [8]. Badminton is characterized by high intensity, intermittent actions [8]. For this, quick changes of direction, hops, lunges at the net, and swift arm motions from various postural postures are necessary [8]. The attributes needed by badminton players include muscle power, muscle endurance, power, speed, agility, balance, and coordination [3].
The core can be visualized as a muscular box with the abdominals in the front, the paraspinals and glutes in the back, the diaphragm as the roof, and the pelvic floor and hip girdle muscles as the bottom [9, 11]. The thoracolumbar fascia, known as "nature's back belt," mediates the actions of the core [11]. To the middle and posterior layers of the thoracolumbar fascia, the transversus abdominis bears substantial attachments [1]. Moreover, the lumbarspinous processes are attached to by the deep lamina of the posterior layer [11]. A connection between the lower limb and the upper limb is made possible by the thoracolumbar fascia, which is a component of the "hoop" that surrounds the trunk [11]. The thoracolumbar fascia also performs as a proprioceptor, giving feedback on the location of the trunk, as the muscle contents contract [11].
The distal segments move on an anatomical foundation provided by the core [14]. This qualifies as "proximal stability for distal motion [14]." Based on placement and attachment sites, the muscles that make up the core can be categorized into local and global groups [14]. The local group is made up of the small, deep muscles (such as the quadratus lumborum, multifidus, rotatores, interspinales, inter transversalis, transversus abdominis, and internal oblique

abdominis) that regulate motion between adjacent vertebrae or operate to raise intraabdominal pressure [14]. The global group, on the other hand, is made up of the vast, superficial muscles that move force from the thoracic cage to the pelvis (such as the rectus abdominis, external oblique abdominis, erector spinae, and latissimus dorsi [14].

Coordination is the capacity of the body to integrate several movements into a single, harmonic and effective movement [2]. A badminton player's ability to execute successfully can be significantly impacted by how long it takes them to interpret visual cues [2]. Proper eye-hand coordination requires the cooperative operation of numerous sensorimotor systems, including the visual, vestibular, proprioceptive, and the eye, head, and arm, as well as parts of cognition including attention and memory [12]. For athletes participating in visuomotor demanding sports, it is essential to perceive visual cues in the field of view and to in a targeted motor response under critical time pressure. The head and eyes serve as a point of focus for the arm's aim and serve to focus the desired object [15]. It takes practice to synchronize your vision and arm motion [15]. Saccades, which are quick eye movements, bring the item of interest into focus on the fovea, the area of the retina with the highest level of visual acuity, and are what causes this fixation [15]. Moreover, even when the hand is not visible, efferent and/or afferent signals relating to gaze location can be employed to direct the hand. (Prablanc *et al*., 1979, 1986, 2003) [17].

When performing a typical reaching movement sequence, saccades are precisely timed to arm movement [13]. In addition to improving manual accuracy through visual feedback and the use of gaze-related signals to guide the hand, direct gaze to contact locations may serve two further functions (Johansson *et al*., 2001; Flangan *et al*., 2006) [16, 13]. First, foveating a contact location at the time of contact may facilitate the comparison or predicted and actual sensory events related to contact (including visual, tactile or auditory event) [13]. Second, by aligning gaze with contact events, the sensorimotor system may be able to establish and maintain relations between retinal and extraretinal signals [13].

In order to compete in racket sports, athletes must process information in a Time-constrained environment [8]. Action, observation, and attention are intimately related [8]. In order to regulate, guide, and direct the hands to complete a task, the central nervous system must be able to coordinate the information from the eyes [8]. The brainstem, basal ganglia, cerebellum, some frontal and parietal structures, as well as several regions of these play important roles in the regulation of saccades and EHC. Elite players displayed increased activity in the frontal areas, particularly during the early stages of the action sequence [8]. This serves as a relay, sending from visual-processing regions to motor-processing regions, which promote visuomotor coordination [8].

Thus badminton players have better visuomotor skills than people who don't play racket sports [8]. The sensory-motor programming of badminton players appears to be well developed []. Elite badminton skills require fine motor dexterity of 8the hands because they use the coordination of small muscle movements, such as the fingers in coordination with the eyes [8]. Badminton players employed the visual search strategy to react quickly and move with more speed, accuracy, and precision. The cerebellum is crucial for the synchronization of the eye and hand during reaching and tracking tasks. According to studies, the posterior parietal cortex also contributes to the integration of visual feedback into ongoing arm movements (Desmurget *et al*. 1999; Pisella *et al*. 2000) [12]. It's often believed that vision for reaching is initially encoded in an eye- or gaze-centered frame [12]. Muscular contraction is the last phase of eye-hand coordination [12]. Although hand position is the variable that can be adjusted, the key muscles that do so have stable insertion locations in the upper arm and shoulder, which serve as the ultimate frames of reference for eye-arm synchronization [12]. Although there are studies Johansson *et al*., (2001) [16] and Bowman *et al*., (2009) [13] linking hand-eye coordination to hand dominance, visual reflex, movement time, and reaction time, to our knowledge there are no studies explaining the connection between the hand-eye coordination and core muscle strength. Because both tend to influence gross motor and fine motor function, we hypothesised that the hand-eye coordination might be influenced by the performance of the core muscles. In order to better understand the relationship between core muscular strength and hand-eye coordination, this study is necessary.

Materials and Methods

Materials

- Stopwatch.
- Tennis ball.
- Mat.
- Cones.
- Consent form sheet.

Study type: Observational study
Sampling design: Convenient sampling
Sample size: 45
Study population: Badminton players.
Study duration: 6 months
Study setting: Badminton clubs, Sangli District.

Method of collection

The study was conducted on 45 elite badminton players both male and female of age group 18-30 years who were willing to participate in this study. Subjects with any recent fracture, disc pathology, musculoskeletal, cardiorespiratory, visual, vestibular, neurological and cognitive disorder were excluded. Subjects who had more than 2 years of singles or doubles badminton experience or who regularly participated in badminton training were included. The study was explained to subjects and written consent was taken. First the subjects were evaluated for core muscle strength using the Plank test. Then Hand-eye coordination was assessed using Alternate wall toss test.

Outcome measures

1. Core muscle strength

The plank test

First, the core muscle strength was assessed using the Plank test. Participants had the proper plank position described and demonstrated for them by a physiotherapist. In particular, they were demonstrated how to lie on a yoga mat with just their forearms and toes touching the surface. After that, they were instructed to assume a position with their head, neck, back, and hips in a neutral position and hold it for as long as they could. Participants started the test by holding a basic plank position - a prone bridge supported by the forearms and feet. Hip width apart with the ankles at 90 degree and knees straight. Pelvis tilted into a neutral position and back flat. Elbows bent to 90 degrees and placed directly below the shoulders. Elbows were vertically below the shoulders with the forearms and fingers extending straight forward. The neck was kept neutral so that the body remained straight from the head to the heels. Participants were instructed to maintain a neutral position of the spine and pelvis, and to breathe normally during testing. Time began when the participant was in the proper positioning and indicated they were ready to begin. Time was noted when the position was first established and concluded when participants quit freely or were unable to maintain the necessary neutral position. Participants weren't told of their times. Each test was terminated when the participant was unable to maintain their posture or their pelvis moved up or down five or more cm. Each holding time was recorded using a stopwatch

Table 1: Shows normative data for plank test for females

Percentile	Seconds	Fitness classification
<25	<63	Poor
25-50	63-90	Below average
50-75	91-121	Good
>75	>121	Excellent

Table 2: Shows normative data for plank test for males

Percentile	Seconds	Fitness classification
<25	<77	Poor
25-50	77-106	Below average
50-75	106-128.5	Good
>75	>128.5	Excellent

Fig 1: The plank test.

2. Hand-eye coordination

Alternate wall toss test

After core muscle assessment, hand-eye coordination was evaluated using the Alternate hand wall toss test. Alternate hand wall toss training is one of the training that has been modified from simultaneous ball throw training. To conduct this test, a tennis ball is required. Participants stood facing a wall, two meters behind a retaining line, holding a tennis ball, whether on the right or left hand. Knees should be slightly bent with the feet shoulder width apart. At the starting signal, the participant tosses the tennis ball in an upper-arm motion from the right hand against the wall and catches it with the left hand. Same goes if it has been thrown with the left hand, it should be caught with the right hand. The ball is thrown with this movement repeatedly as many times as possible in 30 seconds and the number of successful catches are recorded. The parameters tested in this specific test include Hand-eye coordination.

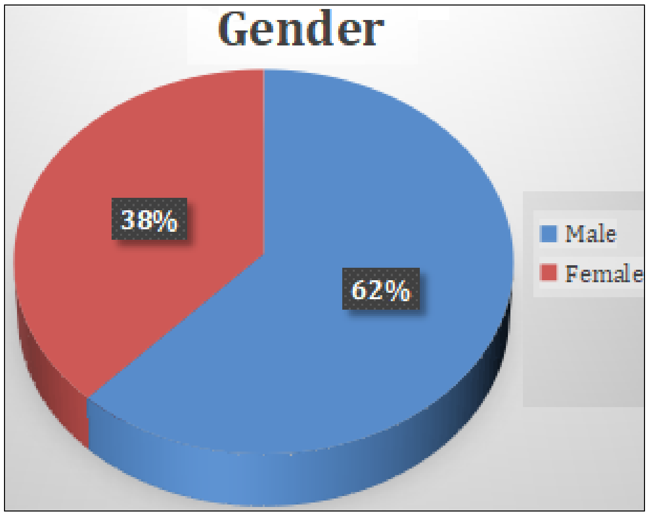
Fig 2: Alternate hand wall toss test.

Results and Discussion

Statistical analysis was done using Karl-Pearson Correlational Analysis

Table 3: Depicts number of males and females

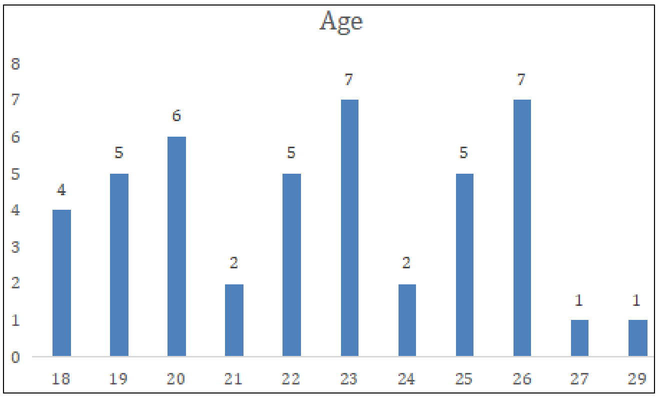
Gender	Frequency	Percent
Male	28	62
Female	17	38
Total	45	100.0



Graph 1: Gender graph

Table 4: shows demographic data of age

Age	Frequency	Percent
18.00	4	8.9
19.00	5	11.1
20.00	6	13.3
21.00	2	4.4
22.00	5	11.1
23.00	7	15.6
24.00	2	4.4
25.00	5	11.1
26.00	7	15.6
27.00	1	2.2
29.00	1	2.2
Total	45	100.0

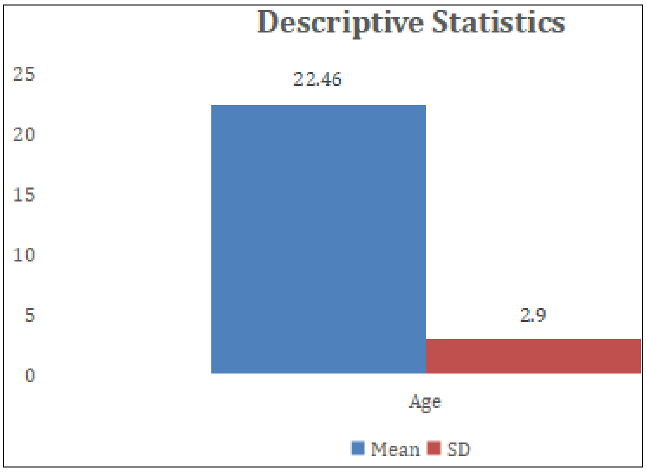


Graph 2: The age Graph

Descriptive Statistics

Table 5: Shows the mean value and standard deviation of age.

Particular	Min	Max	Mean	SD
Age	18.00	29.00	22.46	2.90

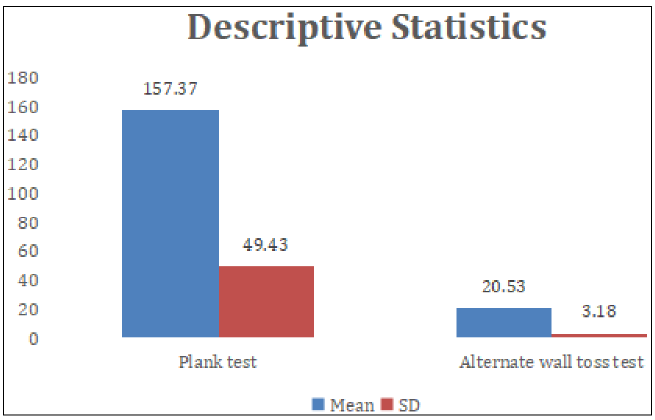


Graph 3: Shows the mean values and standard deviation of the age

Descriptive Statistics

Table 6: Shows the mean values and standard deviation value for the plank test and the alternate wall toss test

Particular	Minimum	Maximum	Mean	SD
Plank test	61.00	226.00	157.37	49.43
Alternate wall toss test	14.00	25.00	20.53	3.18

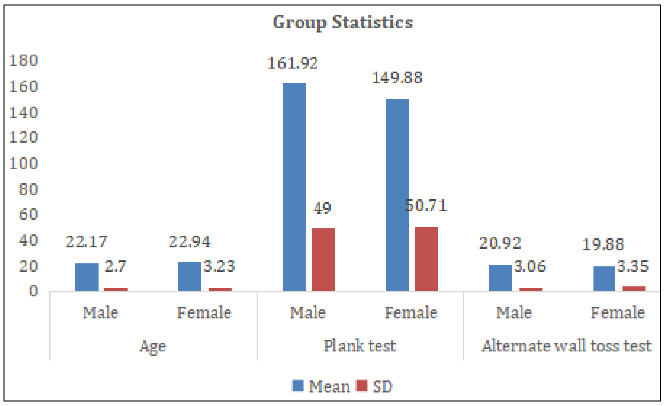


Graph 4: Shows the mean values and standard deviation value for the plank test and alternate wall toss test.

Group Statistics

Table 7: shows group statistics values for the age, plank test and alternate wall toss test

Variable	Gender	N	Mean	SD
Age	Male	28	22.17	2.70
	Female	17	22.94	3.23
Plank test	Male	28	161.92	49.00
	Female	17	149.88	50.71
Alternate wall toss test	Male	28	20.92	3.06
	Female	17	19.88	3.35



Graph 5: shows the group statistics values for the age, plank test and alternate wall toss test.

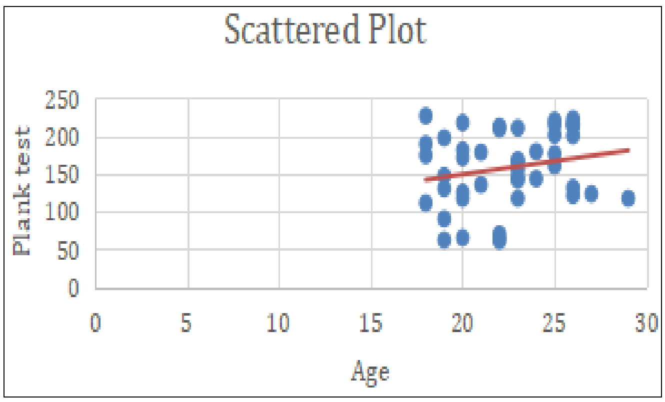
Karl Pearson Correlation Analysis

Table 8: shows the correlation analysis between age and the plank test with alternate wall toss test

Variable X	Variable Y	R-Value	P-Value	Result
Age	Plank test	0.208	0.171	Non-Significant at 5% Linear association
	Alternate wall toss test	0.243	0.108	Non-Significant at 5% Linear association

Correlation coefficient r-value for Age and Plank test has been recorded as 0.208 which is statistically insignificant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables

Correlation coefficient r-value for Age and Alternate wall toss test has been recorded as 0.243 which is statistically insignificant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables



Graph 6: Correlation between Age and the Plank test.

Karl Pearson Correlation Analysis for Male gender

Table 9: Shows correlation analysis for male gender

Variable X	Variable Y	r- value	p-value	Result
Age	Plank test	0.179	0.363	Non-Significant at 5% Linear association
	Alternate wall toss test	0.225	0.251	Non-Significant at 5% Linear association

Correlation coefficient r-value for Age and Plank test has been recorded as 0.179 which is statistically insignificant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables.

Correlation coefficient r-value for Age and Alternate wall toss test has been recorded as 0.225 which is statistically insignificant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables

Karl Pearson correlation analysis for female gender

Table 10: Shows correlation analysis for female gender.

Variable X	Variable Y	r- value	p-value	Result
Age	Plank test	0.293	0.328	Non-Significant at 5% Linear association
	Alternate wall toss test	0.253	0.198	Non-Significant at 5% Linear association

Correlation coefficient r-value for Age and Plank test has been recorded as 0.293 which is statistically insignificant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables

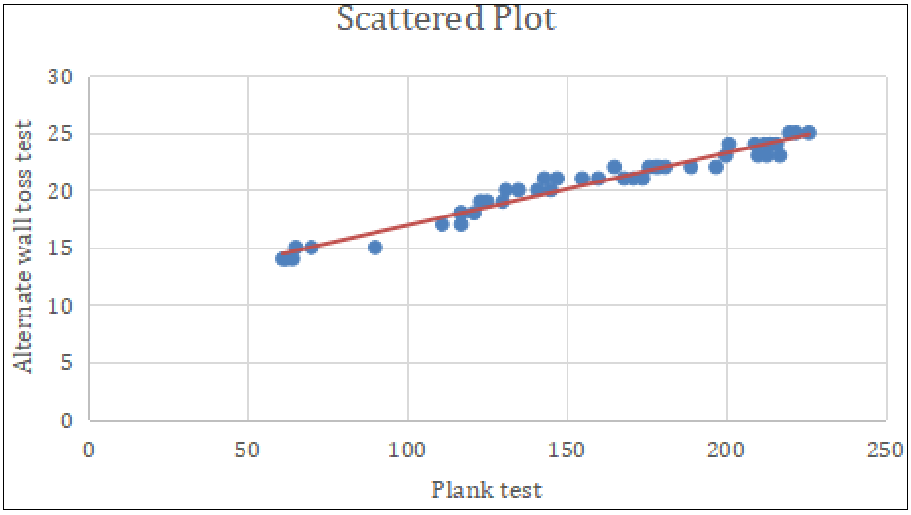
Correlation coefficient r-value for Age and Alternate wall toss test has been recorded as 0.253 which is statistically insignificant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables

Karl Pearson correlation analysis

Table 11: Shows correlation between Plank test and the Alternate wall toss test.

Variable X	Variable Y	R-Value	P-Value	Result
Plank test	Alternate wall toss test	0.979	0.001*	Significant at 5% Linear association

Correlation coefficient r-value for Plank test and Alternate wall toss test has been recorded as 0.979 which is statistically highly significant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables.



Graph 7: Correlation between the Plank test and the Alternate wall toss test.

Karl Pearson Correlation Analysis for Male Gender

Table 12: shows Correlation analysis between plank test and the alternate wall toss test in male gender.

Variable X	Variable Y	R-Value	P-Value	Result
Plank test	Alternate wall toss test	0.979	0.001*	Significant at 5% Linear association

Correlation coefficient r-value for Plank test and Alternate wall toss test has been recorded as 0.979 which is statistically highly significant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables.

Karl Pearson Correlation Analysis for Female Gender

Table 13: shows correlation analysis between the plank test and the alternate wall toss test in female gender.

Variable X	Variable Y	R-Value	P-Value	Result
Plank test	Alternate wall toss test	0.981	0.001*	Significant at 5% Linear association

Correlation coefficient r-value for Plank test and Alternate wall toss test has been recorded as 0.981 which is statistically highly significant at 5% level with linear association. It means both the variables are moving in the same directions at the time association with each other. It is also called as direct relationship between the variables.

Discussion

The present study was done to determine the correlation between core muscle strength and hand-eye coordination. The study included 45 samples. We assessed the core muscle strength of badminton players using the Plank test and hand-eye coordination was assessed using the Alternate hand wall toss test. The results indicate that there is a strong direct correlation between core muscle strength and hand-eye coordination in badminton players. Descriptive statistics were used to find out the mean and standard deviation from demographic data and variables studied, and the mean age (in years) of the study participants is 22.5 years with the standard deviation of 2.90. This particular group was chosen as our target demographic because it is established by Luis-Simon-Chico *et al*. that Women's doubles players attained their greatest ranking at a younger age (23 years) than men's and mixed doubles players (25 years).

Players of badminton need qualities like muscular strength, muscular endurance, hand-eye coordination, power, agility, and balance. When performing athletic skills, a stable core provides a base for the muscles of the upper and lower extremities to accelerate body segments and transfer force between distal and proximal body segments. By hand-eye synchronization, the eyes can indirectly coordinate with hand motion. Although there are studies Johansson *et al*., (2001) [16] and Bowman *et al*., (2009) [13] linking hand-eye coordination with hand dominance, visual reflex, movement time, and reaction time, there are no documented studies explaining the connection between the hand-eye coordination and core muscle strength, as of yet. Because both tend to affect gross motor and fine motor function, we hypothesized that the performance of the core muscles could affect hand-eye coordination.

In our study, the Mean values for plank test for male and female gender are 161.92 and 149.88 respectively with Standard deviation of 49.00 in males and 50.71 in females. The plank test was conducted in this study without a time limit because it has been shown to be a very practical, feasible and accurate method to evaluate torso muscle strength. This positive correlation illustrates how the core provides a solid foundation for the trunk to move on. This demonstrates that the upper limb excursion was stabilized and rendered smooth by core strength. The r-value and p-value for Plank test and Alternate wall toss test has been recorded as 0.979 and 0.001 respectively stating core muscle strength has an influence on eye-hand performance. As part of motor programming, the core muscle contracts on an involuntary basis, according to Friedli *et al*., 1984 [18]. When the sensory-motor system of the mechanoreceptors is triggered, these muscles are recruited in response. Inadequacy in this system causes an imbalance in the load distribution, which reduces stability. The Central Nervous System uses feedback and feed forward control systems to regulate the core muscles. Studies by Chari *et al*. (1986) [19] revealed that a person's lower limb significantly controls their trunk while they are sitting when they reach forward. According to Dean CM, when reaching actions in a sitting position extend beyond the length of the upper limb, the lower limb aids to break the body's forward motion and preserve posture. These studies show that human mobility is complex and that each portion of the body has an impact on the others. This might explain the significant results in our study.

Studies in the sport of badminton have demonstrated the critical importance of core stability with an emphasis on the unique demands of strength to pass from the ankle-knee-badminton-core area-fingers-wrist in badminton skills, which represents the whole system performance in this activity. A powerful lower extremity generates forces that move up to the upper body through the core muscles. (2012) Justin Shinkle *et al*. Rotation is likely to happen if the core is unable to withstand the forces, leading to an energy leak, a breakdown in technique, and eventually a decrease in performance. With the least amount of rotation and energy loss, a strong core will transfer the forces.

According to a study by Justin Shinkle and colleagues, core strength has an impact on how much power is present in the extremities. The stabilizing foundation for the operation of the extremities and the transmission of force is provided by the muscles of the core. The main goal of this investigation was to learn more about any impact the core muscles may have on the distribution of forces within the body. Several indicators of how the core affects forces within the body have been demonstrated through the development and application of a dynamic core test.

The present study shows the mean values for Alternate wall toss test for males and females 20.92 and 19.88 respectively, with standard deviation of 3.06 and 3.35. Redzwan Nazly Razali Chong *et al*. (2013) examined the impact of an alternative hand wall toss test on athletes who compete in archery, shooting, and fencing. The alternating hand wall throw training significantly reduced the group's reaction time when compared to the group who did not practice the training, according to the results. For a five-week period, this study used an alternating hand wall toss training as an intervention to enhance participants' reaction times. After participating in a four-week visual training programme for racquet sports, one study (Abernethy and Wood) found no improvement in motor vision performance.

In order to ascertain the relationship between core muscular strength and hand-eye coordination in non-athletes with low back pain, Anusha Reddy *et al*., (2017) [1] did a study. Based on the selection criteria, 20 non-athletic subjects with low back discomfort were chosen. The Plank Test and Sorensen Test were used to measure the strength of the core muscles on Day 1. The alternate wall toss test was used to gauge hand-eye coordination on day two. The study's findings demonstrated a large, strong positive association between core muscular strength and hand-eye coordination in non-athletes with LBP. The examination of the plank test relationship with AWT indicated a perfect positive correlation ($r=0.8$) with a maximal strength, indicating that the more core muscular endurance, the better the hand-eye coordination.

If there is an impact on arm muscular power, hand-eye coordination, flexibility, and confidence to smash badminton skills, either directly or indirectly, has been studied by Myrza Akbari *et al*. (2017) [2]. The findings revealed that (1) Arm strength has a 66.55% indirect impact on badminton smash skills. (2) Badminton smash skills are directly impacted by hand-eye coordination by 8.64%. (3) Badminton smash skills are directly impacted by torso flexibility by 10.43%. These results suggest that in order to develop smash badminton skills, arm muscle power, hand-eye coordination, and torso flexibility must be taken into account and increased.

Hand-eye coordination and Agility were compared in a study by Memet Muhamad *et al*., (2020) [5].

It was determined from the results that a cricket player's fielding abilities are partially influenced by hand-eye coordination.

Heli Nitin Savla *et al*. (2020) [3] presented a similar correlational investigation between core strength and agility in badminton players. According to this research, badminton players' core strength and agility are correlated.

Core strength has been demonstrated to affect badminton players' dynamic balance and agility by Dr. Sighamoney *et al*. Postural control seems to be improved by repeatedly engaging the core muscles and moving the extremities. A strong core gives the muscles in the upper and lower extremities the foundation they need to accelerate body segments and transfer force between distal and proximal body segments while performing sports skills.

There is strong evidence that the cerebellum plays a critical role in the coordination of the eye and hand during pointing, tracking, and reaching actions. The cerebellum is known to facilitate motor control, coordination, motor learning, temporal prediction, and timing. It's commonly believed that the cerebellum acts as a "forward model" of the hand, taking into account information about the current state of the motor system as well as the desired outcome to help design the next motor command.

Badminton training, according to Dane, Hazar, and Tan was linked to better eye-hand visual reaction speed and visuospatial intelligence. Badminton players' needed visual reaction times were quicker than those of inactive controls, according to Dube, Mungal, and Kulkarni's report from 2013. Badminton practice, including work on high-capacity visuospatial processing and hand-eye coordination, has been linked to neuroplastic changes in the cerebellum (like increased gray matter density) and functional changes in frontoparietal connectivity [14]. We therefore proposed that badminton players' eye-hand coordination is better than that of non-players.

Only a few reliable tests exist to measure hand-eye coordination, and the same is reflected in the literature. The main finding of this correlational study is that hand-eye coordination exercises should be taught to subjects in Badminton players, which is the main conclusion we aim to convey. Additionally, we place a strong emphasis on the utilization of core muscle development as a strategy for enhancing athletic hand-eye coordination.

Conclusion

There is a strong positive correlation between core muscle strength and hand-eye coordination in badminton players. More the core muscle strength, more fine is the hand-eye coordination in badminton players.

Appendix

Ethical clearance letter
Consent form

Acknowledgement

I, take this wonderful opportunity to thank all the “Hands” which have joined together to make this project a Success.

It’s my great pleasure and privilege to express my deep-felt gratitude to our respected Principal Dr. Aakanksha JOSHI and Guide Dr. Chintan Solanki who immensely helped me and rendered their advice, precious time, constant encouragement, knowledge and relevant information regarding my study, and whose suggestion and guidance has enlightened me on this subject. I express my sincere thanks to all the teaching & non-teaching staff of the Miraj Medical Centre, College of Physiotherapy. I would also thank the medical students for willingly accepting to be part of this project and sparing their precious time for it. I would like to thank my parents for their blessings, love, constant support, affection and encouragement. Praise and Glory to the God Almighty who is the source of strength, foundation of my knowledge and the source of inspiration in every walk of life.

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