CHALLENGES OF SPORTS POLICY IMPLEMENTATION IN INDIA: A SPORTS MANAGER'S PERSPECTIVE

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Abstract:
Sports development in India has been significantly impacted by a persistent issue related to the implementation of policy initiatives introduced as early as 2001. Consequently, this research examines the measures and obstacles faced in the implementation of Sports Policies in India focusing mainly on the perception of Sports Managers. A total number of 25 (n=25) Sports Managers from a diverse region across the country participated in the study, providing their insights through questionnaires and interviews. The gathered data was meticulously analysed, leading to the identification of several hindrances across all aspects of sports development in India where corruption and poor governance being identified as the major ones. Hence, by understanding the perspectives of these key stakeholders, valuable suggestion has been made to address the barriers and enhance the overall sports ecosystem in the country.

Key words: Sports, Sports Policy, Sports Governance, Sports Development

Introduction

According to the seventh schedule of the Indian constitution, the domain of sports falls under the purview of State governments. The responsibility for the advancement and promotion of sports predominantly lies with the State governments, while the Central government offering support to the States only in specific endeavours.

Sports policy in India plays a crucial role in shaping the development and promotion of sports and athletic activities across the country. According to Anderson (2005) a policy is a principle or procedure to guide decisions and attain rational outcomes, it serves as a framework that guides and governs various aspects related to sports infrastructure, talent identification and nurturing, funding and support systems, and the overall growth of sports at all levels.

Over the years, the Indian government has recognized the significance of sports in fostering national unity, promoting physical fitness, and achieving excellence in international competitions. As a result, several policy initiatives have been introduced to provide a structured approach to sports development. In 1984, India introduced its first sports policy, which marked the initial governmental effort to mainstream sports and create a favourable environment for its growth and expansion. Subsequently, in 2001, a new sports policy was formulated and adopted with a focus on talent identification, nurturing, and achieving excellence at the national and international levels.

India, despite being the second-most populated country in the world with a strong-growing economy, it is still considered an underachiever in sports (Chelladurai et al. 2002, Chelladurai and Nair 2017, The Economic Times 2019a). This is clearly due to a lack of investment in sport, as India has yet to manage to implement numerous initiatives (Chelladurai and Nair 2017)

One of the significant milestones in Indian sports policy was the establishment of the Ministry of Youth Affairs and Sports in 1982. This dedicated ministry oversees the formulation and implementation of sports policies and programs at the national level, working in collaboration with various sports bodies and organizations. Kraus and Curtis (1990) viewed policies as a guide to accomplishment. Additionally, the Sports Authority of India (SAI) plays a crucial role in implementing sports policies and programs. SAI is responsible for developing and maintaining sports infrastructure, providing coaching and training facilities, and identifying and nurturing talented athletes through its various training centres and academies.

Kraus and Curtis (1990) viewed policies as a guide to accomplishment. They also looked at policies as management strategies that reflect major departmental moralities in the provision of services, operation of amenities, management of employees, or similar areas of organization concern. Essentially, policymaking aids the management of public recreation facilities and other sporting organizations in pursuing aims and objectives free from the influence of outside forces. Therefore, a policy is like a compass that shows how the development should go (Ajibua, 2012).

While sports policy implementation in India has encountered various challenges, there is a growing recognition of the importance of sports and a commitment to overcoming these obstacles.

Key policy measures in India

National Sports Policy: The National Sports Policy serves as a comprehensive framework for sports development in India. It focuses on areas such as infrastructure development, talent identification and training, sports science and technology, sports medicine, and promotion of sports culture. The policy aims to provide opportunities for all individuals to participate and excel in sports.

Khelo India: Launched in 2018, the Khelo India program is a major initiative to promote sports at the grassroots level. It aims to identify and nurture young talent, provide them with adequate training facilities, and support their development through scholarships, expert coaching, and exposure to competitive events. The program encourages mass participation in sports and aims to create a sports culture in the country.

Target Olympic Podium Scheme (TOPS): The TOPS program was launched to identify and support potential medal contenders for the Olympic Games. It provides financial assistance, training support, and specialized coaching to elite athletes with the goal of maximizing their chances of winning medals at international events.

National Sports Talent Search Portal (NSTSP): The NSTSP is an online platform launched to discover young talent in various sports disciplines. It allows talented individuals to register and showcase their skills, enabling talent scouts and sports bodies to identify and provide suitable training and support.

Sports Infrastructure Development: The government has emphasized the development of sports infrastructure across the country. This includes the construction and upgradation of stadiums, sports complexes, training centres, and sports academies at different levels. Efforts have been made to ensure the availability of quality facilities and equipment to support athletes in their training and competitions.

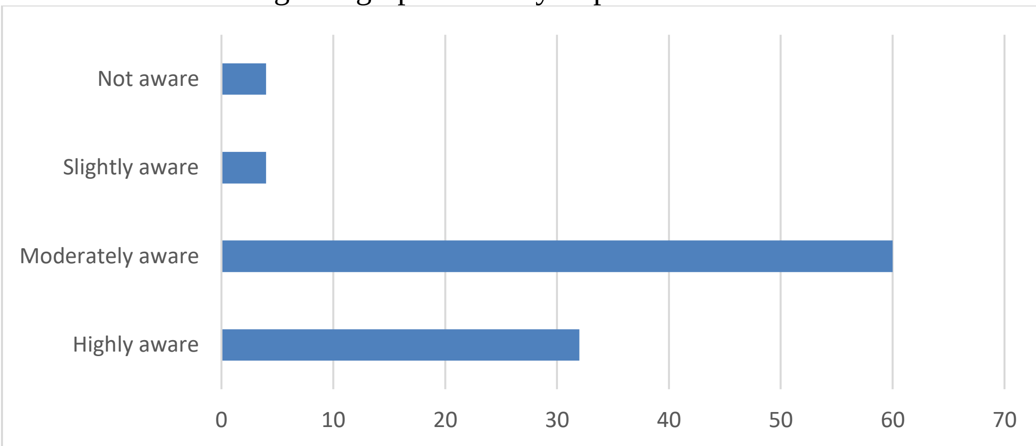
National Sports Development Code of India: The National Sports Development Code of India, formulated in 2011, is a comprehensive set of guidelines and regulations aimed at promoting transparency, accountability, and good governance in sports administration in the country. The code establishes the framework for the functioning of national sports federations, state sports associations, and other sports bodies, outlining their roles, responsibilities, and governance structures.

Methodology

This research uses a ‘mixed method’ of quantitative and qualitative approach to find out the opinions of sports managers regarding the challenges of sports policy implementation in India. A total number of Twenty-five sports managers (n=25) from various regions of the country were included in the study, and their opinions were collected. To gain descriptive insights into their views, a validated questionnaire was distributed among the participants. The collected data were analysed descriptively using the percentage method, and the participants' suggestions were documented. Furthermore, additional information was gathered from web-accessible documents. The findings were reported using the tables presented below.

Results

Figure 1: Level of Awareness regarding Sports Policy implemented in India.



As shown in the figure above, a majority of the respondents, comprising of 60%, possess a moderate awareness on the sports policy of India. 32% of the respondents exhibit a high level of awareness, while a smaller proportion of 4% indicate only slight awareness or no awareness at all regarding the implemented Sports Policy in India.

Table 1: Degree of consensus regarding the challenges associated with the implementation of the sports policy.

SL.NO	**STATEMENTS**	**SRRONGLY DISAGREE**		**DISAGREE**		**NEUTRAL**		**AGREE**	
		N=	**%**	**N=**	**%**	**N=**	**%**	**N=**	**%**
1.	The lack of adequate sports infrastructure hinders the implementation of sports policies in India.	1	4%	2	8%	5	20%	17	68%
2.	Insufficient funding is a major obstacle to the effective implementation of sports policies in India.	-	-	3	12%	6	24%	16	64%
3.	Lack of Good Governance and Transparency is a major setback of implementing sports policy in India	-	-	-	-	5	20%	20	80%

4.	Gender biases and limited support for women's sports hinder the effective implementation of sports policies in India.	3	12%	1	4%	8	32%	13	52%
5.	Inadequate coaching and training facilities hinder the development of policy in India	1	4%	1	4%	5	20%	18	72%
6.	Lack of effective monitoring and evaluation mechanisms hampers the implementation of sports policies in India	2	8%	-	-	7	28%	16	64%
7.	The lack of emphasis on sports in school curriculums negatively affects sports policy implementation in India	1	4%	4	16%	3	12%	17	68%
8.	The presence of corruption has a detrimental impact on the implementation of sports policy in India.	-	-	-	-	3	16%	22	88%
9.	Insufficient awareness and understanding among policy holders significantly impede the effective implementation of sports policy in India.	-	-	3	12%	4	16%	18	72%

N= Number of respondents, %= Percentage of the number of respondents.

Table 1 depicts the respondents' perspectives on various challenges impeding the implementation of sports policy in India. A majority of 88% identified corruption as a significant obstacle, while 80% recognized poor governance and transparency as another major issue. Additionally, 72% believed that inadequate coaching and training facilities, along with insufficient awareness and understanding among policy holders, pose challenges. Moreover, 68% acknowledged the negative impact of the lack of sports infrastructure and inadequate emphasis on sports in school curriculums. Furthermore, 64% expressed concerns about insufficient funding and the lack of effective monitoring and evaluation mechanisms hindering sports policy implementation. Lastly, 52% of the respondents identified gender biases and limited support for women's sports as further hurdles to overcome in promoting effective sports policies in India.

Table 2: Degree of consensus regarding measures on enhancing the development of sports in India.

SL.NO	STATEMENTS	DISAGREE		NEUTRAL		AGREE	
		N=	%	N=	%	N=	%
1.	The grassroots development system in India needs significant improvement to identify and nurture young sporting talent.	-	-	3	12%	22	88%
2.	India needs better talent identification mechanisms to identify and groom athletes at a young age.	-	-	4	16%	21	84%
3.	Sports policies in India should prioritize the promotion of inclusivity and breaking stereotypes.	2	8%	3	12%	20	80%
4.	Athlete welfare initiatives need to be strengthened for the effective implementation of sports policies in India.	-	-	4	16%	21	84%
5.	There is a need for improved coordination and collaboration between various sports organizations and institutions in India.	-	-	6	24%	19	76%
6.	Sports science support and facilities need to be enhanced for the development of athletes in India	-	-	7	28%	18	72%
7.	The allocation of resources for sports development should be prioritized in the national budget.	-	-	5	20%	20	80%
8.	The Indian government should establish stronger partnerships with public and private organizations for sports policy implementation.	4	16%	5	20%	16	64%

9.	Public awareness and promotion campaigns are necessary to foster a sporting culture in India	-	-	5	20%	20	80%

N= Number of respondents, %= Percentage of the number of respondents.

The table above depicts the consensus levels regarding measures to enhance sports development in India. A significant majority of 88% of the respondents agreed that the grassroots development system requires substantial improvement to identify and nurture young sporting talent. Similarly, 84% of the participants expressed the belief that talent identification and athlete welfare initiatives should be strengthened to ensure the effective implementation of sports policies in India. Moreover, an overwhelming percentage of 80% believed that India should prioritize the promotion of inclusivity and breaking stereotypes, with a focus on allocating resources for sports development and conducting public awareness and promotion campaigns to foster a vibrant sporting culture in the country. Furthermore, 76% of the respondents advocated for improved coordination and collaboration between various sports organizations and institutions in India to further the growth of the sports sector. In addition, 72% of the respondents agreed on the need to enhance sports science support and facilities for the development of athletes in India, while 64% endorsed the idea of the Indian government establishing stronger partnerships with both public and private organizations to effectively implement sports policies.

Discussion

Challenges:

- The survey reveals that a significant majority of 68% of the respondents, shares the view that the insufficient sports infrastructure poses a hindrance to the effective implementation of sports policies in India. Additionally, 20% of the participants responded neutrally to this statement, while 8% expressed disagreement, and 4% strongly disagreed. Evidently, the lack of adequate sports infrastructure stands out as one of the key challenges impacting the successful execution of sports policies in the country.
- A significant portion of the respondents, comprising 64%, indicated their agreement with the statement that insufficient funding represents a major obstacle to the effective implementation of sports policies in India. In contrast, 24% remained neutral on this issue, and 12% expressed disagreement. These findings underscore the consensus that inadequate funding poses a substantial challenge in successfully executing sports policies in the country.
- The survey findings indicate that a significant majority, totalling 80% of the respondents, agrees that the Lack of Good Governance and Transparency stands as a major setback in implementing sports policy in India. Conversely, 20% of the participants expressed a neutral stance on this matter. These results underscore the widespread acknowledgment of the critical role good governance and transparency play in overcoming obstacles and ensuring effective sports policy implementation in the country.
- A majority of the respondents, amounting to 52%, agrees with the assertion that gender biases and limited support for women's sports pose obstacles to the effective implementation of sports policies in India. Meanwhile, 32% of participants remained neutral on this issue, 4% disagreed, and 12% strongly disagreed. These results underscore the importance of addressing gender biases and providing adequate support to women's sports in order to ensure a more successful execution of sports policies in the country.
- The results reveals that a significant majority of 72% of the respondents, agrees that inadequate coaching and training facilities impede the development of sports policy in India. Meanwhile, 20% of

the participants maintained a neutral viewpoint on this matter, while 4% disagreed, and another 4% strongly disagreed. These findings underscore the crucial role of enhancing coaching and training infrastructure to foster a more conducive environment for the advancement of sports policy in the country.

- The findings indicate that a substantial majority, amounting to 64% of the respondents, agrees that the lack of effective monitoring and evaluation mechanisms hampers the implementation of sports policies in India. In contrast, 28% of the participants remained neutral on this issue, while 8% strongly disagreed. These results highlight the importance of establishing robust monitoring and evaluation processes to enhance the effectiveness and success of sports policies in the country.
- According to the findings, a significant majority of 68% of the respondents agrees that the lack of emphasis on sports in school curriculums has a negative impact on the implementation of sports policy in India. Additionally, 12% of the participants remained neutral on this matter, while 16% disagreed, and 4% strongly disagreed. These findings emphasize the need to address the incorporation of sports in school curriculums as a crucial aspect to bolster the successful execution of sports policies in the country.
- A majority of 88% of the respondents agrees that the presence of corruption has a detrimental impact on the implementation of sports policy in India. Additionally, 16% of the participants remained neutral on this matter. These results highlight the pressing need to address and combat corruption as it poses a significant obstacle to the effective execution of sports policies in the country.
- Bases on the findings, a considerable majority of 72% of the respondents agrees that insufficient awareness and understanding among policy holders significantly impede the effective implementation of sports policy in India. Furthermore, 16% of the participants expressed a neutral stance on this issue, while 12% disagreed. These findings underscore the importance of increasing awareness and knowledge among policy holders to overcome barriers and ensure the successful execution of sports policies in the country.

Measures:

- The findings reveals that a significant majority of 88% of the respondents agrees that the grassroots development system in India requires substantial improvement to identify and nurture young sporting talent. Additionally, 12% of the participants remained neutral on this matter. These findings emphasize the importance of enhancing the grassroots development infrastructure to better support and cultivate young sporting talent in the country.
- A substantial majority of 84% of the respondents agrees that India needs better talent identification mechanisms to identify and groom athletes at a young age. Furthermore, 16% of the participants expressed a neutral stance on this matter, while no one disagreed. These findings underscore the significance of implementing more effective talent identification strategies to identify and nurture promising athletes from an early stage.
- A significant majority of 80% of the respondents agrees that sports policies in India should prioritize the promotion of inclusivity and breaking stereotypes. Additionally, 12% of the participants remained neutral on this matter, while 8% disagreed. These results underscore the importance of prioritizing inclusivity and challenging stereotypes within sports policies to foster a more diverse and equitable sporting environment in the country.
- According to the findings, a significant majority of 84% of the respondents agrees that athlete welfare initiatives need to be strengthened for the effective implementation of sports policies in India. Additionally, 16% of the participants expressed a neutral stance on this matter. These findings

highlight the importance of bolstering athlete welfare programs to ensure the successful execution of sports policies and the well-being of athletes in the country.

- The findings indicate that a substantial majority of 76% of the respondents agrees that there is a need for improved coordination and collaboration between various sports organizations and institutions in India. Moreover, 24% of the participants expressed a neutral stance on this matter. These findings underscore the significance of fostering better cooperation and partnership among sports entities to enhance the overall sports ecosystem in the country.
- Based on the findings, a considerable majority of 72% of the respondents agrees that sports science support and facilities need to be enhanced for the development of athletes in India. Additionally, 28% of the participants expressed a neutral stance on this matter. These findings emphasize the importance of improving sports science resources and facilities to better support the growth and performance of athletes in the country.
- A majority of 80% of the respondents agrees that the allocation of resources for sports development should be prioritized in the national budget. Additionally, 20% of the participants expressed a neutral stance on this matter. These results highlight the importance of giving due attention and significance to sports development funding in the national budget to promote the growth and advancement of sports in the country.
- The results reveal that a substantial majority of 64% of the respondents agrees that the Indian government should establish stronger partnerships with public and private organizations for sports policy implementation. Additionally, 16% of the participants expressed a neutral stance on this matter, while another 16% disagreed. These findings underscore the importance of forging collaborative relationships with both public and private sectors to effectively execute sports policies in the country.
- Based on the findings, a significant majority of 80% of the respondents agrees that public awareness and promotion campaigns are necessary to foster a sporting culture in India. Additionally, 20% of the participants expressed a neutral stance on this matter. These results underscore the importance of conducting effective awareness and promotion campaigns to promote and encourage a vibrant sporting culture in the country.

Recommendation and Conclusion

Based on the suggestions provided by the respondents, here are a few key points to improve sports development in India:

- Enhance sports infrastructure and provide sufficient funding for sports programs: It is crucial to invest in the development of sports infrastructure across the country, including stadiums, training centres, and sports facilities. Additionally, allocating adequate funding for sports programs will help in providing necessary resources, equipment, and opportunities for athletes to excel.
- Strengthen the grassroots development system to identify and nurture young sporting talent: Focusing on grassroots development is essential for identifying and nurturing talented young athletes. This involves establishing programs and initiatives at the grassroots level, such as school sports programs and community sports clubs, to encourage participation and identify promising talent from an early age.
- Address the challenge of balancing education and sports for aspiring athletes: Many young athletes face the challenge of balancing their education and sports aspirations. It is crucial to create a supportive environment that allows athletes to pursue their sporting dreams without compromising their education. This can be achieved by implementing flexible education programs, providing academic support, and creating partnerships between educational institutions and sports organizations.

- Streamline sports administration, eliminate bureaucratic hurdles, and increase transparency: The sports administration system should be streamlined to ensure efficient decision-making and effective implementation of sports policies. Reducing bureaucratic hurdles and promoting transparency in processes such as athlete selection, funding allocation, and governance will foster a more conducive environment for sports development.
- Address gender biases and provide greater support for women's sports: Efforts should be made to address gender biases and promote gender equality in sports. Providing equal opportunities, resources, and support for women's sports will help in nurturing and promoting female athletes, and create a more inclusive and diverse sporting landscape.
- Establish better talent identification mechanisms to identify and groom athletes at a young age: Implementing robust talent identification mechanisms, such as talent scouting programs, sports academies, and talent identification camps, will aid in identifying promising athletes at a young age. Once identified, these athletes can receive specialized training and support to enhance their skills and maximize their potential.
- Enhance coaching and training facilities for the development of athletes: Improving coaching and training facilities is essential for the holistic development of athletes. Investing in qualified coaches, providing advanced training methodologies, and upgrading sports training facilities will help athletes refine their skills and compete at a higher level.
- Strengthen athlete welfare initiatives for effective sports policy implementation: Ensuring the well-being and welfare of athletes is crucial for the success of sports development initiatives. This involves providing proper medical support, insurance coverage, financial assistance, and career guidance to athletes, enabling them to focus on their training and performance without undue concerns.
- Improve coordination and collaboration among various sports organizations and institutions: Enhancing coordination and collaboration among sports organizations, government bodies, educational institutions, and private entities will create synergies and optimize resources for sports development. This can be achieved through partnerships, joint initiatives, and sharing best practices.
- Implement effective monitoring and evaluation mechanisms for sports policy implementation: Establishing robust monitoring and evaluation mechanisms is vital for tracking the progress and impact of sports development initiatives. Regular assessments, data collection, and analysis will help in identifying strengths, weaknesses, and areas of improvement, leading to evidence-based decision-making and effective policy implementation.
- To ensure the smooth functioning of sports organizations, it is recommended to recruit professional sports managers across all sectors. Recruiting professional sports managers can contribute to the overall growth and development of the organization. Their expertise can lead to improved governance, effective implementation of policies, and better utilization of resources. They can also bring fresh perspectives, innovative ideas, and best practices from the sports industry, fostering innovation and driving organizational success.

By incorporating these suggestions and implementing them effectively, India can significantly contribute to the overall improvement and advancement of sports. This will lead to the fostering of a vibrant sports culture, the nurturing of talent, and ultimately achieving excellence in both national and international sporting events.

In conclusion, recruiting professional sports managers across all sports organizations is crucial for maintaining a smooth flow within the organization. These managers bring expertise in sports management, enabling them to navigate the complexities of the industry effectively. They can oversee various aspects of the organization, enhance professionalism, streamline operations, and drive growth and development. With their strategic planning, financial management, and athlete development skills, professional sports managers contribute to improved governance, efficient resource utilization, and talent identification. Ultimately, investing in professional sports managers is a valuable step towards achieving organizational success and elevating the sports industry as a whole.

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EFFECT OF YOGIC PRACTICES THERAPEUTIC EXERCISE PRACTICES AND COMBINED PRACTICES ON STRESS AMONG LOW BACKACHE MEN

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ABSTRACT
The present study was designed to find out the effect of yogic practices therapeutic exercise practices and combined practices on stress among Low backache men. It was hypothesized that there would be significant differences on stress among Low backache men due to the influences of effect of yogic practices therapeutic exercise practices and combined practices. To achieve the purpose of the study, 45 low backache men from Chennai city aged between 30 and 40 years. The Experimental group I, II and III underwent effect of yogic practices therapeutic exercise practices and combined practices for the period of 6 weeks of an hour in the morning. The control group was not exposed to any specific training but they participated in the regular activities. The pre-test and post- test were conduct before and after the training for four groups. The data pertaining to the variables collected from the three groups before and after the training period were statistically analyzed by using Analysis of Covariance (ANCOVA) to determine the significant difference and tested at 0.05 level of significance.
Keywords: yogic practices, therapeutic exercise practices, combined practices, Stress.

INTRODUCTION
Back ache (also known "dorsalgia") is functional disorder. In this pain felt in the back that usually originates from the muscles, nerves, bones, joints or other structures in the spine.
The people should not be surprised that backache is so common when we understand the highly complex mechanics involved in the functioning of the spinal column. Since man became a biped, the center of gravity (COG) has become narrowed to a small zone (the area of one foot) as compared to the wide area of the center of gravity when we were four legged animals. The

brunt of the weight of entire body has to be borne by the spinal column. While having to do this the spinal column also has to allow for enormous degree of flexibility. This is ensured by a highly complex organization of various anatomical structures such as bones, discs, ligaments, tendons, nerves, blood vessels and strong muscles. Any one of these structures could be injured or affected by diseases or subjected to excessive stress and strains thus contributing to pain in most mobile parts of the spine namely the neck and lumbar region.
Lumbosacral pain has been a recognized human affliction for a long time. Hippocrates also talked about lumbosacral pain. In western medicine, we find the very first reports on naked eye descriptions of the normal and degenerate spine in the writings of Vesalius in 1555. Virchow first described what is now known as a lumbar disc prolapse in 1875. Middleton and Teacher first described lumbar disc herniation. Goldthwaite in 1905 described the result of manipulating the lower back of a patient who was thought to be suffering from a sacroiliac subluxation. Yoga is an ancient Indian practice which involves moving the body and mind to achieve balance and well-being. The purpose of traditional yoga is for each individual to be healthy, both physically and mentally, and able to reach his ot her highest potential as a person. Practicing yoga as a lifestyle can be beneficial for individuals with disabilities or chronic health conditions through both the physical postures and breathe work. Each pose can be modified or adopted to meet the needs of the student.

The subtle anatomy of the humans is divided into five energetic sheaths known as 'pancha kosha'. Pancha, meaning five and kosha, meaning layer or sheath. This ideology describes the human being "as multi-dimensional, with the source or foundation in a spiritual dimension." The so-called 'spiritual dimension' is pure consciousness which is hidden by the other four koshas, the outermost layer being the most dense, physical body.

Each kosha can be thought of as energy vibrating at a different frequency. The physical body therefore vibrates at the slowest rate and the 'inner light of consciousness' or 'atman' vibrates at fastest rate or frequency. Although all five layers interpenetrate one another.

These five sheaths can be divided into three bodies:

1. Sthula Sharira / Physical Body

Annamayakosha

2. Sukshma Shariria / Astral Body

Pranamayakosha, Manomayakosha, Vijnanamayakosha

3. Karana Shariria / Causal Body

Vijnanamayakosha, Anandamayakosha

Of all these, Anandamayakosha is not bound by time or space and does not die. When the practitioner resides in this sheath, they have remembered or realized their true nature, reached enlightenment and health will pervade on all layers.

AIM OF THE STUDY

The present study was designed to find out the effect of yogic practices therapeutic exercise practices and combined practices on Stress among Low backache men.

HYPOTHESIS

It was hypothesized that there would be significant differences on Stress among low backache men due to effect of yogic practices therapeutic exercise practices and combined practices groups than the control group.

REVIEW OF RELATED LITERATURE

Patra S, and Telles S, (2010) conducted the study on Resting pulse rate variability during sleep following the practice of cyclic meditation and supine rest. Day time activities are known to influence the sleep on the following night. Cyclic meditation (CM) has recurring cycles. Previously, the low frequency (LF) power and the ratio between low frequency and high frequency (LF/HF ratio) of the resting pulse rate variability (HRV) decreased during and after CM but not after a comparable period of supine rest (SR). In

this study, on thirty male volunteers, CM was practiced twice in the day and after this the HRV was recorded (1) while awake and (2) during 6 h of sleep (based on EEG, EMG and EGG recordings). This was similarly recorded for the night's sleep following the day time practice of SR. Participants were randomly assigned to the two sessions and all of them practiced both CM and SR on different days. During the night following day time CM practice there were the following changes; a decrease in resting pulse rate , LF power (n.u.), LF/HF ratio, and an increase in the number of pairs of Normal to Normal RR intervals differing by more than 50 ms divided by total number of all NN intervals (pNN50) ($P < 0.05$, in all cases, comparing sleep following CM compared with sleep following SR). No change was seen on the night following SR. Hence yoga practice during the day appears to shift sympatho-vagal balance in favor of parasympathetic dominance during sleep on the following night.

Upadhyay Dhungel K, et.al, (2008) conducted the study on effect of alternate nostril breathing exercise on cardiorespiratory functions.Pranayama (breathing exercise), one of the yogic techniques can produce different physiological responses in healthy individuals. The responses of Alternate Nostril Breathing (ANB) the Nadisudhi Pranayama on some cardio-respiratory functions were investigated in healthy young adults. The subjects performed ANB exercise (15 minutes everyday in the morning) for four weeks. Cardio-respiratory parameters were recorded before and after 4-weeks training period. A significant increment in Peak expiratory flow rate (PEFR L/min) and Pulse pressure (PP) was noted. Although Systolic blood pressure (SBP) was decreased insignificantly, the decrease in pulse rate (PR), respiratory rate (RR), diastolic blood pressure (DBP) were significant. Results indicate that regular practice of ANB (Nadisudhi) increases parasympathetic activity.

METHODOLOGY

For the purpose of the study, 60 Low backache men from Chennai aged between 30 and 40 years were selected. They were equally divided into four groups: Experimental group I (yogic practices), Experimental group II (therapeutic exercise practices), Experimental group III (yogic practices & therapeutic exercise practices) and control group (no intervention).

This study employed the experimental random group design, effect of yogic practices therapeutic exercise practices and combined practices as the independent

variable and Stress as the dependent variable. The training scheduling comprises of six days per week for the maximum of one hour for six weeks. The data were collected before training as pre-test from four groups. After six weeks of effect of yogic practices therapeutic exercise practices and combined practices, data were again collected from all the three experimental groups and control group. The equipment used to measure the level of Stress through standard questionnaire. Analysis of covariance (ANCOVA) was used to find out the significant differences among the groups. The level of significance was fixed at 0.05%.

RESULT AND DISCUSSION

Stress was measured through standard questionnaire. The pre and post test means of the experimental groups and control group statistically analyzed to find out the significance of Table

TABLE - I
COMPUTATION OF ANALYSIS OF COVARIANCE OF STRESS
(Total Scores in Marks)

	EX.GR.I	EX.GR.II	EX.GR. III	Control	Source of Variance	Sum of Squares	df	Mean Squares	Obtained F
Pre Test Mean	80.20	84.73	82.60	79.27	between	272.73	3.00	90.91	0.21
					within	24221.87	56.00	432.53	
Post Test Mean	67.53	72.13	54.40	81.00	between	5533.67	3.00	1844.56	4.85*
					within	21307.07	56.00	380.48	
Adjuste	68.49	70.21	53.8	82.55	between	6211.70	3.00	2070.57	9.89*

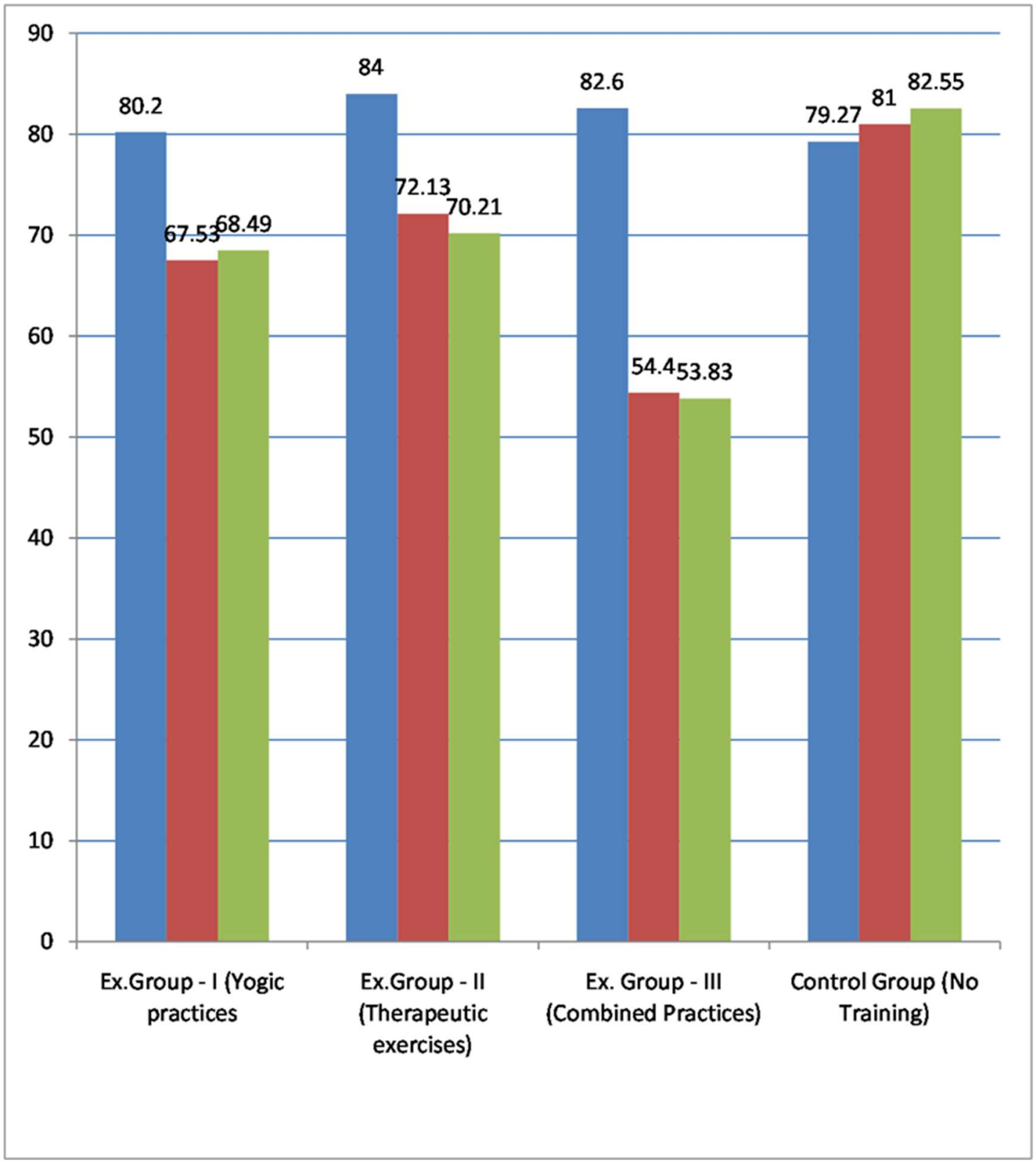
dPost Test Mean			3		within	11520.58	55.00	209.47	
Mean Diff	12.67	12.60	28.20	1.73					

Table value at 0.05 level of confidence for 3 and 56 (df) is.2.77, 3 and 55(df) is 2.77.
* Significant at 0.05 level.

TABLE - II
SCHEFFE'S CONFIDENCE INTERVAL TEST SCORES ON STRESS
(Scores in marks)

Control Group	Experimental Group – I (Yogic practices)	Experimental Group – II (Therapeutic exercises)	Experimental Group – III (Combined Practices)	Mean Difference	CI
82.55	68.49			14.06*	12.26
82.55		70.21		12.34*	
82.55			53.83	28.72*	
	68.49	70.21		1.72	
	68.49		53.83	14.66*	
		70.21	53.83	16.38*	

FIGURE 1
BAR DIAGRAM ON ORDERED ADJUSTED MEANS OF STRESS
(Scores in marks)



DISCUSSION ON THE FINDINGS OF STRESS

The Table shows that Scheffe's confidence interval values of Stress of yogic practices with and without diet modification groups and control group of Low backache men.

The findings of the study on Stress reveal that the experimental groups namely EX.GR-I (yogic practices), EX.GR-II (therapeutic exercise practices) and EX.GR-III (combined) had significantly improved after the training. Besides, the results of the study indicated that there was significant difference between the EX.GR-I (yogic practices), EX.GR-II (therapeutic exercise practices) and EX.GR-III (combined).

DISCUSSION ON HYPOTHESIS

The hypothesis results shows that the calculated 'F' value is greater than the table value on the Stress among Low backache men for post test scores as Stress is increased. This proves that there was significant difference between the experimental groups and control group. Hence the hypothesis was accepted at 0.05 level of significance.

CONCLUSION

There was a significant improvement in Stress of experimental groups when compared to the control group. Combined group (Yogic practices with therapeutic exercise practices) group has shown mild improvement than the Yogic practices group and therapeutic exercise practices) group. .

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An Assessment of Good Governance in the All India Football Federation (AIFF)

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Abstract: *The aim of this research is to conduct a comprehensive evaluation on the level of Good Governance within the All India Football Federation (AIFF). Utilizing the National Sports Governance Observer (NSGO) tool, the study meticulously assesses AIFF's governance practices while identifying areas of strength and weaknesses. Notably, the dimensions of Transparency and Democracy emerge as a commendable aspect by receiving a positive score of 73% and 61% on the AIFF's governance framework; however, Internal Accountability and Societal Responsibility reveal room for Improvement. The study's recommendations form a foundational roadmap to enhance AIFF's governance. By shedding light on AIFF's governance landscape and offering a strategic pathway for enhancement, this research underscore the vital significance of effective governance in sports organisation, contributing to the broader discourse on elevating governance standards within the domain of Football administration.*

Keywords: *Sports, Good Governance, Football, Sports Governance, Transparency, Democracy*

1. Introduction

Football in India has a rich history and is deeply ingrained in the country's sporting culture. Introduced during British colonial rule in the 19th century, the sport quickly gained popularity and evolved into a passion shared by millions of Indians. Despite cricket's dominance, football maintains a dedicated following and continues to thrive at the grassroots level. The All India Football Federation (AIFF) governs the sport in the country, and has made notable strides in recent years, with a growing focus on youth development and international competitions, signaling a promising future for Indian football.

Indian football boasts a rich and enduring heritage as a widely celebrated spectator sport. It once held a prominent position in Asian football and made notable strides on the international stage. However, since the 1970s, the sport in India has encountered a complex array of challenges. In a determined effort to reinvigorate the game, the All India Football Federation announced its long-awaited "Vision 2047" during a press conference in New Delhi. This strategic roadmap, spanning 25 years, aspires to shape India into a footballing powerhouse by the nation's centenary year of independence. Developed in collaboration with various stakeholders within Indian football and incorporating insights from the Asian Football Confederation (AFC) and FIFA, the plan envisions India among the top four footballing nations in Asia, hosting premier leagues within the continent, and fostering a thriving football ecosystem. The unveiling of "Vision 2047" reflects a profound commitment to reviving the glory of Indian football and charting a dynamic course for its future. The objective lies in governing football with the utmost integrity and inclusivity, fostering teamwork and collaboration, and setting a paradigm for Good Governance. The All India Football Federation (AIFF) recognizes the imperative for effective governance, believing that it holds the key to elevating Indian Football to greater heights in the future.

Good governance, in this context, transcends choice and stands as a compelling necessity to attain excellence. Distinguished sporting organizations embrace a robust regulatory framework that safeguards the interests of stakeholders, ensures the integrity of sporting events, champions social and environmental responsibility, and enforces stringent controls over the allocation and utilization of development funds. This approach not only adds value to the sport itself but also extends its positive impact to the broader community. The significance of adhering to principles of good governance in sports organizations is underscored by several compelling factors. The evolving landscape of sports, characterized by increasing commercialization, professionalization, and globalization, has amplified public and media scrutiny. Consequently, the need to address these issues and uphold good governance principles has become paramount in the world of sports.

1.1. Key Elements of AIFF's Governance Include

1. **Executive Committee:** The AIFF is governed by an Executive Committee, which consists of elected members responsible for making key decisions regarding football in India. This committee includes the President, Vice Presidents, and members representing various state associations and stakeholders in Indian football.
2. **General Body:** The General Body of the AIFF comprises representatives from state associations, football clubs, and other relevant bodies. It plays a crucial role in shaping the policies and direction of Indian football.
3. **Transparency:** Transparency is a fundamental principle of good governance within AIFF. The organization is expected to provide clear and open information about its activities, financial matters, and decision-making processes.
4. **Accountability:** AIFF is accountable for its actions and decisions. It is responsible for ensuring that funds allocated for football development are used appropriately and that the interests of stakeholders are protected.
5. **Stakeholder Engagement:** The AIFF engages with various stakeholders in Indian football, including players, coaches, referees, clubs, and fans, to gather input and involve them in decision-making processes.
6. **Compliance:** AIFF is expected to comply with its own statutes, rules, and regulations, as well as those of international football governing bodies like FIFA and the Asian Football Confederation (AFC).
7. **Development Programs:** AIFF is responsible for implementing and managing development programs that promote the growth of football in India, including youth development, grassroots initiatives, and infrastructure development.
8. **Ethics and Fair Play:** Ensuring ethical conduct and fair play in Indian football is an integral part of AIFF's governance responsibilities. This includes addressing issues related to match-fixing, doping, and discrimination.
9. **Financial Oversight:** AIFF must manage its finances transparently and efficiently, ensuring that funds allocated for football development are utilized effectively and for their intended purposes.
10. **International Relations:** As the governing body for football in India, AIFF maintains relationships and collaborations with international football organizations like FIFA and AFC.

Effective governance is crucial for the continued growth and success of football in India. It helps maintain the integrity of the sport, ensures that resources are used effectively, and fosters a positive environment for players, fans, and all stakeholders involved in Indian football. AIFF's commitment to good governance principles is essential in achieving these goals and promoting the sport's development and excellence in the country.

2. Review Of Literature

Sports as an activity are attracting the interest of millions of people worldwide. It is indeed, considered a universal activity that permeates every society at every corner of the world (Oketch, 2005). Governments worldwide have recognized the importance of the sector and have as such committed themselves to supporting the independence of these sports associations (Rogge, 2004). This support however is with the assumption that the sports associations observe proper governance principals. Sports federations must recognize that they influence to oversee their sport as trustees and the authority to oversee is essentially conferred in their associates and implemented by them unswervingly and indirectly over an organization of depiction (Kings Report, 2004). In order to regulate the governance of sports, the formulation and enforcement of national policies on sports administration is mandatory (Oketch, 2005). Despite there being structures for the governance of sports federations in India, there are numerous challenges being faced in the operative and well-organized delivery of sports amenities in the country. Many of the employees working in the various federations as managers are not adequately trained in the various areas of sports governance and as such the federations suffer from inadequate management which ultimately leads to poor performance of the federations.

Good governance has generally meant that organization's policies and procedure are put in place to ensure that organization achieve their goals. According to Andanje et al. (2014), good governance is not all about rules and regulations but also an attitude in mind as well as the ethical culture of the organization and the behaviors of the people on the governing body. An organization is said to have good governance if they demonstrate transparency, accountability, participation and responsibility with all the involved stakeholders. Mardiasmo (2012) stated that when an organization is seen to be governed to a high standard, it promotes confidence amongst its stakeholders, leading to better and more ethical decision making and help in to meets their legislative responsibilities.

3. METHODOLOGY

This study takes a comprehensive approach by employing the National Sports Governance Observer (NSGO) tool as a fundamental benchmarking instrument to evaluate the governance quality within the All-India Football Federation (AIFF). The NSGO tool is specifically designed to assess and score the performance of individual sports organizations, covering a total of 46 unique principles related to good governance. These principles are spread across four distinct dimensions: Transparency (7 Principles), Democracy (13 Principles), Internal Accountability and control (14 Principles), and Societal Responsibility (12 Principles).In order to meticulously scrutinize the governance practices, the researcher adopted a document analysis methodology, characterized by an in-depth examination of pertinent materials. The data collection process primarily consisted of desktop research, encompassing a thorough analysis of the AIFF's official websites, governing statutes, internal regulations, and any other pertinent documents that were readily available for analysis. It is essential to highlight that the scoring procedure relied exclusively on publicly accessible data, ensuring a rigorous and objective assessment. Therefore, the researcher leveraged the pre-existing National Sport Governance Observer survey tool developed by Play the Game as the foundational framework for evaluating governance practices within the AIFF. This choice was predicated on its applicability and suitability within the Indian sports context, given the AIFF's organizational structure and statutes, which align closely with the parameters of the assessment tool.

Furthermore, the selection of the NSGO tool was driven by the pragmatic consideration that it aligns harmoniously with the inherent structures and regulatory frameworks present within the Indian sports ecosystem. Consequently, this assessment tool emerged as a judicious choice for gauging and comprehending the governance landscape within the AIFF, ensuring the research's relevance and reliability in the context of the Indian sports milieu.

To quantify the results for each indicator, the survey employs the following scoring scales:

Not relevant	Not fulfilled	Weak	Moderate	Good	Very good
	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %

4. RESULTS AND DISCUSSION

Table1. *NSGO Index Score*

Dimension	Score	Label
Transparency	73%	Good
Democracy	61%	Good
Internal Accountability and control	49%	Moderate
Societal responsibility	46%	Moderate
NSGO index total	57%	Moderate

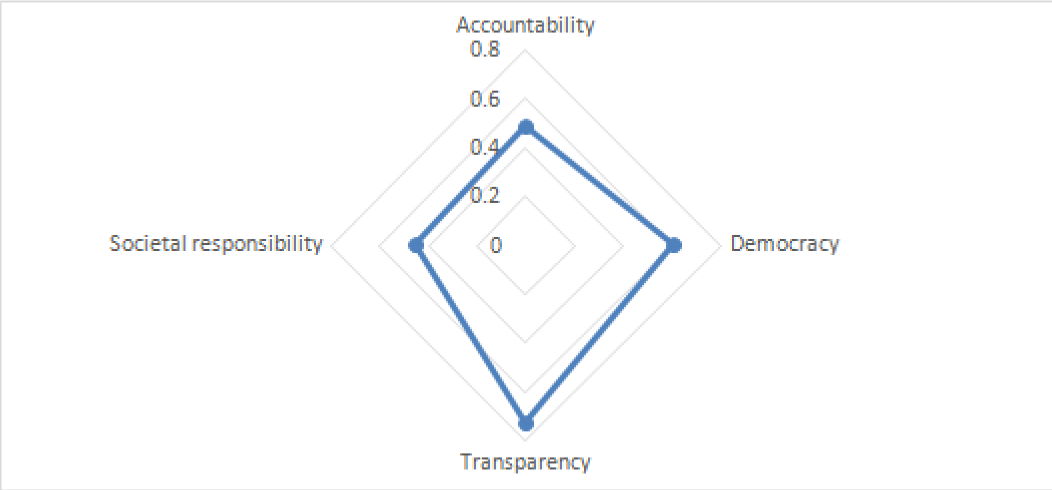

Figure1.

The results presented in the table and figure above shed light on the overall performance ofgood governance in the All India Football Federation (AIFF). As assessed by the National Sports Governance Observer (NSGO) tools, the AIFF attains an average NSGO index score of 57%, positioning it within the 'moderate' range of governance performance.

Delving deeper into the specific dimensions of governance, we observe a noteworthy pattern. The AIFF demonstrates a commendable level of governance in the areas of Transparency and Democracy, achieving a classification of 'Good' in these dimensions. Transparency, in particular, stands out as the strongest suit, boasting the highest score of 73%. This signifies that the AIFF excels in being open, clear, and accountable in its operations, a crucial aspect of good governance. Additionally, the Democracy dimension, with a score of 61%, reflects the extent to which the AIFF involves stakeholders and ensures a democratic decision-making process within its structure.

However, it is important to note that the AIFF's governance performance dips into the 'moderate' territory when we consider the Internal Accountability and Control as well as Societal Responsibility dimensions. In Internal Accountability and Control, the AIFF garners a score of 49%, indicating room for improvement in ensuring that it adheres to its internal rules and regulations effectively. Similarly, the Societal Responsibility dimension attains a score of 46%, suggesting that while the AIFF is making contributions to society, there is potential for enhancing its societal impact further.

In summary, these results provide valuable insights into the AIFF's governance landscape. While the organization exhibits strengths in transparency and democratic processes, there are areas within internal accountability and societal responsibility where efforts for improvement could lead to an even more robust governance framework. These findings offer a foundation for further exploration and refinement of governance practices within the AIFF to enhance its overall performance and impact on the Indian football landscape.

5. RECOMMENDATION

1. **Enhance Internal Accountability:** The AIFF should focus on strengthening its internal accountability mechanisms to ensure strict adherence to its governing statutes and regulations. Regular audits and oversight can facilitate this process.
2. **Promote Ethical Conduct:** Foster a culture of ethics and integrity within the organization to prevent any potential misconduct or unethical behaviour. This includes establishing a code of conduct and ethics training for staff and officials.
3. **Increase Stakeholder Engagement:** Continue to involve a wide range of stakeholders, including players, coaches, fans, and local communities, in decision-making processes to ensure a more democratic and inclusive approach to governance.
4. **Transparency in Decision-Making:** Maintain and improve the high level of transparency achieved in the Transparency dimension. Make sure that all decisions and financial information are easily accessible to the public.

5. **Societal Impact Initiatives:** Increase efforts in the Societal Responsibility dimension to enhance the AIFF's social impact. This could include more community outreach programs and partnerships with organizations dedicated to social causes.
6. **Professionalize Governance:** Invest in professional governance structures and practices, including employing qualified and experienced individuals in key administrative roles within the organization.
7. **Strategic Planning:** Develop a comprehensive strategic plan that outlines clear objectives, timelines, and performance indicators for the AIFF. Regularly review and adjust this plan to ensure it remains relevant and effective.
8. **Training and Development:** Invest in the training and development of AIFF personnel, including administrators, coaches, and referees, to ensure they are well-equipped to perform their roles effectively.
9. **Financial Transparency:** Maintain a high level of financial transparency, including detailed reporting of income and expenses. Regular financial audits by independent bodies can further enhance credibility.
10. **Benchmarking and Continuous Assessment:** Continue to use tools like SGO and NSGO to benchmark the AIFF's governance against international standards. Regularly assess and reassess governance practices to identify areas for improvement and track progress over time.

These recommendations aim to guide the AIFF toward further improvements in governance, transparency, and accountability, ultimately contributing to the development and success of football in India.

6. CONCLUSION

The evaluation of All India Football Federation (AIFF) governancethrough the National Sports Governance Observer (NSGO) index highlights a governance landscape marked by commendable transparency and democratic engagement, positioning the AIFF favorably in these critical dimensions. However, there is a clear need for bolstering internal accountability and societal responsibility. By heeding the recommendations for governance enhancement, the AIFF can embark on a path toward more robust and inclusive governance, reinforcing its pivotal role in fostering the development and success of football in India, benefiting both the sport and its diverse stakeholders.

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EFFECT OF HATHA YOGA PRACTICES AND THERAPEUTIC EXERCISES ON PAIN AMONG OLD AGED WOMEN WITH ARTHRITIS

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Abstract

The purpose of the present study was to find out the effect of hatha yoga practices and therapeutic exercises on pain among old aged women with arthritis. The study was conducted on 45 old aged women with arthritis. Totally three groups, namely, control & experimental group I & II, consisting of 15 old aged women with arthritis underwent six weeks of practice in Hatha yoga practices and therapeutic exercises whereas the control group did not under go any type of training. The Pain was measured before and after the experimentation using the "Visual Analogue Scale (VAS)" to measure the Pain. The data were analyzed by Analysis of Co-variance (ANCOVA) and it was concluded that the Hatha yoga practices and therapeutic exercises had significant ($P < 0.05$) effect on the Pain level.

Key words: Hatha yoga practices and therapeutic exercises, Pain.

INTRODUCTION

"Sama dosha samagnisca sama dhatu mala kriyaha"

The person who always eats wholesome food, enjoys a regular lifestyle, remains unattached to the objects of the senses, gives and forgives, loves truth, and serves others, is without disease. The total of body, mind and spirit. It includes physical health, mental health, emotional health, and social health.

Yogic exercises recharge the body with cosmic energy. This facilitates

- Attainment of perfect equilibrium and harmony
- Promotes self- healing.
- Removes negative blocks from the mind and toxins from the body
- Enhances Personal power
- Increases self-awareness
- Helps in attention focus and concentration, especially important for children
- Reduces stress and tension in the physical body by activating the parasympathetic nervous system.

According to Patanjali, one can attain this (the individual self with the Supreme One) union by controlling and eliminating the ever- arising **'vrittis'** or modifications of the mind. He also suggests that the mind, in turn, can be controlled through the right kind of discipline and training. Patanjali says that there are basic obstacles pervading the mind that are not conducive to yoga practice.

He divides these **obstacles** into two groups:

1. Antarayas (intruders in the path of yoga)
2. Viksepasahabhuvah (co-existing with mental distraction)

There are nine Antarayas. They are,

1. Vyadhi (physical disease)
2. Styana (mental laziness)
3. Samsaya (doubt)
4. Pramada (heedlessness)
5. Alasya (physical laziness)
6. Avirati (detachment)
7. Bhrantidarsana (false perception)
8. Alabdha- bhumikatva (non-attainment of yogic states)
9. Anavasthitatva (falling away from yogic states attained)

The above obstacles block the flow of prana (life force) in Astral body (koshas and chakras) leads to ATHI.

This ATHI (stress) spread from one place to and occupy the entire body known as Vyathi (diseases). If stress occurs in the Astral body (sukshuma sarira) it reflects in the physical body (sthoola sarira). So as the result the entire body became prey to deadly diseases and disorder.

"LIFE is MOVEMENT, and MOVEMENT is LIFE"

Live movements take place at joints. Arthritis hampers joint movement and disturbs normal life. Arthritis is "Chronic Inflammation of Joint''. Inflammation is indicated by stiffness, swelling, redness or warmth in the joints. Any part of the body can become painful due to arthritis. Typically, when one suffers from arthritis, these symptoms are exhibited

1. Apparent loss of flexibility in a joint
2. Extreme fatigue
3. Lack of energy.

TYPES OF ARTHRITIS

1. Osteoarthritis

In osteoarthritis, the cartilage begins to fray and may entirely wear away. Osteoarthritis can cause joint pain and stiffness.

2. Rheumatoid Arthritis

It is a type of chronic or long-lasting disease which mainly affects the joints in the body. Here in this type the immune system of the body causes the swelling in the joints. This creates the pain, stiffness, swelling joint damage and loss of function of some of the bones.

3. Juvenile Rheumatoid Arthritis

This is a rare type of arthritis which mainly affects the children. It causes the pain, stiffness, swelling, loss of function of the joints. The reason for the cause for this type of arthritis is not known till now. But it is considered that it is an autoimmune disease. Juvenile rheumatoid arthritis is not hereditary.

4. Gout

Gout is created because of the deposits of needle-like crystals of uric acid in the joints. These crystals cause inflammation, swelling, and pain in the affected joint, which is often the big toe. Apart from toe it affects foot, ankle, knee etc.

5. Infectious Arthritis

This type of arthritis is caused by infectious agents such as bacteria or viruses.

6. Psoriatic Arthritis

This type of arthritis occurs in patients with psoriasis. Psoriatic arthritis often affects the joints at the ends of the fingers and toes. Back pain will occur if the spine is involved.

7. Fibromyalgia

This causes a widespread pain at tender points such as head, neck, spine, hips, elbows and shoulders of the body. People with fibromyalgia usually have fatigue, disturbed sleep and stiffness. Fibromyalgia does not cause any joint or muscle damage.

8. Lupus

It is a type of disease that mainly affects the skin and the joints and, in some cases, it may affect the internal organs also such as the kidneys, lungs or heart. Women are more affected by these diseases then their counterparts.

9. Bursitis and tendonitis

Bursitis and tendonitis are caused by irritation from injuring or overusing a joint. Bursitis affects a small sac called the bursa that helps to cushion the muscles and tendons surrounding the joint. Tendonitis affects the tendons that attach muscle to bone.

9. Ankylosing Spondylitis

This is a type of chronic inflammatory arthritis that mainly affects the spine and pelvis.

10. Reactive arthritis

This is a temporary inflammation of the joints as a reaction to an infection elsewhere in the body.

11. Polymyalgia Rheumatica

This is an inflammatory condition affecting the muscles and soft tissues in the shoulder and upper arm, buttocks and thighs. It causes tiredness, stiffness, loss of weight and occasionally circulation problems.

STATEMENT OF THE PROBLEM

The purpose of the study was to find out the effect of Hatha yoga practices and therapeutic exercises on Pain among Old aged women with arthritis

HYPOTHESIS

It was hypothesized that there would be a significant difference on Pain among old aged women with arthritis due to Hatha yoga practices and therapeutic exercises groups than the control group.

METHODOLOGY

The purpose of the study was to find out the effect of Hatha yoga practices and therapeutic exercises on Pain among Old aged women with arthritis. For the purpose of this study, forty-five old aged women with arthritis were chosen on random basis from Chennai only. Their age group ranges from 55 to 60.

The subjects were divided into three group of fifteen each. The experimental group I would undergo Hatha yoga practices with therapeutic exercises and the experimental group II undergo Hatha yoga practices without therapeutic exercises and third group consider as control group not attend any practices, and the pre test and post test would be conducted before and after the training. Training would be given for six weeks. It would be found out finally the effect of Hatha yoga practices and therapeutic exercises on Pain among Old aged women with arthritis in scientific method. The visual analog scale measured for Pain. The collected data were statistically analyzed by using analysis of covariance (ANCOVA).

Training Schedule

Experimental Group I : Hatha yoga practices with therapeutic exercises
Experimental Group II : Hatha yoga practices without therapeutic exercises
Group III : Control Group (No Training).

COMPUTATION OF ANALYSIS OF COVARIANCE AND POST HOC TEST ON PAIN

The statistical analysis comparing initial and final means of Pain due to Hatha yoga practices and therapeutic exercises among Old aged women with arthritis is presented in Table I.

TABLE – I

ANALYSIS OF COVARIANCE OF THE MEANS OF TWO EXPERIMENTAL GROUPS AND THE CONTROL GROUP IN PAIN

					df			F

Test	Ex. Group. I	Ex. Group. II	Control group	Source of variance		Sum of square	Mean square	
Pre-test mean	7.26	7.07	7.33	Between	2	0.58	0.289	0.21
				Within	42	57.20	1.36	
Post-test mean	5.8	4.33	7.40	Between	2	70.58	35.29	31.31*
				Within	42	47.33	1.13	
Adjusted mean	5.78	4.41	7.35	Between	2	64.48	32.24	37.67*
				Within	41	35.087	0.86	

* $F_{(0.05)}$ (2,42 and 2, 41) = 3.23. *Significant at 0.05 level of confidence.

Since significant improvements were recorded, the results were subjected to post hoc analysis using Scheffe's Confidence Interval test. The results were presented in Table II.

To find out which of the paired means had a significant difference, the Scheffe's post-hoc test is applied and the results are presented in table II.

TABLE II

SCHEFFE'S POST-HOC TEST FOR PAIN

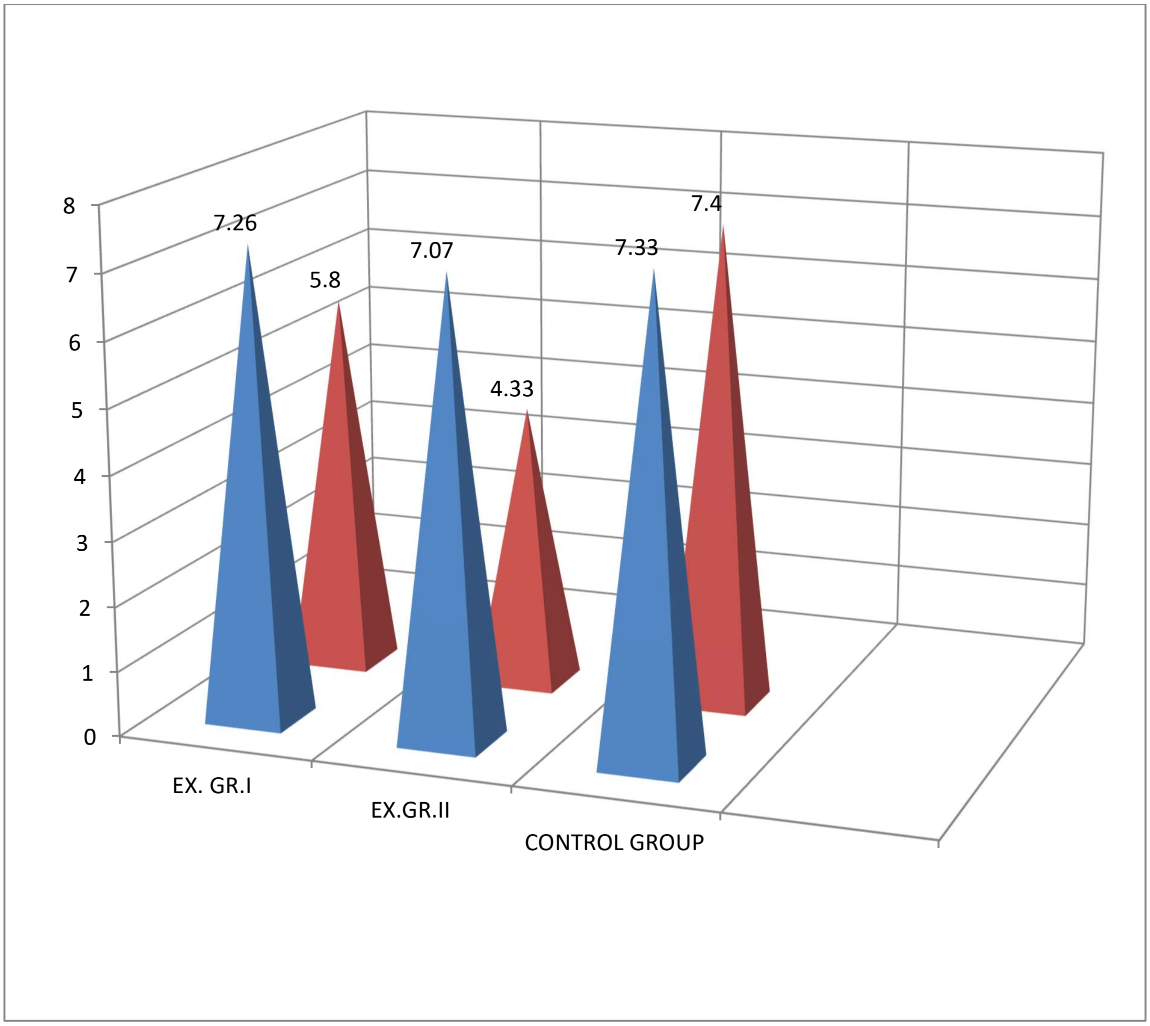
Ex. Group. I	Ex. Group. II	Control group	Mean Difference	CI
5.78	---	7.35	1.57	0.84
---	4.41	7.35	2.94	0.84
5.78	4.41	---	1.37	0.84

* Significant at 0.05 level.

The ordered adjusted means were presented through bar diagram for better understanding of the results of this study in Figure 1.

FIGURE – 1

Bar diagram showing the mean difference among Experimental Group I, Experimental Group II and Control Group of Pain



RESULTS AND DISCUSSIONS OF PAIN

Taking into consideration of the pre test means and post test means adjusted post test means were determined and Analysis of Covariance was done and the obtained F value 37.67 was greater than the required value of 3.23 and hence it was accepted that the Hatha yoga practices and therapeutic exercises significantly improved (Decrease) the Pain among male Old aged women with arthritis at 0.05 level.

The post hoc analysis of obtained ordered adjusted means proved that there was significant differences existed between Hatha yoga practices with therapeutic exercises group and control group and Hatha yoga practices without therapeutic exercises group and control group on Pain. This proved that due to six weeks of Hatha yoga practices with therapeutic exercises practices and Hatha yoga practices without therapeutic exercises Pain was significantly improved (Decrease) among Old aged women with arthritis

DISCUSSION ON THE FINDINGS OF PAIN

The Analysis of Co-variance of Pain indicated that experimental group I (Yogic practices with diet modifications), experimental group II (Hatha yoga practices without therapeutic exercises Practices), were significantly improved (Decrease) than the control group on Pain. It may be due to the effect of Hatha yoga practices with therapeutic exercises and Hatha yoga practices without therapeutic exercises Practices.

The findings of the study showed that the experimental group I (Hatha yoga practices with therapeutic exercises) had improvement (Decrease) Pain more than the experimental group II (Hatha yoga practices without therapeutic exercises Practices). Nearly everything in life requires balance. Hatha yoga practices and therapeutic exercises on its own is a good step toward a healthy life style. However, as individual, it is important to malaise that we need to work on our body as well as our mind.

CONCLUSION

There was a significant improvement (Decrease) in Pain of experimental groups when compared to the control group. Hatha yoga practices with therapeutic exercises group has shown improvement than the Hatha yoga practices without therapeutic exercises.

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A Study on Effect of Yoga and Dietary Practices on Health Parameters of Menopause Women

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Abstract:
The investigation studying the impact of yoga on the health status of early-menopause, during menopause and post-menopausal women in terms of Physical (anthropometry), and physiological variables namely signs and symptoms, to document the dietary practices, and to develop an educational module for menopausal women. A total of 50 menopausal women between the age group of 40-55 years were selected for the study General information regarding the subjects was collected using questionnaires and personal interviews. The information on anthropometric measurements viz., height, weight, waist-to hip ratioand BMI were calculated further dietary habits like frequency of food consumption pattern were recorded. Information about the age of onset of menopause age of the respondent, was collected. Good results were observed in percent of recovery among the physiological variables i.e. signs and symptoms of Early, During and Post menopause women after yogic intervention.

This study shows the physiological variables namely the signs and symptoms of early-menopausal, during-menopausal and post-menopausal women where the number of women found with irritability symptom was 7 out of 10, 14 out of 15 and 19 out of 25 among the early, during and post-menopausal groups respectively before intervention. whereas fall in number and change in recovery percent was observed as 57%, 71%and 68% among early, during and post menopausal groups after yogic intervention respectively. The percent of recovery of the symptom Mood swings was observedas 75% in early, 64% in during and 100% in post menopause women after yogic intervention. Recovery percent for Tension and depression noted symptom was observed to be 60%, 38% and 58% among early, during and post menopause women after yogic intervention. Joint and musclepain was commonly observed among all the groups and there was great change in recovery percent observed after intervention of yoga i.e. 73% in during menopause group 62% in early and 61 percent among post menopause women. Almost similar results were found in all the groups which shows thatyogic intervention is very much effective on the symptom of joint and muscle pains. There was no recovery percent observed before and after yogic intervention in symptoms namely facial hair growth, dry and wrinkle skin and tender breasts as they might beinfluenced by factors like genetics, age and might need more time for practice of yoga. Thus, these observations show that yogic intervention has positive effect on the above symptoms among menopause women.

Keywords: Menopause, Yoga, Meditation, Pranayama, Menopause foods.

Introduction:

Menopause is a natural part of a woman's life. It is a phase when she no longer experiences menstruation, technically her body begins to produce less and less progesterone and estrogen, and eventually her periods cease. Menopause typically occurs in a woman's late 40's to early 50's. A "Premature" menopause is one which occurs spontaneously before the age of 40 as a result of surgical removal, irradiation or abnormalities of ovaries, occurring in the fashion in 8 per cent women [3] (Devi et al.,2003).
During menopause, the women develops certain physical, physiological changes. The symptoms start appearing soon after the ovaries stop functioning. The main cause for the symptoms is lack of estrogen and progesterone. The symptoms may be mild in some and severe in others. Physiological symptoms namely Hot-flushes, dizziness, faintness, nausea, vomiting, bloating, dryness, muscle and joint pains, anorexia, night sweats, changes in bowel habit, weight gain, headaches or migraines, pelvic discomfort, skin and hair disorders, edema and swelling. These in turn are thought to increase the risks of various chronic diseases including heart diseases and osteoporosis [4] (Frankenfeld et al.,2003).
Behavioral changes of menopause women include avoiding social activities, lowered work performance, staying at home and in bed. All these, psychological and physiological changes have impact on food intake and food choices of menopausal women. It is an established fact that well balanced diet is important for good health and to combat some of the complications of menopause to certain extent. Therefore, there is a need to study the nutritional status of menopausal women [1] (Agarwal R P *et al*.,2003).
Typically lasting 5-10 years, the menopausal transition is associated with symptoms including hot flushes, night sweats, and liable mood. As these symptoms often hinder a woman's successful functioning in everyday life, hormone therapy is commonly early scribed as a means to diminish symptoms. However, many women are seeking complementary and alternative treatments due to side effects and/or detrimental health-risks associated with conventional therapies. A mixed methods study helped to determine changes in physiological symptoms associated with menopause and changes in women's quality of life, as a result of participation in a ten-week yoga intervention [2] (Brandi M. Crowe *et al*.,2015)
Similar results were found in a study conducted on "Effect of yoga on menopausal symptoms" by [5] Joshi S *et al.* 1998, they proved that the effect of yoga on menopausal symptoms using a prospective, randomized, controlled and interventional study. On day 90, the scores in the yoga group showed a reduction in score on all sub scales, which was statistically significant. No significant difference was noted in the control group. Yoga is effective in reducing menopausal symptoms and should be considered as alternative therapy for the management of menopausal symptoms. Effect of Yoga on Objective and Subjective Menopausal Hot Flashes [8] (GLAM) (2000). The purpose of this research study is to compare yoga and health and wellness classes
for helping peri menopausal or newly postmenopausal women who are experiencing hotflashes.

METHODOLOGY:

A detailed Questionnaire was structured to collect necessary information of the subjects. The details of various aspects of questionnaire includes general information of menopausal women such as age, education, occupation, type of family, income, number of children were collected by self-structured questionnaire through personal interview method.
Details about The Menopause women: Information about the age of onset of menopause of the respondent, present and past trend of menstrual cycle, number of days of bleeding at present and past symptoms of menopause and irregularity of menses were collected.
The lifestyle pattern of the women such as exercise behavior and physical activities performed were

assessed by personal interview.

SAMPLE DESIGN:

Visakhapatnam (Phase 1)

↓

Sivajipalem AU quarters (40– 55 age)

↓

75 Women (Phase 2)

↓

50 menopausal women selected (Phase 3)

↓

YOGA INTERVENTION (8 weeks- 8 sessions)

(40-45 yrs., n=10)
Early-menopause women group

(51-55 yrs., n=25)
Post-menopause women group

(46-50 yrs., n=15)
During-menopause Women group

SAMPLE SELECTION

The sample for this study consists of 50 women both working women and housemakers living at Sivajipalem, AU quarters area, Visakhapatnam. They are divided in to three groups: 10 women of age group 40-45 years (Early- menopause) before onset of menopause.15 women of age group 46-50 years (During-menopause) during onset of menopause.25 Women of age group 55 years (Post- Menopause) after onset of menopause.

INTERVENTION

Yogic regimes were suggested among the selected menopause women of AU Staff quarters Sivajipalem. Total eight sessions for 8 weeks were given for the selected sample who were divided into three batches as early-menopause, during-menopause and post-menopause groups.

Every weekend Nutrition Awareness sessions included symptoms of menopause, factors affecting menopause and diets for menopause like Iron, calcium and fiber rich diets, balanced diet concept was explained and importance of omega fats essential fats as well as complete protein foods were suggested, functional foods for menopause were included in diet, vitamin A, D, C and B complex foods were suggested for each batch. Weekday sessions included yogic intervention pre and post test results were observed i.e. yoga asanas for menopause, meditation and pranayama techniques were taught both theoretically and practically.

The present study in the year 2019 consisted of three phases. In Phase 1, permission was obtained from the yoga village. After seeking permission from the head of the department of yoga, Andhra University, then the women of age 40-55 years were informed and explained about the purpose of the study, finally 50 women were selected. The researcher gave instructions to them about filling of the questionnaire. They were asked to read the instructions carefully and give their authentic responses after reading each of the items and select responses. They were informed to respond only to one option to every item. The respondents were also told to answer all the items without fail. They were also informed that the responses will be kept highly confidential and used for research purpose only. The instrument was administered. Whenever doubts were raised, the researcher explained to the sample.

In phase 2**,** based upon the findings of phase 1 data, a yoga module intervention was designed with the help of yoga expert guide.

YOGA SCHEDULE

Prayer	5mins
Pawana mukta series(warm up)	10 min.
Suryanamaskaras	10 min.
Sitting and Standing asanas	10 min.
Khapalabathi	5mins
Pranayama	5mins
Meditation	5mins
End prayer	5mins
Total time	**50- 60mins**

Yoga for a period of eight weeks was administered for all the three groups. In Phase 3, testing of the effectiveness of the developed yoga module intervention was done on the selected experimental groups. Soon after the completion of intervention of eight weeks' duration Post-test on symptoms of early-menopause group, during-menopause group and post-menopausal women group was conducted. The responses of subjects were analyzed in frequency and percentages, mean values in tabular form are shown in the results.

RESULTS AND DISCUSSION:

The results related to demographic profile, anthropometry, dietary history, and physiological assessment (pre and post intervention) are included in this section.

The data collected on the demographic profile of 50 women consisting of 10 women of early-menopause, 15 women of during-menopause and 25 women of post-menopause are presented in Table 1. Among the different age groups, majority of early-menopausal (90%) were in 40-45 years followed by 46-50 years (10%). While, 50 percent of during-menopausal and post-menopausal women belonged to the age group of 46-50 years followed by 51-55 years (40%) and 40-45 years (12%).

Table 1: Demographic profile of Menopausal Women (N=50)

Particulars	Stage					
	Early-menopausal (n=10)		During -menopausal (n=15)		Post-menopausal (n=25)	
	Frequency	%	Frequency	%	Frequency	%
Age(years)						
40-45	9	90.00	7	46.67	3	12.00
46-50	1	10.00	8	53.33	12	48
51-55	-	-	-	-	10	40
Educationalstatus						

Illiterate	-	-	1	6.67	2	8.00
High school	2	20.00	8	53.33	15	60.00
Graduate	4	40.00	4	26 .67	6	24.00
Post-graduate	4	40.00	2	13.33	2	6.00
Occupational status						
Employed	4	40.00	1	6.67	1	4.00
Non-employed	6	60.00	14	93.33	24	96.00
Types of family						
Nuclear	10	100.00	15	100	21	84.00
Joint	-	-	-	-	4	16.00
Marital status						
Married	10	100.00	15	100.00	23	92.00
Un-married	-	-	-	-	2	8.00
Number of children						
1-2	9	90.00	9	60.00	16	64.00
3-4	1	10.00	4	26.66	5	20.00
>4	-	-	1	6.67	2	8.00
No children			1	6.67	2	8.00
Family Income (Rs./>10,000)						
LIG(<10,000)	2	20.00	2	13.3	5	20.00
MIG (10,000-25,000)	8	80.00	13	83.33	20	80.00
Food Habits						
Vegetarians	9	90.00	12	70.00	23.00	92.00
Non-Vegetarians	1	10.00	3	30.00	02	8.00
Tubectomystatus						
YES	1	10.00	5	40	18	70.00
NO	9	90.00	9	60.	7	30.00

When the women were distributed based on education level, nearly half the during-menopausal and post-menopausal women (53.33% and 60% respectively) and only 20% of early-menopause women had high school education. Only (6.67%) and (8%) were illiterates in during -menopausal and post-menopausal groups and none of them belonged to illiterate category in early-menopausal group.

Higher percentage of early-menopausal women had graduation and post-graduation (40% and 40% respectively) when compared to during -menopausal (26.67% and 13.33% respectively) and post-menopausal women (24% and 6% respectively).

Majority of the early-menopausal (60%), During –menopausal (93.33%) and post-menopausal women (96%) were not gainfully employed. About 40% of early-menopause, (6.66 %) of During -menopausal and only (4%) of post-menopausal women were employed. Nuclear family system was common among the study group. All of the early-menopausal women and majority of during –menopausal (86.66%) and post-menopausal women (98%) belonged to nuclear type of family, while very few belonged to joint family from post-menopausal women (92%) were married and a few post-menopausal women were found unmarried (8%).

Majority of early-menopausal (90%) and 60 per cent of During -menopausal and 64 per cent of post-menopausal women had one to two children. 80 per cent of early, during and post-menopausal women belonged to middle income group and rest of them were in low income group (20%, 13.33% and 20% respectively)

Maximum number of women (early-menopausal 90%, during-menopausal 80% and post-menopausal 92%) were vegetarians. Women who had undergone tubectomy (early-menopausal women 10%, during-menopausal women 60% and post-menopausal 72%). Majority of women undergone tubectomy during the period of menopause and after attaining menopause.

Table 2. Mean anthropometric measurements of menopausal women

Types	Stages	Mean
Height (cm)	Early-menopausal	146.00 ± 24.8
	During -menopausal	152.00 ± 3.46
	Post-menopausal	149.12±19.85
Weight (kg)	Early-menopausal	60.90 ± 9.04
	During -menopausal	61.60±9.81
	Post-menopausal	67.11±9.22
Waist circumference (cm)	Early-menopausal	86.60±7.71
	During -menopausal	86.90±11.10
	Post-menopausal	89.61±8.47
Hip circumference(cm)	Early-menopausal	102.00±8.36
	During -menopausal	103.00±7.16
	Post-menopausal	110.87±8.86

The mean height was higher in During -menopausal women (152 cm) compared to post-menopausal women (149.12 cm) and early-menopausal women (146 cm), with no significant difference. The mean weight was maximum for post-menopausal women (67.11 kgs) followed by During -menopausal women (61.6 kgs) and early-menopausal women (60.9 kgs). The difference between the means for early and post-menopausal women was found to be significant at 5 % level. On the contrary, differences between during and post-menopausal women was found to be significant at 1 per cent level. Similar trend was observed for hip circumference.

The mean hip circumference of post-menopause women was highest (110.87 cm) followed by during-menopausal and early-menopausal (103 cm and 102cm). The mean waist circumference of post-menopausal women(89.61 cm) was found to be higher when compared to early-menopausal(86.6%) and During -menopausal women(85.9 cm), with no significant difference

Table 3. Mean BMI and WHR of menopausal women

Indices	stage	mean
BMI+	Early-menopausal	26.50±3.05

	During --menopausal	26.80±3.75
	Post--menopausal	29.15±3.39
WHR	Early-menopausal	0.83±0.05
	During --menopausal	0.82±0.05
	Post--menopausal	0.80±0.03

The mean BMI and WHR of menopausal women. Mean BMI was higher in post-menopause women (29.15%) followed by During -menopause women (26.8) and early-menopause women (26.5). The mean BMI of post-menopausal women was higher compared to early and post-menopausal women. The mean waist to hip ratio of early-menopause women was maximum (0.83) followed by During -menopause women (0.82) and post-menopause women (0.80). The mean WHR of early-menopause women was significantly higher when compared to post-menopausal women and that of During -menopause women.

Table 4. Exercise Behavior of menopausal women

particulars	Stage					
	-menopausal(n=10)		During-menopausal (n=15)		menopausal(n=25)	
	Frequency	%	Frequency	%	Frequency	%
Exercising habit	6	60.00	9	60.00	7	28.00
yes	4	40.00	6	40.00	18	72.00
No						
Type of exercise						
walking	4	40.00	8	53.33	12	24.00
yoga	1	10.00	1	6.66	-	-
walking and yoga	1	10.00	-	-	1	4.00
Period of initiation						
1-2	3	30.00	4	26.67	1	4.00
2-5	3	30.00	5	33.33	4	16.00
5-10		40.00	-	-	2	8.00
Frequency of exercise						
Daily	2	20.00	2	13.33	2	8.00
Once a week	1	10.00	2	13.33	2	8.00
Thrice a week	3	30.00	5	33.33	6	12.00
Duration						
30 minutes	-	-	-	-	3	12.00
45 minutes	1	10.00	2	13.33	3	12.00
1 hour	8	45	7	46.66	1	4.00

A Higher percentage of During-menopausal women were 60%, who exercised compared to Early- and

Post-menopause women were 55% and 28% respectively. Among the exercising women, walking was the form of exercise performed by higher number of During-menopausal women were 56.67% followed by early and post-menopausal women 45 % and 24 % respectively.

Very few of the During-menopausal (3.33%) and early-menopausal (5%) followed yoga. About (5%) from early and (4 %) from Post-menopausal women did walking as well as yoga. Most of the During-menopausal has started doing exercise for the last 2-5 years were (33.33) when compared to early-menopausal were (30%) and post-menopausal women (16%) and about 26.67, 25.00, and 4,00 percent of during-menopausal, early-menopausal and post-menopausal women had started doing exercise for the last 1-2 years and only very few of post-menopausal women (8%) were doing exercise from last 5-10 years.

Higher percentage of women in early-menopause women performed exercise daily when compared to during-menopause and post-menopause women, (early-menopausal 20%, during-menopausal 16.67 % and post-menopausal women 6%). Equal number of During- and Post-menopausal women each 10% and 5%. Early-menopausal women exercised thrice a week compared to post-menopausal women i.e. during-menopausal 33.3%, early-menopausal 30% and post-menopause women 12%.

Table 5. Mean Nutrient Intake of early, during and post-menopausal women

Nutrients	Stages of Menopause			
	Early-menopause women (n=10)	During- Menopause women (n=15)	Post-Menopause women (n=25)	RDA*
Energy (kcal /day)	2204 ± 321	2236 ± 415	2206 ± 713	1875
Proteins (g/day)	65.59 ± 12.90	69.13 ±13.36	64.69 ±15.80	50
Fat (g/day)	53.98 ± 13.48	55.16 ± 14.12	52.92 ± 14.18	20
B-Carotene (mg/day)	2170.45 ± 2275.60	2469.03 ± 2088.63	1824.66± 1853.87	2400.0
Thiamine (mg/day)	1.33 ± 0.27	1.34± 0.66	1.15 ± 0.49	0.90
Ascorbic acid (mg/day)	35 ± 2.16	31 ± 2.86	32 ± 1.39	40.00
Calcium (mg/day)	248.85 ± 104.78	229.69 ± 105.37	279.90 ± 154	400.00
Iron (mg/day)	33.56 ± 10.30	28.80 ± 0.66	23.36 ± 3.19	30.00

*[10] RDA by ICMR 2010

The mean nutrient intake of menopausal women is presented in Table 3. The mean energy intake among During-menopausal women was slightly higher compared to post and early-menopause women (2236, 2204, 2206 kcal/day) for energy respectively. The mean intake of proteins in early, during and post menopause women was (69.13,65.59,64.69 g/day) respectively, B-carotene levels almost met the RDA among early-menopause and during-menopause group i.e. 2170 and 2469 mg/day respectively whereas B-carotene was slightly deficient among Post-menopause group women may be due to lack of absorption age as a factor. Thiamin was almost met the RDA in all three groups i.e. nearly 1mg/day. The ascorbic acid intake was below the RDA ranging between 31 mg/day to 35mg/day in all the three groups which might affect Iron absorption among the menopause women. Appropriate diets and foods were suggested among all the three groups during weekend sessions. The mean intake of Calcium was found to be below the RDA levels among all the three groups i.e. very low in during-menopause group (229mg/day), (248mg/day) among early-menopause group and (279mg/day) among post-menopause group. The mean intake of Iron was found to be 33mg, 28mg and 23 mg/day among early, during and post-menopausal women which shows slight iron deficiency among during-menopauseal group and much difference in RDA levels was found in post-menopausal group.

Table 6. shows the physiological variables namely the signs and symptoms of early-menopausal women, during-menopausal and post-menopausal women where the number of women found with irritability symptom was 7 out of 10, 14 out of 15 and 19 out of 25 among the early-menopausal group, during-menopausal and post-menopausegroups respectively before intervention. whereas fall in number and change in recovery percent was observed as 57%, 71% and 68% among early-menopausal, during-menopausal and post menopause groups after yogic intervention respectively.

The percent of recovery of the symptom Mood swings was observed as 75% in early-menopause women, 64% in during-menopause and 100% in post-menopause women after yogic intervention. Recovery percent for tension and depression noted symptom was observed to be 60%,38% and 58% among earl-menopausal, during-menopausal and post menopause women after yogic intervention.

Joint and muscle pain was commonly observed among all the groups and there was great change in recovery percent observed after intervention of yoga i.e. 73% in during-menopause group 62% in early-menopause women and 61 percent among post menopause women. Almost similar results were found in all thegroups which shows that yogic intervention is very much effective on the symptom of joint and muscle pains.

For the Symptom of thinning and hair loss, good recovery percent observed in early menopause group i.e., 71% after yogic intervention where as during- menopause and post -menopause groups showed 46% and 16% only. 80 to 100% results were observed after yogic intervention for the symptoms likeheadache, migraine, sleep disturbances and water retention and loss of bladder control. Thus,these observations show that yogic intervention has positive effect on the above symptoms among menopause women. There was no recovery percent observed before and after yogic intervention in symptoms namely facial hair growth, dry and wrinkle skin and tender breasts as they might be influenced by factors like genetics, age and longer time for practice of yoga.

The physiological changes observed among menopause women may be also due to the nutrient deficiencies like calcium, iron and vitamin C which were presented in table 5. some nutrients were adequately met as per RDA among the early, during and post-menopausal groups but the symptoms like muscle and joint pains or hair loss, headache and migraine may be due to lack of absorption among menopausal women. In the post-menopause group most of the nutrient intake was good but lack of absorption might be the reasons for the severity of signs and symptoms. A pilot study on Integral Yoga on Hot flushes showed benefits of yoga for reducing hot flashes [6] (Nancy E. Avis, et al.,2015). [11] Vasudeven, et al., (1994) have found that Statistically significant reduction in pain perception was observed. Yogic Meditation was effective in reducing tension headache. Yoga is most commonly used complementary therapies for menopausal symptoms [7] (Lunny.C.A et al,. 2010).

Table . 6. Menopausal symptoms of early, during and post-menopausalwomen. (before and after yoga intervention)

PhysiologicalSigns and Symptoms	stage								
	menopausal(n= 10)			menopausal(n = 15)			– menopausal(n = 25)		
	Before Intervention	After Intervention	% of Recovery	Before Intervention	After Intervention	% of Recovery	Before Intervention	After Intervention	% of Recovery
Irritability	7	3	57.1	14	4	71.1	19	6	68.4
Mood swings	4	1	75	14	5	64.2	22	0	100
Tension and depression	10	4	60	12	8	33.3	12	5	58.3
Aching jointsand muscles	8	3	62.5	15	4	73.3	21	8	61.9
Dry and wrinkly skin	2	2	0	6	5	16.6	3	3	-
Facial hair growth	2	2	0	4	4	0	0	0	-
Thinning and hair loss	7	2	71	13	7	46.1	24	20	16.6
Headaches/ migraines	9	2	77	15	3	80	10	2	80
Heart palpitation	3	0	100	11	9	81.1	9	6	33.3
Hot flushes	2	0	100	15	8	46.6	14	6	57
Night sweats	4	1	75	14	6	42.8	9	4	55
Sleep disturbances	7	0	100	15	7	53.3	23	3	86.9
Loss of bladder control	9	4	55.5	11	1	90.9	21	8	61.9
water retention	3	0	100	8	4	50	4	0	100
Breast tenderness	5	5	nil	15	13	13.3	3	3	nil

From this study it can be concluded that menopausal phase has been a moderate problem in the study group. The abdominal obesity prevalent among women may create health related problems. Hence an intensive orientation and education is absolutely necessary. Yoga, meditation and Pranayama and diet can do miracles among these women.

Conclusion:

The amazing thing about Yoga is that its positive effects on the health and mind are visible over time. Another specialty about yoga is wide choice of asanas. Depending upon the stamina and overall health, one can choose from mild pranayama, asanas to high intensity asanas. It is a medication without the actual cause of medicines. Moreover, no visible side effects are associated with the practice of yoga on a regular basis. All you need to know is the most appropriate exercises meant for the structure of body, while choosing the asanas of the activity. In addition, one needs to know the right way of performing the asnas because any wrong attempt can cause sprain and injuries.

Healthy women can cope up with all the problems faced due to Stress and hormonal changes during different age level. Physiological changes during menstruation may cause stomach pain, headache and other Premenstrual Syndrome due to hormonal changes, so to overcome these troubles the female should be healthy. Yoga can help Women to manage all the health issues and develop the state of their body and mind. Yoga poses are intended to tone and exercise the muscles of the body to remove excess fat, and formulate it more flexible and stronger. Practicing yoga can provide women with both unpredicted and obvious benefits for the mind, body, and spirit. Some yoga postures relieve stress that occurs due to hormonal changes in women during pregnancy and menopause. A regular yoga practitioner has high tolerance capacity, mentally and physically more flexible and more self-confidentt.

Many studies concluded that Yoga improved the mental health of women. It showed that yoga improved quality of life, quality of sleep and provided peace of mind and reduced depression, anxiety and psychological symptoms of stress related problems, illness and insomnia, menopausal symptoms. It also helped breast cancer survivor to achieve psychological wellbeing. Though there were certain limitations these studies have shown the benefit of yoga on mental health of women. Yoga can be a useful tool for all physical, physiological and mental wellbeing.

Out of 120 articles found in the database, six articles entered the study based on the inclusion criteria and were investigated for intervention methods and consequences. The results indicated positive impact of yoga on quality of life in menopausal women. Considering the effects of yoga on the symptoms and quality of life in menopausal women it is suggested that this low-cost methods be used to improve their quality of life and health.[9] (Neda Sharifi, et al., 2021)

Most of the volunteers felt calmness of mind, a sense of well-being, and some felt sleepy, thus supporting parasympathetic stimulation. This may be the effect of increased melatonin production after a regimen of slow breathing pranayamic exercises. Slow pranayama breathing was also reported to elicit alpha waves, indicating a parasympathetic dominance and may be the cause of the sleepy feeling. Slow pace pranayama shows a strong tendency of improving or balancing the autonomic nervous system through enhanced activation of the parasympathetic system and thus can be practiced for mental relaxation and reduction of stress of daily life.

Thus there was a very positive impact of Yoga, pranayama and meditation in alleviating the symptoms and health problems of Menopause women. The results suggest that Yoga, Meditation and pranayama leads to Samadhi, kaivalya, eternal bliss, which aim to maintain physical fitness, mental stability, emotional quietness and spiritual elevation.

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The effect of 12-week step and floor aerobic exercise programs on physical and psychophysiological health parameters in obese men

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Wpływ 12-tygodniowych programów ćwiczeń aerobowych na fizyczne i psychofizjologiczne parametry zdrowotne otyłych mężczyzn

Streszczenie

Ćwiczenia aerobowe zalecane są w celu zapobiegania i kontrolowania nadwagi i otyłości. Niniejsze badanie miało na celu ocenę skuteczności dwóch 12-tygodniowych programów ćwiczeń aerobowych w poprawie stanu zdrowia fizycznego i psychofizjologicznego otyłych mężczyzn. Sześćdziesięciu dorosłych mężczyzn w średnim wieku 18,92 (SD 1,54 lat) i wskaźniku masy ciała (BMI) ≥ 30 kg/m^2 zostało losowo przydzielonych do trzech równych (n = 20) grup: trening aerobowy z wykorzystaniem stepów (SAET), trening aerobowy bez stepów (FAET) lub grupa kontrolna (która nie podejmowała aktywności fizycznej). Procedury treningowe SAET i FAET wykonywano trzy dni w tygodniu przez 12 tygodni. Wybrane parametry zdrowotne (fizyczne i psychofizjologiczne) oceniono na początku badania i po 12 tygodniach. Stwierdzono istotne różnice w zakresie parametrów zdrowia fizycznego i psychofizjologicznego u uczestników, którzy przeszli trening SAET i FAET w porównaniu z grupą kontrolną (p < 0,05). SAET i FAET okazały się pomocne w poprawie zdrowia fizycznego i psychicznego otyłych mężczyzn. Aby uzyskać lepsze perspektywy zdrowotne, szkoły i uczelnie wyższe powinny organizować sesje ćwiczeń aerobowych dla dorosłych.

Słowa kluczowe: aerobik, siła, wytrzymałość, ćwiczenia fizyczne, cholesterol.

Abstract

Aerobic exercise training is recommended to prevent and control obesity. The present study aimed to evaluate the effectiveness of a twelve-week step aerobics or floor aerobics exercise program in improving the physical and psychophysiological health of obese men. Sixty male adults of mean age 18.92 (SD 1.54 years) and Body Mass Index (BMI) ≥ 30 kg/m^2 were randomly allocated into three equal (n = 20) groups: Step Aerobics Exercise Training (SAET), Floor Aerobic Exercise Training (FAET), and a control group (which did not perform any exercise). The SAET and FAET training protocols were performed three days per week for 12 weeks. Health-related physical fitness, biochemical, physiological, and psychological variables were used as outcome measures and measured at baseline and at 12 weeks. There were significant differences in terms of physical and psychophysiological health parameters in participants who underwent SAET and FAET training compared with the control group ($p < 0.05$). SAET and FAET proved to be helpful in managing the physical and psychological health of obese adults. Schools and colleges should administer aerobic exercise sessions to adults for better health perspectives.

Keywords: aerobics, strength, endurance, physical exercise, cholesterol.

Introduction

Obesity is a chronic disease affecting food habits, exercise levels, and sleep schedules. Genetics, social factors of health, and the use of specific medications, all of them have an impact on body fat. Machines have changed human life and humans now enjoy a maximum level of physical comfort. Modern technology is working hard to make our lives easier, more luxurious, and more pleasant while also reducing physical exertion. Consequently, humans are becoming increasingly inactive globally. People now ride instead of walking, sit instead of standing, and watch instead of participating. These lifestyle changes have reduced physical labor and increased mental stress and strain. As a result, it is critical to affect positive changes in today's lifestyles through involvement in sports and physical education programs. The development of physical fitness among the public or participants should be one of the major goals of every physical education and sports program. Physical education should try to make all child physically, cognitively, and emotionally healthy, as well as develop personal and social traits in them, allowing them to live happily with others and develop as good citizens. Consequently, an individual's physical fitness can be improved through a variety of programs or activities [7].

Obesity was once considered a developed world issue; nevertheless, its incidence is increasing in both developed and developing countries. It is a life-threatening condition caused by a sedentary lifestyle that affects millions of people in both developed and developing countries. Both obesity and overweight contribute the most to non-communicable disease morbidity and mortality [14]. In 2008, the World Health Organization estimated that over 1.4 billion adults were overweight, with more than half of them being obese [15]. According to the National Health and Nutrition Examination Survey, the prevalence of obesity was 39.6 percent among rural people in 2005–2008, compared to 33.4 percent among urban adults [1]. The prevalence of generalized obesity ranged from 11.8 percent to 33.6 percent among people in a recent ICMR-INDIAB study conducted in three Indian states: Tamil Nadu, Maharashtra, and Jharkhand, as well as in one Union Territory, Chandigarh [13]. The prevalence of obesity among Indian women has increased from 10.6% to 12.6 percent, according to a comparison of two major surveys conducted by the National Family Health Survey (NFHS-2) in 1998–1999 and NFHS-3 in 2005–2006 [5]. According to the Chennai Urban Rural Epidemiology Study, the age-standardized prevalence of generalized obesity is 45.9% [3].

Anaerobic exercise, which includes strength training and short-distance running, can be compared to aerobic exercise and fitness. The duration and intensity of muscular contractions as well as how energy is created within the muscle differ between the two types of exercise. Recent research on the endocrine functions of contracting muscles has found that both aerobic and anaerobic exercise promote the secretion of myokines, which has a variety of benefits, including new tissue growth, tissue repair, and anti-inflammatory functions, lowering the risk of developing inflammatory diseases. The quantity of muscle contraction, as well as the duration and severity of contractions, all influence myokine secretion. Count is used in floor aerobics. Floor aerobics was created to eliminate the need for open-air exercise. Women took advantage of the opportunities presented to them daily. Many gyms and fitness facilities with a group workout program offer step-aerobic programs. Gin Miller introduced the concept of step aerobics in 1989. Gin visited an orthopaedic doctor after suffering a knee injury, who advised her to strengthen the muscles supporting the knee by stepping up and down on a milk crate, which she did, and from which she devised step aerobics [8]. The present study aimed to analyze the changes in physical and psychological health among obese adults after participating in 12 weeks of step-aerobic or floor-aerobic exercise protocols.

Methods

Participants and Study Design

Sixty obese male adults were recruited from the SRM Institute of Science and Technology (Kattankulathur, Tamil Nadu, India). The participants were randomly selected from various family backgrounds and participated in similar academic activities. The age range of the patients was 18–24 years. The following inclusion criteria were met by each participant for them to be part of this study: age of 18–24 years old, healthy sedentary obese men with a Body Mass Index (BMI) of ≥ 30 kg/m^2, and each participant had a sedentary lifestyle (less than 1 h of physical activity per week during the last year). The exclusion criteria were being female, having a BMI of less than 25–30 kg/m^2, undergoing any prior open surgery during the previous 8 months, having cardiovascular disease, and both the lower and upper extremities amputated. All the participants read and signed an informed consent form. Before the measurements started, the *SRM* Medical College Hospital and Research Centre (SRM CHRC, Kattankulathur, Tamil Nadu, India, Number 8484/IEC/2022) evaluated and approved the study procedures. The most recent revision of the Declaration of Helsinki was followed for all procedures.

Males with a BMI of 30 kg/m^2 or higher were considered obese for the purposes of this study. All participants were randomly divided into three groups, with 20 participants in each group: step aerobics exercise training (SAET), floor aerobics exercise training (FAET), and control group (CG). The aerobic and floor aerobic groups were subjected to respective exercises for 12 weeks, whereas the control group did not perform any exercise. Physical and psychological health were compared at baseline and endpoint in all groups. The requirements of the experimental procedures, testing, and exercise schedule were explained to the participants prior to the administration of the study to obtain full cooperation in the effort required on their part. The subjects completed training three days a week, except for Saturdays and Sundays, from 6.30 to 7.30 a.m. The exercises were gradually introduced. A simple to complex procedure was used.

Outcome Measures

Health Related Physical Fitness Measures

Following a review of the literature and consultation with professionals and experts, the following variables were chosen as criteria for this study: cardiovascular endurance (CRE) was measured using Cooper's 12 Minute Run / Walk test [20]. Muscular flexibility (F) was measured through Sit and Reach test [21]. Muscular Strength (MS) was measured using push-ups [11]. Muscular Endurance (ME) was measured using the half-squat jump test [23]. Body Composition (BC) was calculated based on the following formula: percent body fat = 0.41563 x (sum of three sites) - 0.00112 x (sum of three sites) 2 + 0.36661 x (age) + 4.03653, where the sum of the three sites were skinfold caliber measures at the triceps, medial region of the navel part, and suprailium [22].

Physiological Measures

The vital capacity (VC) was measured using a Spirometer [6]. Resting Heart (RHR) rate was measured using a digital heart rate measuring machine (Model No. EW 243, National Company, Japan) [16]. Mean arterial blood pressure (MABP) was measured using systolic and diastolic blood pressure, as suggested by Mathews and Fox [4]. Breath-holding (BH) time was measured using a nose clip and a stopwatch, as suggested by Mathew [10]. Respiratory Rate (RR) was measured using a bio-monitor, as suggested by Saroja [19].

Biochemical Measures

To conduct a hematological analysis, blood was immediately transferred into tubes of Vacationer (Becton Dickinson, Rutherford, NJ, USA) with or without 0.1% EDTA as an anticoagulant. Serum and plasma were separated by centrifugation at 2500 rpm for 15 minutes at four °C, and the separated components were stored at 80°C until assessment. After sitting for 20 minutes, following a fast of 12-hour overnight, blood was taken from an antecubital vein between 7:00 and 9:00 a.m. at Week 0 and Week 12 for analysis. The sample size was 15 ml. Fasting glucose, total triglyceride levels (TG), total cholesterol (TC), high-density lipids (HDL), and low-density lipids (LDL) were examined using an automated biochemical analyzer and measured using standard laboratory methods [17].

Psychological Measures

Self-confidence (SC) scale used in the current study was to rate self-confidence levels within the selected sample using a 5-point Likert scale ranging from totally disagree (1) to totally agree (5), Emotional Adjustment (EA) was quantified using a 5-point Likert scale ranging from totally disagree (1) to totally agree (5). Assertiveness (A) 19-item scale version demonstrated good psychometric characteristic regarding reliability. Interpersonal Relationship (IR) 5-point scale ranged from "strongly agree" to "strongly disagree," and Stress Management (SM) was measured using Personality Development Index Questionnaire developed by Kaliappan [9].

Interventions

The investigator constructed a 12-week training schedule for FAET and SAET, with much focus on the progression of the training load. The FAET group was allotted to Experimental group I, SAET was allotted to Experimental group II, and another group called the control group was allotted no training except for their regular activities. The training period for the experimental groups was restricted to 12 weeks, thrice a week. The duration of each training session was 60 min, which included warm-up and cool-down. The investigator personally supervised and ensured the appropriate execution of training, along with assistance from a trained expert. The Floor Aerobic Exercise Training group performed for 60 minutes per session, 3 times per week for 12 weeks. Each session started with a 10-minute warm-up exercise for weeks 1–4 (32 counts, 8 sets), weeks 5–8 (32 counts, 10 sets), and weeks 9 – 12 (32 counts, 12 sets). The aerobic exercise training group performed for 60 min per session, 3 times per week for 12 weeks. For weeks 1- 4 (32 counts, 4 sets), weeks 5–8 (32 counts, 10 sets), and weeks 9 – 12 (32 counts, 12 sets), at the end of each training session, a 10-minute cool-down exercise was given.

Data analysis

Means and standard deviations (±) were used to describe all data, and Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine if the data were normal. We ensured that there was no significant difference between the groups. The intraclass correlations (ICCs) and test and retest accuracies for all tests were analyzed. The effects of exercise were also examined using a two-way analysis of variance (ANOVA) and repeated measurements (three groups, twice). If group-by-time connections were found to be important, Bonferroni post-hoc tests were performed. Statistical significance was set at $p<0.05$.

Results

There were no significant differences ($p > 0.05$) in any baseline parameters between groups (Table 1).

Table 1. Participant characteristics (mean ± SD)

Characteristics	SAET	FAET	CG
Age (years)	18.41 ± 1.61	18.72 ± 1.92	18.89 ± 1.40
Height (cm)	170.5 ± 4.51	172.8 ± 4.69	173.4 ± 5.19
Weight (kg)	88.26 ± 4.30	88.60 ± 5.49	90.20 ± 6.10
BMI (kg/m^2)	30.10 ± 1.11	30.00 ± 1.30	30.20 ± 1.41

SD: Standard Deviation; BMI: Body Mass Index; SAET: Step Aerobics Exercise Training; FAET: Floor Aerobic Exercise Training; CG: Control Group.

Health Related Physical fitness

The main influence of time on some outcomes has been found to be CRE ($F = 27.37$, $\eta p^2 = 0.32$, power value: 0.99, $p < 0.001$), MS ($F = 31.27$, $\eta p^2 = 0.35$, power value: 0.99, $p < 0.001$), ME ($F = 56.35$, $\eta p^2 = 0.49$, power value: 0.99, $p < 0.001$), Flex (F = 1.40, $\eta p^2 = 0.71$, power value: 0.99, $p < 0.001$), and BC ($F = 35.95$, $\eta p^2 = 0.38$, power value: 0.99, $p < 0.001$). Significant group (three) and time (pre and post) interactions were seen for CRE ($F = 2.67$, $\eta p^2 = 0.09$, power = 0.51, $p = 0.08$), MS ($F = 0.67$, $\eta p^2 = 0.23$, power value: 0.15, $p = 0.51$), ME ($F = 6.90$, $\eta p^2 = 0.19$, power value: 0.99, $p < 0.002$), Flex ($F = 11.82$, $\eta p^2 = 0.29$, power value: 0.99, $p < 0.001$), and BC ($F = 2.06$, $\eta p^2 = 0.07$, power value: 0.40, $p = 0.14$).

A post-hoc analysis showed considerable pre-to-post improvement ($p < 0.001$) in both step aerobic exercise training and floor aerobic exercise training for cardiorespiratory endurance ($\eta p^2 = 0.07$; $\eta p^2 = 0.20$, respectively), muscular strength ($\eta p^2 = 0.08$; $\eta p^2 = 0.15$, respectively), and muscular endurance ($\eta p^2 = 0.04$; $\eta p^2 = 0.12$, respectively) compared to the control group. The post-hoc analysis showed a considerable pre-to-post decrease ($p < 0.001$) in both step aerobic exercise training and floor aerobic exercise training for body composition ($\eta p^2 = 0.04$; $\eta p^2 = 0.14$, respectively) compared to the control group. The participants engaged in step aerobics aerobic training and floor aerobics aerobic fitness showed no significant improvement in any of the training protocols tested in terms of cardiovascular endurance, muscular endurance, muscular strength flexibility, or body composition, whereas the control group showed no significant improvement in any of the training protocols tested (Table 2).

Table 2. Mean (± SD) values of health-related physical fitness parameters for the three groups

Variables	Group	Before	After	Partial eta-squared (ηp^2)		
				Main effect group	Main effect time	Interaction group x time
CRE (ml/kg/min)	SAET	28.89 ± 2.13	30.95 ± 1.09 [ac]	0.06 (p = 0.16)	0.32 (p < 0.001)	0.09 (p = 0.08)
	FAET	28.58 ± 0.84	30.54 ± 1.01 [a]			
	CG	28.97 ± 2.15	29.54 ± 1.64			
MS (numbers)	SAET	19.10 ± 1.37	20.45 ± 1.43 [a]	0.03 (p = 0.40)	0.35 (p < 0.001)	0.02 (p = 0.52)
	FAET	19.15 ± 2.18	20.90 ± 1.41 [ac]			
	CG	18.90 ± 1.86	19.95 ± 1.76			
ME (numbers)	SAET	22.85 ± 2.30	25.40 ± 1.27 [ac]	0.01 (p = 0.80)	0.50 (p < 0.001)	0.19 (p = 0.002)
	FAET	22.95 ± 1.82	25.00 ± 1.16 [a]			
	CG	23.55 ± 1.63	24.10 ± 1.51			
F (cm)	SAET	22.85 ± 1.75	24.85 ± 1.26 [ac]	0.03 (p = 0.37)	0.79 (p < 0.001)	0.41 (p < 0.001)
	FAET	22.00 ± 2.55	24.25 ± 1.99 [a]			
	CG	22.80 ± 1.90	23.45 ± 1.70			
BC (%)	SAETG	39.33 ± 0.35	38.67 ± 0.60 [a]	0.05 (p = 0.24)	0.39 (p < 0.001)	0.07 (p = 0.14)
	FAETG	39.33 ± 0.61	38.72 ± 0.72 [a]			
	CG	39.33 ± 0.15	39.06 ± 0.43			

SAET: Step Aerobics Exercise Training; FAET: Floor Aerobic Exercise Training; CG: Control Group; CRE: Cardiorespiratory Endurance; MS: Muscular Strength; ME: Muscular Endurance; F: Flexibility; BC: Body Composition; [a]significant difference before and after the intervention; [c]significant interaction between SAET and FAET.

Physiological variables

The main influence of time on some outcomes have been found to be VC (F = 1.84, $\eta p^2 = 0.76$, power value: 0.99, p<0.001), RHR (F = 91.30, $\eta p^2 = 0.61$, power value: 0.99, p < 0.001), MABP (F = 0.01, $\eta p^2 = 0.88$, power value: 0.50, p = 0.982), BHT (F = 73.55, $\eta p^2 = 0.56$, power value: 0.99, p < 0.001), RR, (F = 21.51, $\eta p^2 = 0.27$, power value: 0.99, p < 0.001). Significant group (three) and time (pre and post) interactions were seen for VC (F = 18.33, $\eta p^2 = 0.39$, power = 0.51, p < 0.001), RHR (F = 9.60, $\eta p^2 = 0.25$, power = 0.97, p < 0.001), MABP (F = 1.87, $\eta p^2 = 0.19$, power = 0.62, p = 0.163), BHR (F = 4.90, $\eta p^2 = 0.14$, power = 0.78, p < 0.011), RR (F = 4.58, $\eta p^2 = 0.14$, power = 0.75, p = 0.014).

A post-hoc analysis showed a considerable pre-to-post decrease (p < 0.001 value) in both step aerobic exercise training and floor aerobic exercise training for resting heart rate ($\eta p^2 = 0.08$; $\eta p^2 = 0.16$, respectively), and respiratory rate ($\eta p^2 = 0.07$; $\eta p^2 = 0.18$, respectively) compared to the control group. The post-hoc analysis showed a considerable pre-to-post improvedment (p < 0.001 value) in both step aerobic exercise training and floor aerobic exercise training for breath holding time ($\eta p^2 = 0.04$; $\eta p^2 = 0.11$, respectively) compared to the control group. No training protocols showed significant improvement in vital capacity, breath-holding time, and decreased resting heart rate, mean arterial blood pressure, and respiratory rate in participants performing step aerobics exercise training and floor aerobics exercise training, whereas no significant improvement was observed in the control group (Table 3).

Table 3. Mean (± SD) values of the physiological parameters in the three groups

Variables	Group	Before	After	Partial eta-squared (ηp^2)		
				Main effect group	Main effect time	Interaction group x time
VC (mL)	SAETG	3.07 ± 275.48	3.32 ± 228.49 [ac]	0.63 (*p* = 0.02)	0.76 (*p* < 0.001)	0.39 (*p* < 0.001)
	FAETG	3.07 ± 233.73	3.29 ± 217.40 [a]			
	CG	3.07 ± 451.16	3.14 ± 425.99			
RHR (bpm)	SAETG	75.20 ± 3.73	72.40 ± 3.31 [ac]	0.28 (*p* = 0.04)	0.61 (*p* < 0.001)	0.25 (*p* < 0.001)
	FAETG	75.25 ± 1.77	73.30 ± 2.69 [a]			
	CG	75.65 ± 3.01	74.90 ± 3.50			
MABP (mmHg)	SAETG	97.92 ± 2.61	96.76 ± 2.36 [ac]	0.71 (*p* = 0.01)	0.98 (*p* < 0.001)	0.16 (*p* = 0.06)
	FAETG	97.97 ± 2.59	97.87 ± 2.44 [a]			
	CG	97.16 ± 3.45	98.46 ± 4.57			
BHT (s)	SAETG	36.35 ± 3.03	38.40 ± 3.03 [a]	0.79 (*p* = 0.01)	0.56 (*p* < 0.001)	0.15 (*p* < 0.01)
	FAETG	36.90 ± 4.37	39.20 ± 3.86 [ac]			
	CG	36.95 ± 3.97	37.80 ± 3.83			
RR (numbers)	SAETG	17.00 ± 1.48	16.15 ± 1.26 [a]	0.44 (*p* = 0.02)	0.27 (*p* < 0.001)	0.14 (*p* = 0.014)
	FAETG	17.10 ± 1.11	16.15 ± 0.93 [a]			
	CG	17.00 ± 1.29	16.95 ± 0.94			

SAET: Step Aerobics Exercise Training; FAET: Floor Aerobic Exercise Training; CG: Control Group; VC: Vital Capacity; RHR: Resting Heart Rate; MABP: Mean Arterial Blood Pressure; BHR: Breath Holding Time; RR: Respiratory Rate; [s]significant difference before and after the intervention; [c]significant interaction between SAET and FAET.

Biochemical variables

The main influences of time on some outcomes have been found to be HDL ($F = 30.82$, $\eta p^2 = 0.35$, power value: 0.99, $p < 0.001$), LDL ($F = 1.66$, $\eta p^2 = 0.74$, power value: 0.99, $p < 0.001$), TC ($F = 3.82$, $\eta p^2 = 0.63$, power value: 0.48, $p = 0.056$), TG ($F = 7.27$, $\eta p^2 = 0.11$, power value: 0.75, $p = 0.009$). Significant group (three) and time (pre and post) interactions were seen for HDL ($F = 1.21$, $\eta p^2 = 0.41$, power = 0.25, $p = 0.304$), LDL ($F = 25.11$, $\eta p^2 = 0.46$, power = 0.99,

$p < 0.001$), TC ($F = 3.51$, $\eta p^2 = 0.11$, power = 0.63, $p = 0.036$), TG ($F = 0.88$, $\eta p^2 = 0.30$, power = 0.78, $p = 0.417$).

A post-hoc analysis showed considerable pre-to-post improvement ($p < 0.001$ value) in both step aerobic exercise training and floor aerobic exercise training for high density lipoprotein ($\eta p^2 = 0.05$; $\eta p^2 = 0.14$, respectively) compared to the control group. The post-hoc analysis showed a considerable pre-to-post decrease ($p < 0.001$ value) in both step aerobic exercise training and floor aerobic exercise training for total cholesterol ($\eta p^2 = 0.09$; $\eta p^2 = 0.18$, respectively) and triglycerides ($\eta p^2 = 0.07$; $\eta p^2 = 0.19$, respectively) compared to the control group. The participants who engaged in step aerobics activity and floor aerobics exercise training both showed no significant improvement in any of the training protocols when it came to highly dense lipoprotein, decreased low density lipoprotein, lipid profile, and triglycerides, while no significant improvement was seen in the control group (Table 4).

Table 4. Mean (± SD) values of the biochemical parameters in the three groups

Variables	Group	Before	After	Partial eta-squared (ηp^2)		
				Main effect group	Main effect time	Interaction group x time
HDL (mg/dl)	SAETG	53.95 ± 3.83	55.60 ± 2.13 [a]	0.02 ($p = 0.58$)	0.35 ($p < 0.001$)	0.04 ($p = 0.30$)
	FAETG	52.60 ± 3.06	55.80 ± 2.06 [a]			
	CG	53.85 ± 2.96	55.95 ± 2.08			
LDL (mg/dl)	SAETG	123.78 ± 6.04	120.94 ± 5.63 [a]	0.04 ($p = 0.89$)	0.74 ($p < 0.001$)	0.47 ($p < 0.001$)
	FAETG	123.96 ± 3.86	120.62 ± 3.51 [a]			
	CG	123.49 ± 9.98	122.96 ± 10.37			
TC (mg/dl)	SAETG	214.65 ± 5.19	212.70 ± 4.89 [a]	0.04 ($p = 0.89$)	0.06 ($p = 0.056$)	0.110 ($p = 0.04$)
	FAETG	215.74 ± 5.93	212.85 ± 5.92 [a]			
	CG	214.12 ± 6.83	215.20 ± 11.57			
TG (mg/dl)	SAETG	181.52 ± 11.31	179.30 ± 10.23 [a]	0.008 ($p = 0.79$)	0.11 ($p = 0.009$)	0.03 ($p = 0.42$)
	FAETG	183.88 ± 7.88	180.20 ± 10.09 [a]			
	CG	180.35 ± 11.79	179.42 ± 13.45			

SAET: Step Aerobics Exercise Training; FAET: Floor Aerobic Exercise Training; CG: Control Group; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; TC: Total Cholesterol; TG: Triglycerides; [a]significant difference before and after the intervention.

Psychological variables

The main influences of time on some outcomes have been found to be SC ($F = 24.80$, $\eta p^2 = 0.42$, power value: 0.99, $p < 0.001$), EA ($F = 1.66$, $\eta p^2 = 0.74$, power value: 0.99, $p < 0.001$), A ($F = 3.82$, $\eta p^2 = 0.63$, power value: 0.48,

p = 0.056), IR (F = 7.27, ηp^2 = 0.11, power value: 0.75, p = 0.009). Significant group (three) and time (pre and post) interactions were seen for SC (F = 1.21, ηp^2 = 0.41, power value: 0.25, p = 0.304), EA (F = 25.11, ηp^2 = 0.46, power value: 0.99, p < 0.001), A (F = 3.51, ηp^2 = 0.11, power value: 0.63, p = 0.036), IR (F = 0.88, ηp^2 = 0.30, power value: 0.78, p = 0.417).

A post-hoc analysis showed considerable pre-to-post improvement (p < 0.001 value) in both step aerobic exercise training and floor aerobic exercise training for self-confidence (ηp^2 = 0.05; ηp^2 = 0.14, respectively) compared to the control group. The post-hoc analysis showed a considerable pre-to-post decrease (p<0.001 value) in both step aerobic exercise training and floor aerobic exercise training for assertiveness (ηp^2 = 0.09; ηp^2 = 0.18, respectively) and interpersonal relationships (ηp^2 = 0.07; ηp^2 = 0.19, respectively) compared to the control group. The participants who engaged in both step aerobics activity and floor aerobics exercise training showed no significant improvement in any of the training protocols in terms of self-confidence, decreased emotional adjustment, psychological profile, interpersonal relationships, and stress management, while no significant improvement was seen in the control group (Table 5).

Table 5. Mean (± SD) values of psychological parameters in the three groups

Variables	**Group**	**Before**	**After**	**Partial eta-squared (ηp^2)**		
				Main effect group	Main effect time	Interaction group x time
SC (scores)	SAETG	21.22 ± 1.41	22.16 ± 1.80 [a]	0.02 (p = 0.67)	0.421 (p<0.001)	0.04 (p = 0.310)
	FAETG	20.60 ± 1.82	21.23 ± 1.20 [a]			
	CG	21.86 ± 1.16	21.40 ± 1.45			
EA (scores)	SAETG	46.52 ± 4.31	47.10 ± 1.35 [a]	0.04 (p = 0.84)	0.654 (p <0.001)	0.51 (p<0.001)
	FAETG	45.17 ± 4.15	46.23 ± 2.34 [a]			
	CG	45.70 ± 3.50	45.14 ± 1.30			
A (scores)	SAETG	23.17 ± 2.40	24.40 ± 4.89 [a]	0.05 (p = 0.87)	0.06 (p = 0.06)	0.21 (p = 0.04)
	FAETG	22.43 ± 1.19	23.18 ± 2.80 [a]			
	CG	23.10 ± 1.10	23.10 ± 1.15			
IR (scores)	SAETG	21.34 ± 3.46	22.32 ± 2.14 [a]	0.08 (p = 0.78)	0.11 (p = 0.09)	0.03 (p = 0.42)
	FAETG	20.16 ± 2.31	21.34 ± 1.42 [a]			
	CG	20.35 ± 3.40	20.96 ± 2.17			
SM (scores)	SAETG	35.19 ± 2.15	36.23 ± 3.16	0.06 (p = 0.85)	0.065 (p = 0.06)	0.13 (p = 0.036)
	FAETG	34.16 ± 1.75	35.16 ± 4.40			
	CG	35.80 ± 1.10	34.12 ± 2.34			

SAET: Step Aerobics Exercise Training; FAET: Floor Aerobic Exercise Training; CG: Control Group; SC: Self-Confidence; EA: Emotional Adjustment; A: Assertiveness; IR: Interpersonal Relationship; SM: Stress Management; [a]significant difference before and after the intervention.

Discussion

The main finding of this study was that different aerobic training exercises had various positive effects on physical strength and physiological and biochemical parameters in obese men. After 16 weeks of a randomized control trial undertaking aerobic and resistance training intervention, it was shown to improve the quality of life and physical fitness of obese and overweight cancer patients [24]. These results were consistent with previous studies showing that VO2 max improved [25,26] and that HIIT exercise could reduce resting heart rate in children with obesity [27]. Another previous study showed that 12 weeks of isolated and combined randomized control trials undertaking aerobic, resistance, and combined training showed that overweight and obese adults had considerably improved body percentage of fat and cardiorespiratory fitness [28]. Exercise intervention at 16 weeks follow up MLIP has been suggested to improve physical fitness and body composition in adolescents and obese children [29]. In the present study, we found a significant improvement in selected health-related physical fitness parameters after 12 weeks of aerobic exercise training. Importantly, a reduction in body composition study reported that eight weeks of HIIT aerobic exercise intervention improved the quality of life of patients [30].

Our study findings agree with those of previous studies showing a decrease in blood pressure after 12 weeks of combined exercise training in young obese pre-hypertensive men [31]. Our data indicate that breath-holding time and respiratory rate were significantly enhanced after 12 weeks of intervention in the current study. This may follow another mechanism that effectively improves breath-holding time and respiratory rate due to neuromuscular training intervention [32].

The findings of this study are in line with related studies suggesting that aquatic exercise has a beneficial effect on forced vital capacity [33]. Komathi and Indira previously investigated the effects of step aerobics, floor aerobics, and combination exercises on biochemical variables and psychology in female students [34]. After undertaking floor aerobic exercise for a period of 12 weeks, it was shown that female students showed considerable improvement in all selected biochemical and psychological parameters. After participating in step aerobics for a period of twelve weeks, female students showed significant improvements in all selected biochemical and psychological variables. Women in the combined training group performed better on biochemical variables than did those in the other groups. Similar outcomes were obtained in the present study, in which the biochemical profile of obese male adults was found to improve after twelve-week intervention of steps or floor aerobics. Clary et al. examined the effects of ballate, walking on balance, and step aerobics in women aged 50–75 years. Compared to the Ballates program, walking programs and step aerobics result in improved static balance and postural stability [3]. In our study, similar results were obtained in steps aerobics and floor aerobics. Melam et al. examined the effects of aerobics and brisk walking in overweight individuals. For ten weeks, this program was carried out five days a week [18]. Body mass index, hip and waist circumference, and the thickness of the skinfolds in the abdomen, subscapular region, biceps, and triceps were measured in all three categories before and after the experiment. All values fell in women who performed 10 weeks of brisk walking and aerobics. In the present study, body composition was found to be significantly improved among adult obese male after 12 weeks of aerobic exercise. Maiyanga and Gunen investigated the effect of step aerobics on percentage of body fat and visceral fat in obese female nurses in Bauchi's specialty hospital and discovered that step aerobics reduced percentage body fat [19].

Limitations

Being pilot in nature, the present study has several limitations that suggest a lacune on which future studies could be conducted. One limitation of this study is that we only included male participants in the current study. Obesity is also prevalent in females; therefore, future studies should be conducted with female participants. Another limitation of the study is that it focused on specific age groups, and future studies could be conducted by considering all age groups. This will help validate the results of the current study for all age groups. Another limitation of this study was the sample size. Because the sample size of the present study was small, the results of the present study cannot be validated for the general population. Moreover, the present study was a single-centric study, and future studies using a multicentric approach should be conducted to determine the role of aerobic exercise in the management of obesity among adults.

Conclusion

The present study revealed significant improvement in adult obesity in terms of body composition, muscular strength and endurance, cardiovascular and respiratory parameters, biochemical parameters, and psychological domains after practising steps and floor aerobics. Aerobic exercise proved to be helpful in managing the physical and psychological health of obese adults. It is recommended that schools and colleges administer aerobic exercise sessions to adults for better health perspectives.

STATEMENT OF ETHICS

This study was conducted in accordance with the World Medical Association Declaration of Helsinki. The study protocol was reviewed and approved by the SRM Medical College Hospital and Research Centre (SRM CHRC, Kattankulathur, Tamil Nadu, India, Number 8484/IEC/2022). All participants provided written informed consent to participate in this study.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interests with respect to the research, authorship, and/or publication of the article *The effect of 12-week step and floor aerobic exercise programs on physical and psychophysiological health parameters in obese men.*

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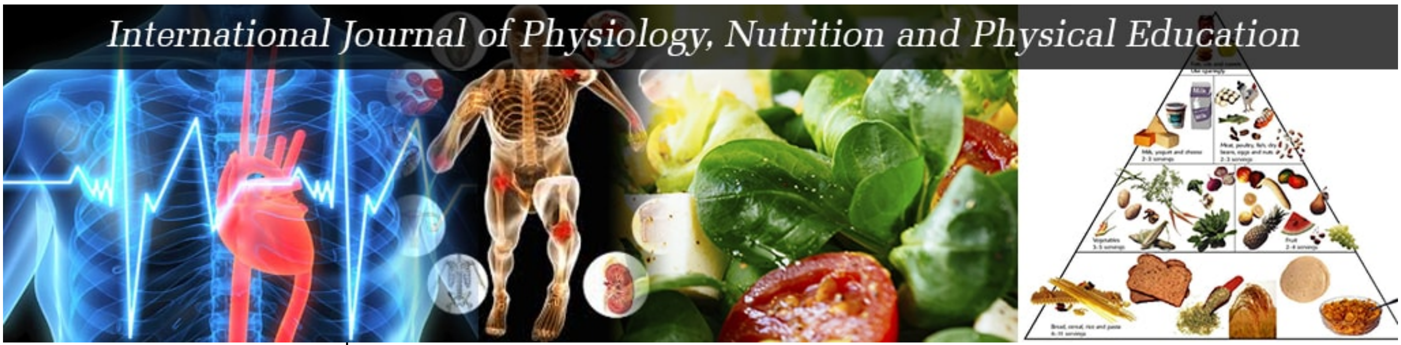

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Comparative analysis of static and nonballistic active stretching on hamstring flexibility and sprint acceleration performance in collegiate level football players

Vadivelan Sundaramurthy, Dr. Grace Helina and Dr. J Anitha

Abstract
Purpose: This research aimed to investigate and compare the effects of static and nonballistic active stretching on flexibility and sprint acceleration performance among collegiate-level football players.
Methods: Forty male football players, aged 17-21, voluntarily participated from the Indra Gandhi Academy for Sports and Education. Participants were randomly assigned to two groups: Nonballistic Active Stretching (NAS, n=20) and Static Stretching (SS, n=20). Anthropometric measures, including body height, body weight, and body mass index, were collected alongside performance metrics, such as the 20-meter sprint test and Hamstring flexibility was assessed using an active knee extension test conducted before and after a 12-week stretching intervention.
Results: The results indicated significant improvements within both groups. The NAS group exhibited a remarkable increase in hamstring flexibility (pre: 25.20±5.35, post: 20.90±5.37, $p<.001$) and enhanced sprint acceleration performance (pre: 2.18±0.18, post: 2.07±0.169, $p<.004$). Similarly, the SHS group demonstrated notable improvements in flexibility (pre: 27.10±6.71, post: 16.10±5.11, $p<.001$) and sprint metrics (pre: 2.06±0.18, post: 1.87±0.27, $p<.001$). However, an independent samples t-test revealed no significant baseline differences between the groups in outcome measures, sprint performance, or hamstring flexibility.
Conclusion: These findings underscore the efficacy of both static and nonballistic active stretching in enhancing flexibility and sprint acceleration among collegiate-level football players. The study contributes valuable insights to sports science, offering practitioners evidence-based options for designing stretching interventions tailored to the specific needs of football athletes. Additionally, the absence of baseline differences highlights the study's robust methodology, ensuring that observed changes can be attributed to the stretching interventions rather than pre-existing group disparities.

Keywords: Static stretching, nonballistic active stretching, flexibility, sprint acceleration, collegiate-level football players

Introduction

People who are physically active and athletes who play competitive sports like football, rugby, and sprinting frequently sustain hamstring injuries [1]. Numerous factors, including as inadequate warm-up, low flexibility, imbalanced muscles, tension in the nervous system, and exhaustion, increase the risk of hamstring injuries [1]. Lack of hamstring flexibility is the one of the most important aspects of hamstring injuries in athletes [2]

The adaptive shortening of the muscles' contractile and non-contractile components, known as muscular tightness, often happens in muscle groups in a predetermined manner, with the biarticular muscles having a higher propensity to shorten [3]. There are numerous methods for improving hamstring flexibility. One of the most popular and safest stretching techniques for lengthening muscles is static stretching. It has been observed that static stretching increases muscular flexibility instantly due to the viscoelastic nature of the soft tissues [4]. But this impact is transient and disappears rapidly [5].

It has also been demonstrated that hamstring tightness can result from increased tension in neural structures in addition to musculoskeletal factors. Gajdosik [6] noted that a straight leg raise test can be limited in addition to the hamstrings by the deep fascia of the lower limb and the soft tissues of the pelvis, including neurological structures [7]. Similarly, during passive or active movements of hip flexion or knee extension, these noncontractile tissues may experience tension. If the tension of non-contractile tissues limits indirect measurements of hamstring flexibility i.e. straight leg raise or active knee extension test, then usage of a stretching technique that highlights these neurological tissues together with the hamstrings may be appropriate.

A neural tension test (also known as the slump test) was described by Maitland [8]. It involves individuals sitting and performing active knee extension while maintaining cervical and thoracolumbar flexion. The lumbosacral nerve roots, spinal cord, and dura are all effectively tensed in this position. In the flexed, or slumped, posture, a natural response would be limited knee extension and ankle dorsiflexion range of motion; nevertheless, the complete range was only reached once cervical flexion was removed and the head was brought back to an upright position [9]. Rather than shortened hamstrings, Maitland [8] linked the lack of flexibility of the dura mater and nerve root sleeves inside the spinal canal as the reason for reduced knee extension and ankle dorsiflexion range of motion during the slump maneuver. Maitland [10] and Butler [11] discuss in detail the slump test sequence and its clinical application in the diagnosis and treatment of spinal dysfunction. Tensioning the neural and hamstring tissues appears to be achieved through the use of active knee extension movement in a neural slump test posture.

Research has indicated that the integration of neural mobilization techniques, as slump mobilisation, into a therapeutic regimen can effectively restore normal neural tension and nervous system dynamics. Traditionally, hamstring tightness is treated using stretches that target the extensibility of the hamstring muscles, such as static and dynamic stretches. There is a dearth of research evaluating the superiority of activities that target neurodynamics or neural tissue mobility over traditional hamstring stretching exercises.

Achieving maximum acceleration over a short distance is essential for carrying out critical offensive and defensive activities [12]. Recent studies have unequivocally demonstrated that the primary mechanical aspect of sprint acceleration performance was the horizontal component of the resulting, or total, ground reaction force (GRF). It has been repeatedly demonstrated that the hip extensor and knee flexor muscle movements played a predominant role [13] when running speed climbed and reached high (>7 ms−1) to maximal sprint speeds utilizing different levels of experimental/modelling data and a variety of people, including elite sprinters. While this predominance was demonstrated to occur throughout both swing and contact phases in the majority of these studies, it was not directly linked to concurrent direct measurements of net horizontal GRF(F_H) [14].

This research aims to investigate and compare the effects of static and nonballistic active stretching on flexibility and sprint acceleration performance among collegiate-level football players. The findings may provide valuable insights into the most effective stretching techniques for optimizing both flexibility and acceleration performance, thereby contributing to the development of evidence-based flexibility program routines for football players at the collegiate level.

Methods

Participants

Forty collegiate male participants from Indra Gandhi Academy for Sports and Education, Cuddalore, Tamil Nadu, India. (age range: 17-21 years old; age average: 19.35±1.23 years old; body mass: 59.93±8.16 kg; height: 168±6.59 cm; body mass index [BMI] 21.16±2.85 kg · m−2) successfully completed the study. Participants in the study attended football practice three times a week during the season. Before taking part in the study, all coaches and players completed an informed permission form after being made aware of the procedure and risks associated with the experiment. For participants who were younger than eighteen, parental consent was acquired.

Procedures

Measuring hamstring flexibility with Active Knee Extension test. Before warming up, the participants performed two maximal trials for AKE test for right leg in a randomised order. The average of each test score was used in subsequent analysis.

Active Knee Extension Test: The angle formed by the intersection of the thigh and lower leg lines was used to calculate the knee flexion angle. The subjects were held in a supine position, with the right limb stabilized by a stabilizing belt in the 90-90 hip knee flexion position and the left lower extremity in zero-degree hip flexion. After that, the subjects were told to consciously extend their right knee to its maximum while maintaining a relaxed plantar flexion stance. To calculate the degree from full extension, a goniometer was utilized.

After that, the participants engaged in a standard football warm-up that included five minutes of low-intensity running and five minutes of general exercises, such as sprints, leg lifts, lateral running, high skipping, and arm rotations in front and behind. A 20-meter sprint test (S20 m) was run following the warm-up.

20-meter sprint test: A speed test conducted on a straight 20-meter line was used to evaluate sprint performance (Maio Alves *et al*., 2010). Markers were set up at 10 (S10 m) and 20 (S20 m) meters. Performances at S10 m were interpreted as acceleration (García-Pinillos, Martínez-Amat, *et al*., 2014). To prevent players from trying to set a faster time by taking a final dip at 10 meters, the sprints over 20 meters were tested. We tried to mimic the normal testing protocols, which typically entail a 10-m split for sprint protocols for team-sport athletes. Stopwatches were used to record the halt times. Participants started from a stationary position with their feet parallel behind the start line to eliminate response time.

Following pre-test assessment of hamstring flexibility and sprinting performance, Subjects were then randomly assigned to two groups. I) Nonballistic Active Stretching group (NAS, n=20) performed 30 active knee extension repetitions while maintaining ankle dorsiflexion in sitting neural slump posture. 2) Static Stretching (SS, n=20) group performed static hamstring stretching for 30 seconds. After 12 weeks of intervention, hamstring flexibility and sprint performance were reassessed.

Static Hamstring stretch: The static hamstring stretch was performed on the floor in a modified hurdler's position. The subjects attempted to keep their spines in a neutral position by flexing forward from their hips. Each participant received emphasis on the need to minimize cervical flexion and to move solely from the hips in order to preserve the neutral spine. The subjects extended their hips until they felt a stretch in their knee, calf, or posterior thigh. After reaching this position, the stretch was maintained for thirty seconds. The

30-second stretch was implemented based on the findings of Bandy and Irion (2), who found that stretching for 30 seconds increased hamstring flexibility more effectively than stretching for 15 seconds and equally effectively as stretching for 60 seconds. To estimate the 30-second stretch duration, each participant employed a vocal self-count ranging from "one" to "thirty".

Nonballistic Active Stretch: This type of stretch was done while sitting on an elevated platform, high enough to prevent feet from touching the ground. The participant was seated as slumped as possible, achieving full thoracolumbar flexion, with the legs flexed, thighs supported, and popliteal fossae touching the elevated platform edge. At that point, the cervical spine was totally flexed. The subject's hands were put on the back of their head, fingers interlocked. The relaxed arms placed excessive pressure on the thoracolumbar and cervical spines. The dorsiflexion of the right foot was maximum. Dorsiflexion was then maintained while the knee was extended to the end range. The operational definition of the end range of knee extension was the point at which the posterior thigh, knee, and/or calf felt a strong resistance or stretch. For a vocal self-count of "one," this end range knee extension stretch position was maintained. The individual then relaxed the foot in plantar flexion and lowered the leg. For thirty repetitions in all, this stretch movement sequence was done rhythmically. The sitting slump postures was maintained by overpressure throughout the total repetitions. With each active knee extension repetition maintained at end range approximately 1 second, the total time spent at end range in the neural slump sitting position would approximate the 30 seconds of the static stretch group. We believed that the 30 active repetitions would highlight the movement component of the active stretch group in comparison to the static stretch group by trying to equalize the amount of time spent at end range for both stretch groups. Furthermore, since the amount of time spent at end range was identical for both groups, any variations in range of motion (ROM) improvements after treatment may be attributed to variations in body postures and how they affect the various tissues that restrict joint movement.

Statistical Analysis

The data analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 25.0, developed by SPSS Inc. in Chicago, Illinois, USA. A significance level of 95% confidence interval was employed for all statistical tests. To assess the normality of data distribution, the Shapiro-Wilk's test was applied. Utilized paired samples t-tests to compare pre- and post-intervention scores within the static stretching group and the nonballistic active stretching group. Significance level set at $\alpha = 0.05$. Calculated effect sizes (e.g., Cohen's d) for hamstring flexibility and sprint acceleration performance within each stretching group. Interpreted effect sizes based on established guidelines (small, medium, large). Conducted independent samples t-tests to compare post-intervention scores between the static stretching group and the nonballistic active stretching group for both flexibility and acceleration performance. Significance level set at $\alpha = 0.05$. Calculated effect sizes (e.g., Cohen's d) to quantify the differences in hamstring flexibility and sprint acceleration performance between the static and nonballistic active stretching groups. Interpreted effect sizes to assess the practical significance of group differences. All statistical analyses were conducted using SPSS 25.0.

Results

The Table 1 provides a paired sample test to compare pre- and post-intervention scores within the static stretching group and the nonballistic active stretching group. The Static Hamstring Stretch Group underwent a comprehensive assessment to investigate the impact of static hamstring stretching on two key variables: Active Knee Extension Test (AKET) and Sprint Time (ST). In terms of AKET, the pre-intervention mean was 27.10 (SD = 6.71), and the post-intervention mean exhibited a notable 16.10 and (SD = 5.11). The paired samples t-test yielded a remarkably high t-value of 9.727 (df = 19, *p*<.001), indicating a significant enhancement in Active Knee Extension flexibility following the static hamstring stretching intervention. This outcome suggests that the participants experienced a substantial improvement in joint flexibility, as measured by the AKET, emphasizing the effectiveness of static hamstring stretching. Moving on to the second variable, Sprint Time (ST), the pre-intervention mean was 2.06 (SD = 0.183). Post-intervention, the mean 1.87 and (SD = 0.273) demonstrated a noteworthy change. The paired samples t-test for ST resulted in a t-value of 4.672 (df = 19, *p*<.001), indicating a significant reduction in sprint times after the static hamstring stretching intervention. This finding highlights the positive impact of static hamstring stretching on sprint acceleration performance. Collectively, these results underscore the dual benefits of static hamstring stretching, not only in promoting flexibility but also in contributing to improved sprint performance among collegiate level football players. The statistical significance, as denoted by p-values less than .001, reinforces the robustness of the observed changes in both AKET and ST.

Table 1: Compare Pre- and post-intervention scores within the static stretching group and the nonballistic active stretching group

Group	Variables	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
SHS	AKET-PRE	27.10	6.711	1.13091	8.63299	13.36701	9.727	19	.000
	AKET-POST	16.10	5.118						
	ST-PRE	2.06	.183	.04077	.10516	.27584	4.672	19	.000
	ST-POST	1.87	.273						
NAC	AKET-PRE AKET-POST	25.20	5.356	.58983	3.06548	5.53452	7.290	19	.000
		20.90	5.379						
	ST-PRE	2.18	.181	.03393	.04049	.18251	3.286	19	.004
	ST-POST	2.07	.169						

Level of significant 0.05. SHS; Static Hamstring stretch, NAC; Nonballistic Active Stretch, AKET; Active Knee Extension Test, ST; 20-meter sprint test.

The Nonballistic Active Stretch Group underwent a comprehensive evaluation to investigate the effects of nonballistic active stretching on two crucial variables: Active Knee Extension Test (AKET) and Sprint Time (ST). For AKET, the pre-intervention mean was 25.20 (SD = 5.356), and the post-intervention mean 20.90 and (SD = 5.379) demonstrated a substantial increase. The paired samples t-test yielded a robust t-value of 7.290 (df = 19, *p*<.001), indicating a significant improvement in Active Knee Extension flexibility following the nonballistic active stretching intervention. This result emphasizes the efficacy of nonballistic active stretching in enhancing joint flexibility, as evidenced by the AKET.

Turning to the second variable, Sprint Time (ST), the pre-intervention mean was 2.18 (SD = 0.181). Post-intervention, the mean 2.07 and (SD = 0.169) reflected a meaningful change. The paired samples t-test for ST resulted in a t-value of 3.286 (df = 19, p = .004), signifying a significant reduction in sprint times after the nonballistic active stretching intervention. This finding underscores the positive impact of nonballistic active stretching on sprint acceleration performance. Together, these results demonstrate the dual benefits of nonballistic active stretching, showcasing improvements in both flexibility (AKET) and sprint performance (ST) among collegiate level football players. The statistical significance, denoted by p-values less than .001 and .004 for AKET and ST, respectively, provides robust evidence of the effectiveness of nonballistic active stretching in promoting these key outcomes.

In addition to assessing statistical significance, the calculation of effect sizes provides a nuanced understanding of the practical significance of observed changes within each stretching group. For the Static Hamstring Stretch Group, the point estimates for effect sizes reveal substantial improvements in both Active Knee Extension Test (AKET) and Sprint Time (ST) following the intervention. The effect size point estimate for AKET pre and post is 2.175, indicating a large and meaningful increase in active knee extension flexibility. Similarly, the effect size point estimate for ST pre and post is 1.045, highlighting a significant improvement in sprint performance. In the Nonballistic Active Stretch Group, the point estimates for effect sizes also suggest meaningful changes. The effect size point estimate for AKET pre and post is 1.630, signifying a considerable enhancement in hamstring flexibility. Additionally, the effect size point estimate for ST pre and post is 0.735, indicating a noteworthy improvement in sprint performance.

These effect size point estimates underscore the practical relevance of the observed changes within each group. The substantial effect sizes in both Static Hamstring Stretch and Nonballistic Active Stretch groups reinforce the positive impact of the stretching interventions on both flexibility and sprint performance among collegiate level football players. These findings contribute valuable insights into the real-world significance of the measured improvements beyond statistical significance alone.

Table 2: Compare Groups Static Stretching and the Nonballistic Active Stretching AKET & ST

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
AKET	Equal variances assumed	.013	.910	-2.891	38	.006	-4.80000	1.66037	-8.16125	-1.43875
	Equal variances not assumed			-2.891	37.907	.006	-4.80000	1.66037	-8.16152	-1.43848
ST	Equal variances assumed	1.543	.222	-2.745	38	.009	-.19750	.07196	-.34318	-.05182
	Equal variances not assumed			-2.745	31.671	.010	-.19750	.07196	-.34414	-.05086

Level of significant 0.05. SHS; Static Hamstring stretch, NAC; Nonballistic Active Stretch, AKET; Active Knee Extension Test, ST; 20-meter sprint test.

The Independent Samples Test was conducted to compare the mean scores of two distinct stretching groups: The Static Hamstring Stretch Group and the Nonballistic Active Stretch Group, focusing on two variables - Active Knee Extension Test (AKET) and Sprint Time (ST). For AKET, the mean score in the Static Hamstring Stretch Group was 20.90 (SD = 5.37), while the Nonballistic Active Stretch Group had a mean of 16.10 (SD = 5.11). The Independent Samples t-test revealed a t-value of 2.891 (df = 38, p = .910), indicating no statistically significant difference in active knee extension flexibility between the two stretching groups. The F-ratio (F = 0.013) further supports this, suggesting minimal variance between the groups for AKET. Regarding Sprint Time (ST), the Nonballistic Active Stretch Group had a mean of 2.07 (SD = 0.16), whereas the Static Hamstring Stretch Group had a mean of 1.87 (SD = 0.27). The Independent Samples t-test for ST produced a t-value of 2.745 (df = 38, p = .222), indicating no significant difference in sprint times between the two groups. The F-ratio (F = 1.543) reinforces this, suggesting comparable variances in sprint performance between the Nonballistic Active Stretch and Static Hamstring Stretch groups. In summary, the Independent Samples Test results for both AKET and ST suggest no significant differences between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group. These findings indicate that, at baseline, the two groups had comparable levels of active knee extension and sprint performance. This information is crucial for understanding the initial equivalence of the groups before the respective stretching interventions were applied.

Discussion on Findings

Baseline Equivalence

The findings from the Independent Samples Test revealed no significant differences in active knee extension test (AKET) and sprint performance (ST) between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group at baseline. This suggests that, prior to the interventions, both groups were comparable in terms of these key variables. This baseline equivalence is critical as it ensures that any subsequent changes observed can be attributed to the specific stretching protocols employed rather than pre-existing disparities between the groups.

Effect of Static Hamstring Stretching

The significant improvements observed in active knee extension test (AKET) and sprint performance (ST) within the Static Hamstring Stretch Group, as indicated by the paired samples t-tests and effect size estimates, align with existing literature emphasizing the positive impact of static stretching on flexibility and athletic performance [15]. The substantial effect sizes further underscore the practical significance of these improvements, providing athletes and coaches with valuable insights into the potential benefits of incorporating static hamstring stretching into training regimens.

Effect of Nonballistic Active Stretching

Similarly, the Nonballistic Active Stretch Group exhibited significant enhancements in active knee extension test (AKET) and sprint performance (ST), supported by the paired samples t-tests and effect size estimates. These findings align with previous research highlighting the efficacy of nonballistic active stretching in promoting both flexibility and performance outcomes [16]. The moderate effect sizes indicate meaningful changes within this group, suggesting that nonballistic active stretching may serve as an effective alternative to static stretching in the context of collegiate football training.

Comparison between Groups

The absence of significant differences between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group at baseline allows for a more meaningful comparison of the effects of each stretching modality. While both groups experienced improvements, the Independent Samples Test results suggest that the magnitudes of these changes did not significantly differ between the two stretching protocols. This implies that, in this specific context, both static hamstring stretching and nonballistic active stretching may be equally effective in enhancing hamstring flexibility and sprint performance among collegiate football players.

Practical Implications

The outcomes of this study have practical implications for athletes, coaches, and sports practitioners involved in collegiate football training programs. Both static hamstring stretching and nonballistic active stretching can be integrated into warm-up routines to improve flexibility and sprint performance. The choice between these stretching modalities may depend on individual preferences, training goals, and specific requirements of the sport.

Limitations and Future Directions

It is essential to acknowledge the limitations of the study, such as the relatively small sample size and the specific population of collegiate football players. Future research could explore the long-term effects of these stretching interventions, consider additional performance metrics, and include a broader range of athletes to enhance the generalizability of the findings.

Conclusion

In conclusion, this study aimed to investigate the effects of static hamstring stretching and nonballistic active stretching on hamstring flexibility (AKET) and sprint performance (ST) in collegiate level football players. The Independent Samples Test results revealed no significant differences in AKET or ST between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group at baseline. This establishes a crucial foundation for interpreting the subsequent changes observed after the stretching interventions. As the study progresses, the data analysis focuses on within-group changes and associated effect sizes, providing a comprehensive understanding of the impact of each stretching modality on flexibility and sprint performance. The findings contribute valuable insights to the field of sports science, guiding practitioners and athletes in optimizing training protocols for improved performance and injury prevention. Future research may explore the longitudinal effects of these stretching interventions and their implications for overall athletic performance in collegiate football players.

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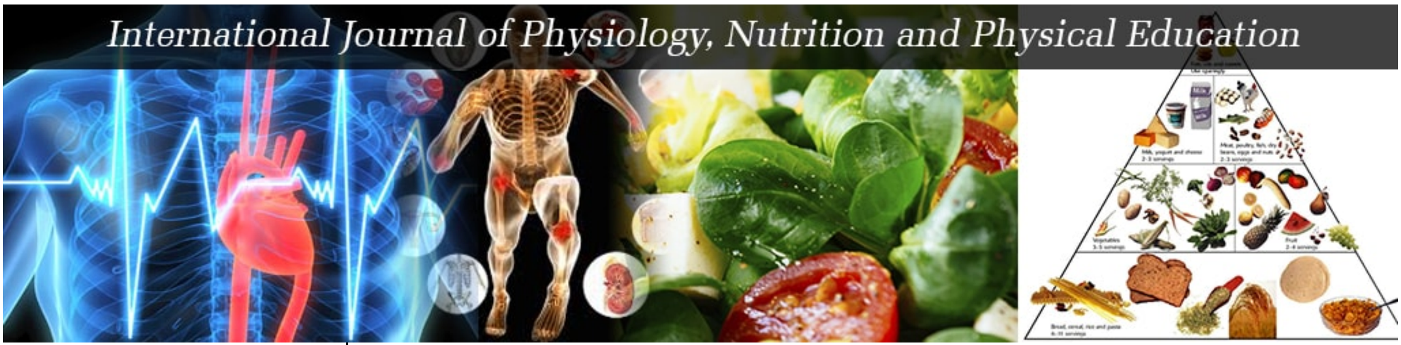

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Impact of sled-pulling sprint training on speed and vertical jump performance in collegiate-level football players

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Abstract
Purpose: This research aimed to investigate and compare the effects of sled-pulling sprint training on speed and vertical jump performance in collegiate-level football players.
Methods: Forty male football players, aged 17-21, voluntarily participated from the Indra Gandhi Academy for Sports and Education. Participants were randomly assigned to two groups: resisted sprint-training group (RST, n=20) and unresisted sprint-training group (URT, n=20). Anthropometric measures, including body height, body weight, and body mass index, were collected alongside performance metrics, such as the sprinting and vertical jump performance conducted before and after a 12-week stretching intervention.
Results: The results indicated significant improvements within both groups. The RST group exhibited a remarkable increase in sprint (pre: 3.61±0.290, post: 3.31±0.33, *p*<.001) and enhanced vertical jump performance (pre: 19.42±2.22, post: 22.92±2.42, *p*<.001). Similarly, the URT group demonstrated notable no improvements in sprint and vertical jump performance.
Conclusion: These findings underscore the efficacy of resisted sprint-training group in enhancing sprint vertical jump performance among collegiate-level football players. The study contributes valuable insights to sports science, offering practitioners evidence-based options for designing resisted sprint-training tailored to the specific needs of football athletes. Additionally, the absence of baseline differences highlights the study's robust methodology, ensuring that observed changes can be attributed to the resisted sprint-training rather than pre-existing group disparities.

Keywords: Acceleration, horizontal resistance training, resisted sprinting

Introduction

In team sport competition, sprint speed and its evolution over time are critical components of athletic success [1]. Different training methodologies and techniques exist to help young athletes develop and improve their speed capability [2]. With differing results in young athletes, coaches have used both non-sprint-specific and sprint-specific training methods [3-5]. Training that is tailored to the movement patterns and direction of sprinting is known as sprint-specific training. On the other hand, non-sprint-specific training usually consists of a variety of resistance exercises, plyometric exercises, and combination training that is largely performed in a vertical plane of motion. The majority of the time, sprint-specific training has been shown to be more beneficial than non-sprint-specific training, with the biggest benefits typically occurring across shorter acceleration distances [6, 7]. Resisted sled training is one type of sprint-specific training that involves pushing or pulling a resistive load in a horizontal plane of motion. It has been demonstrated that resistance sled training works better during the acceleration phase of sprinting than it does during the maximum velocity phase [8]. Both sled pushing and sled pulling, though commonly used by practitioners, have not gotten much scholarly attention; the latter has gotten even less [9].

Young athletes can be prescribed loads with reliability, provided that they understand that loading response varies greatly among individuals, according to a recent study by Cahill *et al.* [10] that looked at the reliability and variability within sled pushing. There are restrictions on the prescription of load as a fixed percentage of body mass in adult and youth populations, as seen in sled pulling [6], Young athletes' high degree of variability in sled load tolerance may be caused by a combination of strength, training history, and maturation [10]. Predicting load based on the decrease in maximal sprint velocity (Vdec) with increases in weight is an alternate technique for sled loading [11]. This approach makes use of the established linear correlations that have been demonstrated to exist for sled pulling between force and velocity and load and velocity [12]. Horizontal strength training exercises may indicate that training would be most effective at heavier loads, especially with young athletes where there is a large potential to develop force production. Cahill *et al.* [10] suggested light, moderate, and heavy loading parameters at sled pushing loads corresponding to 25%, 50%, and 75% Vdec to represent speed-strength, power, and strength-speed zones, respectively [13]. It is possible that different loads during resisted sled push training will have varied transferring effects on the force-velocity and velocity-distance relationships during unresisted sprinting.

The majority of the work analysing sprint performances at distances of 25-50 m [14] provides insight into developmental tendencies in speed development by combining aspects of acceleration and maximal speed. While maximal velocity sprinting is linked to shorter ground contact times and a quicker rate of force creation, acceleration is linked to longer ground contact times, which offer the chance to produce a significant net impulse [15]. A common variation of just 21% was found between acceleration and maximal speed in 16-year-old children, according to Chelly and Denis [16]. This finding lends support to the specificity of these two variables.

According to the authors, maximum speed required more absolute power and stiffer legs, while acceleration depended on relative power. As a result, several sprinting phases indicate distinct qualities that may be affected differently by a common training regimen. Practitioners should think about how maturity and training age can affect the training response, as well as how different training modalities can influence speed development. Training that includes free sprinting or modified sprinting, such as various resisted sprinting exercises (e.g., sled pushing, sled pulling, parachute, uphill), assisted sprinting exercises (e.g., downhill, towed), backward running and sprinting, and technical sprint exercises (e.g. sprint mechanics), is referred to as sprint-specific training. Non-specific training refers to training regimens that do not contain sprinting; instead, they usually incorporate various resistance training modalities, plyometric training, and a combination of training techniques. Non-specific training techniques primarily involve vertical motions (like squats), though they can sometimes involve horizontal motions. The majority of earlier studies focused on lower RST loads (less than 43% BM) [17]; however, more recent studies have started to look at the impact of sled loading at considerably higher loads-above 80% BM [18]-but there isn't much data on this topic for young athletes. In adults, heavier loads are better than lesser loads to increase GRF impulses acutely [19, 20]; in terms of improving acceleration phase split timings [18], longitudinal study has found heavier loads superior to lighter or unresisted. Different loads should be used during training to improve different phases of the sprint [17]. Lighter weights may be useful during the latter phase of acceleration during the transition to maximum velocity (Vmax). Nevertheless, no study has looked at how well RST works on young athletes' force velocity or velocity distance profiles under unresisted, light, moderate, and heavy loads. Adaptation to acceleration and maximum velocity may depend on how much weight is placed on the sled. Thus, it is possible to speculate that training with heavier loading parameters will enhance the phase of acceleration where high horizontal forces are needed, while light to moderate loading will probably enhance the phase of maximal velocity because of low horizontal force and higher velocity requirements [17]. Research is required to support or disprove the theory that heavier sled loading is the stimulus required to cause a specific adaptation in horizontal force output during a sprint [9], acceleration phase.

There is currently a paucity of research that has directly compared responses to sled-pull training at a heavier load from across the force-velocity spectrum, and no research with young athletes. Therefore, the aim of the present study was to assess the effectiveness of unresisted and resisted sled-pull training at heavy loads in collegiate level football players. The authors hypothesize that training at heavier loads in young athletes will lead to greater gains in horizontal force production and velocity over the initial period of a sprint.

Methods

Participants

Forty collegiate male participants from Indra Gandhi Academy for Sports and Education, Cuddalore, Tamil Nadu, India. (age range: 17–21 years old; age average: 19.35±1.23 years old; body mass: 59.93±8.16 kg; height: 168±6.59 cm; body mass index [BMI] 21.16±2.85 kg · m−2) successfully completed the study. Participants in the study attended football practice twice a week during the season. Before taking part in the study, all coaches and players completed an informed permission form after being made aware of the procedure and risks associated with the experiment. For participants who were younger than eighteen, parental consent was acquired.

Procedures

20-meter sprint test: Sprint performance was assessed using a speed test on a 20-meter straight line (Maio Alves *et al.*, 2010). Ten (S10 m) and twenty (S20 m) meters were designated with markers. A stop times were recorded using stopwatches. To reduce response time, participants began from a stationary posture with their feet parallel behind the start line.

Vertical Jump (VJ) Test by Vertec equipment: The VJ tests were one part of a circuit of exercises designed to assess overall fitness. The tests ought to be set up so that further leg testing wouldn't happen until the VJ tests were complete. Every VJ exam was administered by the same tester, who used the same verbal instructions and jump demonstration. If a participant made a mistake on a jump, that jump was not counted, they were corrected, and they had to do the jump again.

The Vertec device was used to measure standing reach height prior to the Vertec jumps. With their feet together and flat on the ground, participants were to stretch up with their dominant hand to the highest vane possible. The test subject's wrist was firmly pulled forward by the tester to guarantee maximum reach height and complete arm extension. Each jump protocol was completed by the participants three times, and peak leg power was determined by taking the highest height jump. The vertical jump height was determined using the countermovement jump (CMJ) technique. The participant was told to stand comfortably with his hands by his sides for the Vertec CMJ. At the tester's cue, the participant jumped vertically without halting, bending his knees, hips, and ankles while swinging his arms backward and then forward immediately. There may be no prejump or step was allowed.

The individual was given three tries, with the vanes being pulled aside after each jump, and the vertical jump height was measured as the difference between the reach height and the jump height.

Study design: Following pre-test assessment of sprinting and vertical jump performance, the participants were randomly assigned into two groups, the resisted sprint-training group (RS; n=20) and the unresisted sprint-training group (US; n=20). The US group completed a similar sprint training program without using sled pulling, while the RS group used sled pulling to pull loads that resulted in less than 50% decrement velocity (%Vdec). To model the load-velocity relationship, a range of loads were applied during resisted sprints. A stopwatch was used to record the greatest velocity reached (Vmax) during each sprint. The loads that corresponded to a Vdec of 10, 25, 50, and 75% were then found for each subject using the specific load-velocity relationships that were established using Vmax. The training regimen was applied twice a week for 12 weeks, with two runs of two sets for the first four weeks, then one set of increments every four weeks. After 12 weeks of intervention, sprint and vertical jump performance were reassessed.

Unresisted Sprinting Protocol: Participants were told to approach the starting line and assume a split stance, placing their dominant foot behind and their preferred foot front for the jump. The task given to the subjects was to run through a set of cones spaced 20 meters apart.

Resisted Sled-Pulling Protocol: Similar to the way in the unresisted sprints, the subjects were given the exact same setup, cues, and instructions. A non-elastic nylon tether secured the heavy-duty, custom-made pull sled (8.7 kg) to a waist harness 3.3 meters behind the subject. When starting the sprint, subjects were told to take up all the slack in the leash to prevent any bouncing or jerking. The instructions for the participants were to run through a 20-meter set of cones. One un-resisted sprint followed by two to three resisted sled pulls with various weights on the sled each rep. Following the first resisted trial, which employed an absolute load of 20% BM, including the weight of the sled, participants had to run three sprints with loads increasing by 10% BM (+30, 40, and 50% BM). Pilot testing was used to identify the range of loads that would cause an athlete's velocity to decrease, allowing for the calculation of individual load-velocity correlations (Table 1 and 2).

Load–Velocity Relationship and Load Optimization: For both resisted and unresisted trials, the maximum sprint velocity was attained. Each participant's unique load-velocity (LV) relationship was established and its linearity was verified. The load that correlated with a velocity decrease of 10% (L10), 25% (L25), 50% (L50), and 75% (L75) was then determined using the linear regression of the load-velocity relationship, with the slope of the line explaining the relationship between load and velocity. An example of this is illustrated in Figure 1.

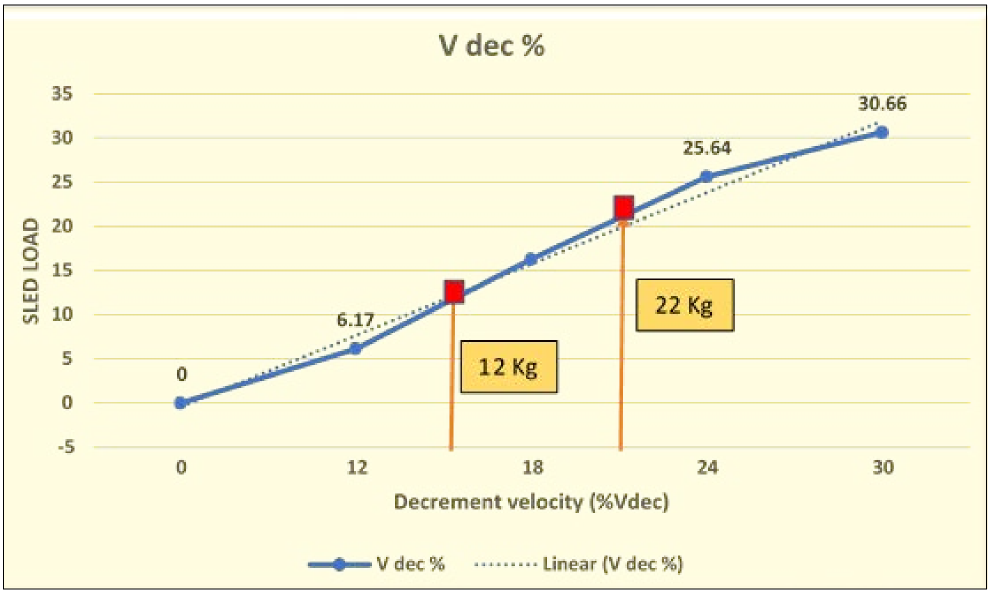

Fig 1: An example of the load–velocity relationship for one subject. Plotting a load velocity profile provides linear data that may be used to create speed-specific strength training zones anywhere on the axis.

Table 1: Sprinting Velocity for different loads

Load (Kg)	Time (Sec)
0	3.80
12	4.05
18	4.54
24	5.11
30	5.48

A formula was applied to determine the Vdec, or velocity decrease for each run.

$V_{dec}\% = 1 -$ (Unresisted sprint velocity / Resisted sprint velocity) x 100

Unresisted sprint velocity must be divided by each resisted sprint velocity and subtracted from one

Table 2: Calculating percentage of Velocity decrease (Vdec %) for different Load

Load (Kg)	Time (Sec)	V_{dec} %
0	3.80	0
12	4.05	6.17
18	4.54	16.3
24	5.11	25.64
30	5.48	30.66

Statistical Analysis

The data analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 25.0, developed by SPSS Inc. in Chicago, Illinois, USA. A significance level of 95% confidence interval was employed for all statistical tests. To assess the normality of data distribution, the Shapiro-Wilk's test was applied. Utilized paired samples t-tests to compare pre- and post-intervention scores within the resisted sprint-training group and the unresisted sprint-training group. Significance level set at α = 0.05. Calculated effect sizes (e.g., Cohen's d) for sprinting and vertical jump performance within each resisted sprint and unresisted sprint-training group. Interpreted effect sizes based on established guidelines (small, medium, large). All statistical analyses were conducted using SPSS 25.0.

Results

The Table 3 provides a paired sample test to compare pre- and post-intervention scores within the resisted sprint-training group and the unresisted sprint-training group. The resisted sprint-training group underwent a comprehensive assessment to investigate the impact of on two key variables: sprinting (ST) and vertical jump performance (VJP). In terms of ST, the pre-intervention mean was 3.61 (SD = 0.29), and the post-intervention mean exhibited a notable 3.31 and (SD = 0.33). The paired samples t-test yielded a remarkably high t-value of 5.451 (df = 19, *p*<.001), indicating a significant reduction in sprinting following the resisted sprint-training intervention. This outcome suggests that the participants experienced a substantial improvement in sprinting, emphasizing the effectiveness of resisted sprint-training intervention. Moving on to the second variable, vertical jump performance (VJP), the pre-intervention mean was 19.42 (SD = 2.22). Post-intervention, the mean 22.92 and (SD = 2.42) demonstrated a noteworthy change. The paired samples t-test for VJP resulted in a t-value of 7.996 (df = 19, *p*<.001), indicating a significant enhancement in vertical jump performance after the resisted sprint-training intervention. This finding highlights the positive impact of resisted sprint-training intervention on vertical jump performance. Collectively, these results underscore the dual benefits of resisted sprint-training, not only in promoting sprinting but also in contributing to improved vertical jump performance among collegiate level football players. The statistical significance, as denoted by p-values less than .001, reinforces the robustness of the observed changes in both ST and VJP.

Table 3: Compare Pre- and Post-Intervention Scores Within the resisted sprint-training group and the unresisted sprint-training group

Group	Variables	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
RST	ST-PRE	3.61	.29	.05458	.18326	.41174	5.451	19	.000
	ST-POST	3.31	.33						
	VJP-PRE	19.42	2.22	.43833	4.42243	-2.58757	7.996	19	.000
	VJP-POST	22.92	2.42						
URST	ST-PRE	3.52	.26	.06859	-.28357	.00357	2.041	19	.055
	ST-POST	3.66	.30						
	VJP-PRE	20.52	2.23	.17945	-.10060	.65060	1.532	19	.142
	VJP-POST	20.25	2.10						

Level of significant 0.05. RST; resisted sprint-training, URST; unresisted sprint-training, ST; Sprinting, VJP; vertical jump performance.

The unresisted sprint-training group underwent a comprehensive evaluation to investigate the effects of two crucial variables: sprinting (ST) and vertical jump performance (VJP). For ST, the pre-intervention mean was 3.52 (SD = 0.26), and the post-intervention mean 3.66 and (SD = 0.30) demonstrated a substantial increase. The paired samples t-test yielded a robust t-value of 2.041 (df = 19, p = .055), indicating no significant improvement in sprinting following the unresisted sprint-training group.

Turning to the second variable, vertical jump performance (VJP)), the pre-intervention mean was 20.52 (SD = 2.23). Post-intervention, the mean 2.25 and (SD = 2.10) reflected no meaningful change. The paired samples t-test for VJP resulted in a t-value of 1.532 (df = 19, p = .0.142), signifying no significant reduction in vertical jump performance after the unresisted sprint-training group. This finding underscores the no positive impact of unresisted sprint-training group on vertical jump performance. Together, these results demonstrate the dual benefits of unresisted sprint-training, showcasing no improvements in both sprinting (ST) and vertical jump performance (VJP) among collegiate level football players. The statistical significance, denoted by p-values greater than .055 and .142 for ST and VJP, respectively, provides robust evidence of the no effectiveness of unresisted sprint-training in promoting these key outcomes.

In addition to assessing statistical significance, the calculation of effect sizes provides a nuanced understanding of the practical significance of observed changes within each resisted and unresisted sprint-training group. For the resisted sprint-training group, the point estimates for effect sizes reveal substantial improvements in both sprinting (ST) and vertical jump performance (VJP) following the intervention. The effect size point estimate for ST pre and post is 1.219, indicating a large and meaningful increase in sprinting. Similarly, the effect size point estimate for VJP pre and post is 1.788, highlighting a significant improvement in vertical jump performance. In the unresisted sprint-training group, the point estimates for effect sizes also suggest meaningful changes. The effect size point estimate for ST pre and post is.456, signifying a considerable enhancement in sprinting. Additionally, the effect size point estimate for VJP pre and post is 0.343, indicating a noteworthy improvement in vertical jump performance.

Discussion on Findings

The investigation into the impact of sled-pulling sprint training on speed and vertical jump performance among collegiate-level football players yielded compelling findings that offer valuable insights into athletic training methodologies. Our study focused on the specific benefits of sled-pulling, a resistance-based sprint exercise, in enhancing the performance metrics crucial to football gameplay.

One notable discovery was a consistent improvement in speed performance among participants. The incorporation of sled-pulling into their training regimen appeared to foster increased lower body strength and power, translating into enhanced acceleration and top-end speed on the field. This finding aligns with the sport-specific demands of football, suggesting that sled-pulling could be a valuable addition to training programs aiming to optimize players' sprinting capabilities.

Furthermore, our investigation revealed a positive correlation between sled-pulling sprint training and vertical jump performance. The resistance provided during sled-pulling sessions seemed to stimulate adaptations in muscle fibres associated with explosive power, contributing to greater force production during the take-off phase of vertical jumps [21]. This result suggests a potential transfer of benefits from sled-pulling to key athletic movements required in football, underscoring the specificity of the training method [22].

However, it is crucial to acknowledge individual variability among participants. While the majority experienced significant improvements in both speed and vertical jump, some athletes showed varying degrees of responsiveness to the sled-pulling protocol. This highlights the importance of tailoring training programs to individual needs and capacities, recognizing that a one-size-fits-all approach may not be optimal for all athletes [10].

The study also delves into the practical implications for coaching and training program design. Recommendations are made regarding the duration, frequency, and intensity of sled-pulling sessions that elicited the most substantial performance gains. Coaches and strength and conditioning professionals can use these findings to inform evidence-based decisions when integrating sled-pulling sprint training into the overall training regimen for collegiate-level football players. In conclusion, our research sheds light on the efficacy of sled-pulling as a targeted and beneficial training modality for improving speed and vertical jump performance in the context of collegiate football.

Conclusion

In conclusion, the investigation into the impact of sled-pulling sprint training on speed and vertical jump performance in collegiate-level football players has provided valuable insights that carry implications for both athletes and coaches. The study's findings indicate a positive relationship between sled-pulling and enhanced speed, showcasing the potential of this resistance-based sprint exercise to contribute to improved on-field performance. The observed improvements in vertical jump performance further underscore the versatility of sled-pulling in targeting explosive power, a crucial aspect of athletic prowess in sports like football.

The recognition of individual variability among participants emphasizes the need for personalized training programs. While the majority of athletes demonstrated positive responses to sled-pulling, the varying degrees of responsiveness highlight the importance of tailoring training methodologies to the unique needs and capabilities of each player. This individualized approach is crucial for optimizing the effectiveness of sled-pulling sprint training and ensuring that it aligns with the diverse characteristics of collegiate-level football players.

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Computational Video Analysis on the Performance of Indian Football Team in World Cup Qualifiers 2026

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Abstract: *The rise of Indian football has been gradual yet consistent. The journey for the Blue Tigers in World Cup Qualifying matches has been challenging thus far. The Indian Men's Football Team experienced their first taste of World Cup Qualifying matches in 1985 for the 1986 FIFA World Cup. Their debut match in the qualifying round resulted in a 2-1 loss against Indonesia. They skipped the 1990 World Cup Qualifiers but returned for the 1994 edition. So far, India has played 48 World Cup qualifiers and won 10 games. Their most successful campaign was the 2002 World Cup Qualifiers, where the Blue Tigers earned 11 points in six games, as per an Indian Super League (ISL) press release. India has been doing well so far in the 2026 world cup qualifiers. While football remains as the most popular sport in the world, there is a lack of understanding of the many components, or parameters, in a match that can lead to an overall successful season. Knowing how to adjust a team's tactics based on several key parameters may provide coaches with the tools necessary to create a successful outcome. This project aims to study the performance of Team India in World Cup Qualifiers 2026 through dartfish video analysis which provides information through statistical data resulting in a better outcome.*

Key Word: *Football Match Analysis, Dartfish Tagging, Team Performance Analysis, World Cup Qualifiers.*

I.INTRODUCTION

Football is the world's most popular ball game in numbers of participants and spectators. Simple in its principal rules and essential equipment, the sport can be played almost anywhere, from official football playing fields (pitches) to gymnasiums, streets, school playgrounds, parks, or beaches. Football's governing body, the Fédération International de Football Association (FIFA), estimated that at the turn of the 21st century there were approximately 250 million football players and over 1.3 billion people "interested" in football; The FIFA organizes the World Cup every four years. The finals tournament is held every four years. In the other years there are only qualifiers (qualifying tournaments) in the six FIFA world regions. These games help to decide which teams will move on. Over 160 national teams play in the qualifying games. The best teams from the qualifying games win a place in the finals. The finals now include 32 teams. Before 1998, only 24 teams were in the finals; starting in 2026, there will be 48 teams in the finals. Many years before each World Cup, FIFA picks the host nation, the country where the finals will be held [8]. Being the host nation means that their team has qualified for the finals tournament automatically and does not need to play any qualifying games [6]. The 32 teams in the finals then play for four weeks, usually between June and July, to decide who the champion (tournament winner) will be.

II.MATERIAL AND METHODS

Video analysis in sports is used for assessing and enhancing the performance of a team or an athlete and it provides visual feedback for the coaches and athletes [4] [5]. It can be used for two purposes; for technical analysis to analyze individual skills and for tactical analysis to analyze the team performance and tactics. Dartfish is one such video analysis program that integrates software and online tools for delivering a flexible, efficient and comprehensive match analysis system [9]. It can be used for many purposes, such as for game strategy, skill development, player development, etc. Dartfish gives an opportunity to "tag" the game either during the game or after the game with the help of a tagging panel [1]. The tags make it easy to find, review and statistically analyze the moments in a game or analyze specific tags in more detail and also sustainable practices in performance can be carried out [11]. Examples of tags are goals, transitions from attack to defense, free kicks, penalties and good or bad outcomes and also motion analysis is possible with dartfish [10] [12]. The recorded videos from the recent matches of the Indian football team in World Cup Qualifiers 2026 are downloaded from various platforms and with the help of tagging using the tagging panel, analysis is carried out. This research work focuses on the statistical analysis of the performance based on ball possession and attacking. The analysis of this research procedures survey method references and sources of specialized scientific and exploratory studies [2].

- Laptop device
- Dartfish program version 8 By using this tagging software, we will identify the variables of the study.

- Shot, Foul, Turnover lost and Kick out

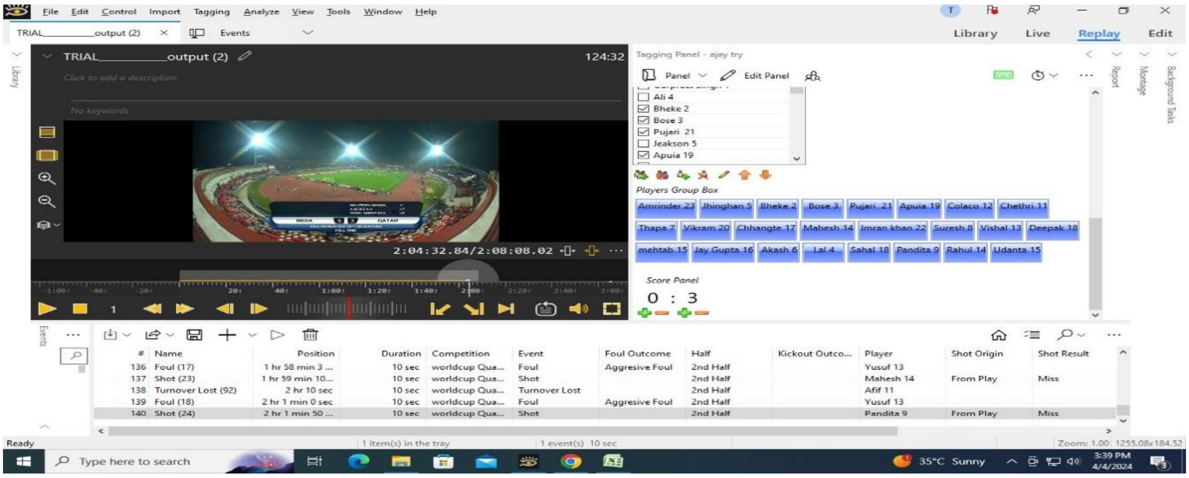


Fig. 1. Tagging Panel

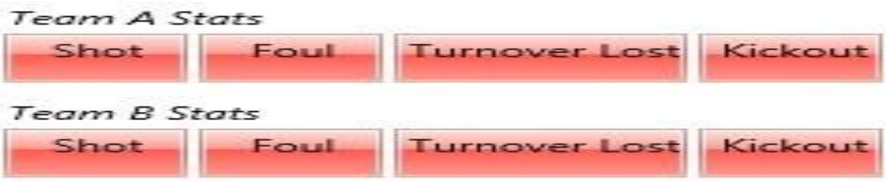


Fig. 2. Event Tagging Panel

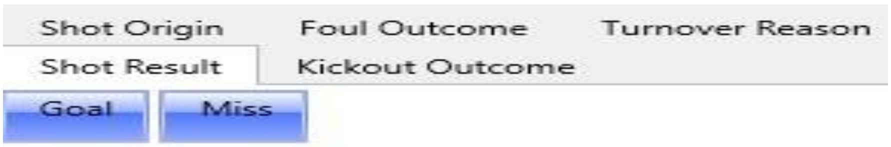
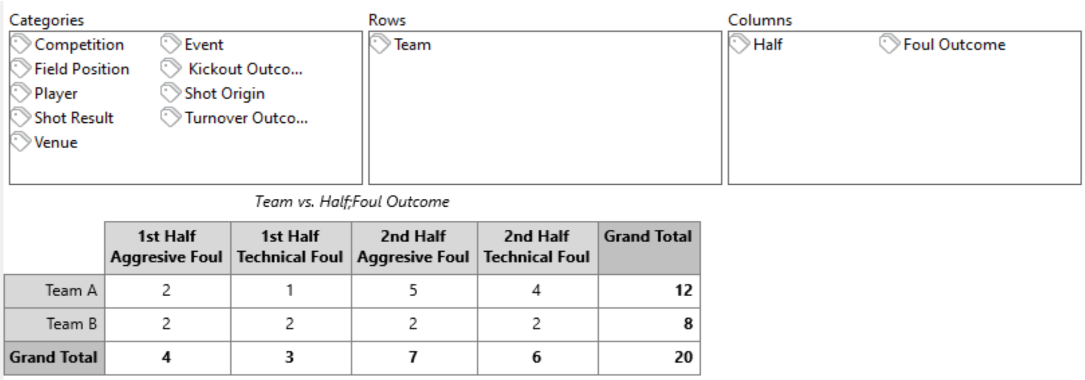


Fig. 3. Tagging Event Outcome Panel

Fig. 4. Player group box and score panel

Statistical analysis

Here is the detailed game statistics of the two games with that occurred in every half of the matches. The tables that we are listing below will define about the foul outcome, turnover outcome, kick out outcome, short origin and short results [3] [7]. Table no 1 Shows that Team A(India) in the first half of the match they have been analyzed with two aggressive foul and one technical foul, likewise in the second half of the match they have been analyzed with 5 aggressive fouls and 4 technical fouls. Team B(Afghanistan) in the first half of the match they have been analyzed with two aggressive foul and two technical foul, likewise in the second half of the match they have been analyzed with 2 aggressive fouls and 2 technical fouls. As a whole, Team A got 12 foul outcomes and Team B got 8 foul outcomes in total.

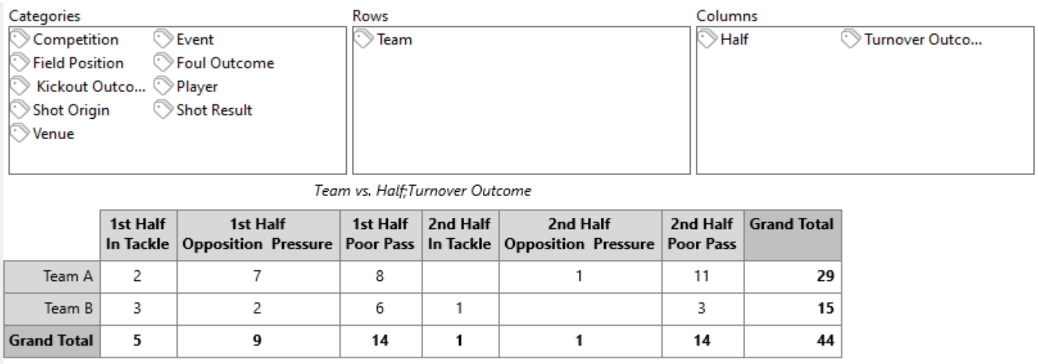


	1st Half Aggresive Foul	1st Half Technical Foul	2nd Half Aggresive Foul	2nd Half Technical Foul	Grand Total
Team A	2	1	5	4	12
Team B	2	2	2	2	8
Grand Total	**4**	**3**	**7**	**6**	**20**

Table no 1: Shows the foul outcome results in both first and second half of the match between India Vs Afghanistan

Table no: 2

Shows that Team A(India) in the first half of the match they have been analyzed with total of seventeen turnover lost which two were lost in tackle and seven were lost in opposition pressure and eight were lost in poor pass, likewise in the second half of the match they have been analyzed with total of twelve turnover lost which the one was last in opposition pressure and eleven were missed by poor pass. Team B (Afghanistan) in the first half of the match they have been analyzed with total of eleven turnover lost where three in tackle and two in opposition pressure and six in poor pass, likewise in second half of the match they have been analyzed with total of sixteen lost over where one was lost in tackle one was lost in opposition pressure and fourteen were lost in poor pass. As a whole, team A got twenty-nine turnover lost and Team B got fifteen turnovers lost in total.

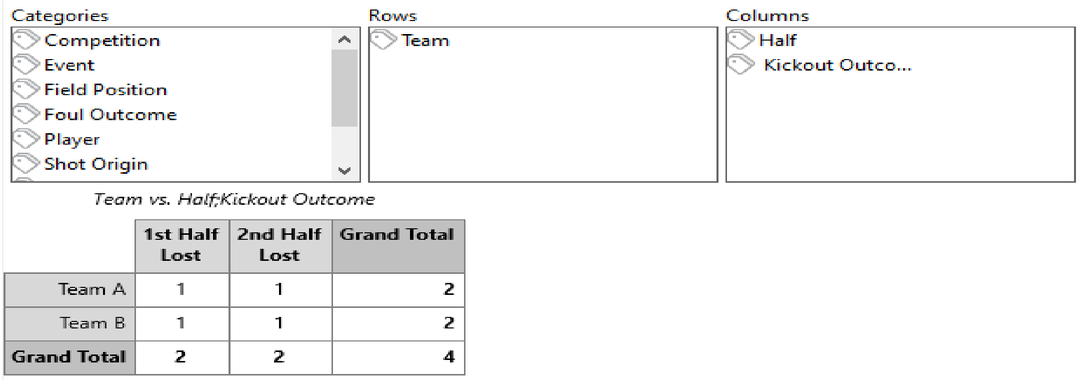


	1st Half In Tackle	1st Half Opposition Pressure	1st Half Poor Pass	2nd Half In Tackle	2nd Half Opposition Pressure	2nd Half Poor Pass	Grand Total
Team A	2	7	8		1	11	29
Team B	3	2	6	1		3	15
Grand Total	**5**	**9**	**14**	**1**	**1**	**14**	**44**

Table no 2: Shows the turnover outcome results in both first and second half of the match between India Vs Afghanistan

Table no: 3

Shows that Team A(India) in the first half of the match they have been analyzed with one kick out, likewise in the second half of the match they have been analyzed with one kick out. Team B (Afghanistan) in the first half of the match they have been analyzed with one outcome, likewise in second half of the match also they have been analyzed with one kick out. As a whole, team A got two kick out and Team B got two kick out outcome in total.

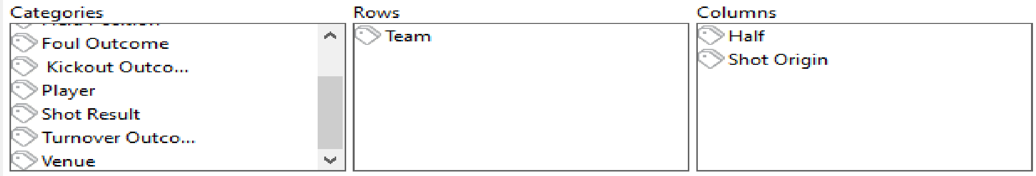


	1st Half Lost	2nd Half Lost	Grand Total
Team A	1	1	2
Team B	1	1	2
Grand Total	**2**	**2**	**4**

Table no 3: Shows the kick out outcome results in both first and second half of the match between India Vs Afghanistan

Table no 4:

Shows that Team A(India) in the first half of the match they have been analyzed with three shot origins from play and two shot origin from set piece, likewise in the second half of the match they have been analyzed with three shot origin from play. Team B(Afghanistan) in the first half of the match they have been analyzed with four shot origins from play and two shot origin from set piece, likewise in the second half of the match they have been analyzed with six shot origin from play and two shot origin from set piece. As a whole Team A got eight shot origin and Team B got fourteen shot origin in total.



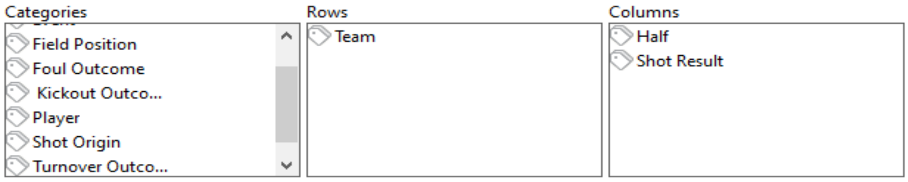
Team vs. Half;Shot Origin

	1st Half From Play	1st Half From Setpiece	2nd Half From Play	2nd Half From Setpiece	Grand Total
Team A	3	2	3		**8**
Team B	4	2	6	2	**14**
Grand Total	**7**	**4**	**9**	**2**	**22**

Table no 4: Shows the shot origin outcome results in both first and second half of the match between India Vs Afghanistan

Table no 5:

Shows that Team A(India) in the first half of the match they have been analyzed with they have got four shots on goal where one shot was succeeded and three shots where missed, likewise in the second half of match they have got three shots on goal and the three were missed. Team B(Afghanistan) in the first half of the match they have been analyzed with they have got six shots on goal where six shots where missed, likewise in the second half of match they have got eight shots on goal where the two shot was succeeded and six shots were missed. As a whole Team A got seven shots and Team B got fourteen shots in total.



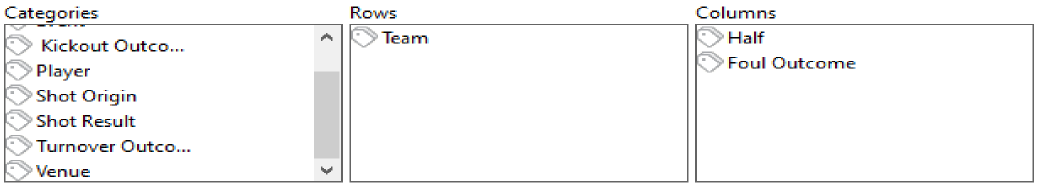
Team vs. Half;Shot Result

	1st Half Goal	1st Half Miss	2nd Half Goal	2nd Half Miss	Grand Total
Team A	1	3		3	**7**
Team B		6	2	6	**14**
Grand Total	**1**	**9**	**2**	**9**	**21**

Table no 5: Shows the shot outcome results in both first and second half of the match between India Vs Afghanistan

Table no 6:

Shows that Team A(India) in the first half of the match they have been analyzed with eight aggressive foul and four technical foul, likewise in the second half of the match they have been analyzed with eight aggressive fouls and two technical fouls. Team B(Qatar) in the first half of the match they have been analyzed with four aggressive foul and six technical foul, likewise in the second half of the match they have been analyzed with four aggressive fouls and zero technical fouls. As a whole, Team A got twenty-two foul outcomes and Team B got fourteen foul outcomes in total.



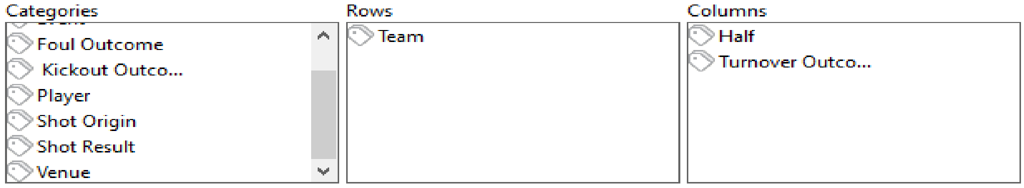
Team vs. Half;Foul Outcome

	1st Half Aggresive Foul	1st Half Technical Foul	2nd Half Aggresive Foul	2nd Half Technical Foul	Grand Total
Team A	8	4	8	2	**22**
Team B	4	6	4		**14**
Grand Total	**12**	**10**	**12**	**2**	**36**

Table no 6: Shows the foul outcome results in both first and second half of the match between India Vs Qatar

Table no 7:

Shows that Team A(India) in the first half of the match they have been analyzed with total of forty-six turnover lost which two were lost in tackle and sixteen were lost in opposition pressure and thirty were lost in poor pass, likewise in the second half of the match they have been analyzed with total of fifty-six turnover lost which the eight was last in opposition pressure and forty-six were missed by poor pass. Team B (Qatar) in the first half of the match they have been analyzed with total of thirty-six turnover lost where zero in tackle and ten in opposition pressure and thirty-six in poor pass, likewise in second half of the match they have been analyzed with total of sixteen lost over where one was lost in tackle one was lost in opposition pressure and fourteen were lost in poor pass. As a whole, team A got one hundred and two turnover lost and Team B got eighty-two turnovers lost in total.



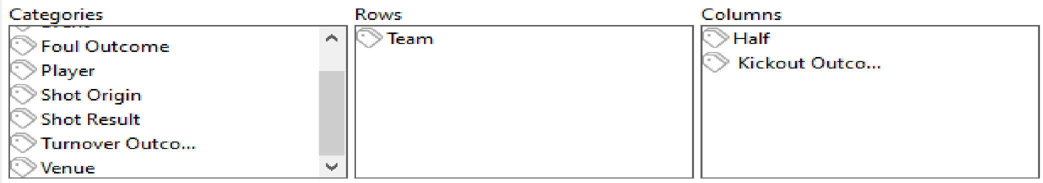
Team vs. Half;Turnover Outcome

	1st Half Opposition Pressure	1st Half Poor Pass	2nd Half In Tackle	2nd Half Opposition Pressure	2nd Half Poor Pass	Grand Total
Team A	16	30	2	8	46	**102**
Team B	12	24		10	36	**82**
Grand Total	**28**	**54**	**2**	**18**	**82**	**184**

Table no 7: Shows turnover outcome results in both first and second half of the match between India Vs Qatar

Table no 8:

Shows that Team A(India) in the first half of the match they have been analyzed with six kick out, likewise in the second half of the match they have been analyzed with zero kick out. Team B (Qatar) in the first half of the match they have been analyzed with four outcomes, likewise in second half of the match also they have been analyzed with two kick out. As a whole, team A got six kick out and Team B got six kick out outcome in total.



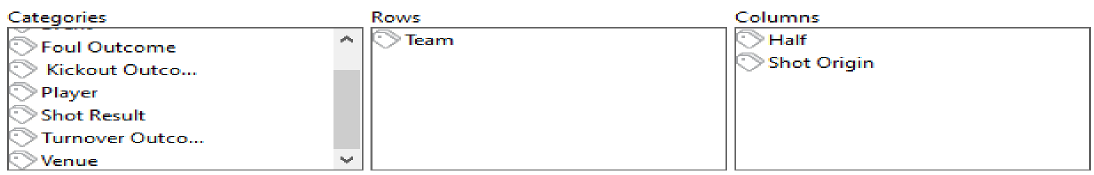
Team vs. Half;Kickout Outcome

	1st Half Lost	2nd Half Lost	Grand Total
Team A	6		**6**
Team B	4	2	**6**
Grand Total	**10**	**2**	**12**

Table no 8: Shows the kick out outcome results in both first and second half of the match between India Vs Qatar

Table no 9:

Shows that Team A(India) in the first half of the match they have been analyzed with six shot origin from play and zero shot origin from set piece, likewise in the second half of the match they have been analyzed with ten shot origin from play. Team B(Qatar) in the first half of the match they have been analyzed with nine shot origin from play and twelve shot origin from set piece, likewise in the second half of the match they have been analyzed with six shot origin from play and two shot origin from set piece. As a whole Team A got sixteen shot origin and Team B got twenty-nine shot origin in total



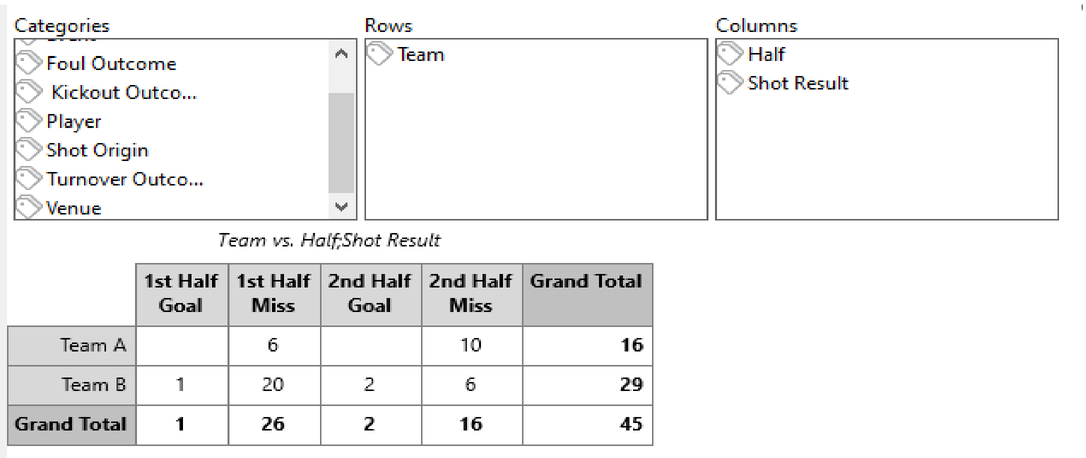
Team vs. Half;Shot Origin

	1st Half From Play	1st Half From Setpiece	2nd Half From Play	2nd Half From Setpiece	Grand Total
Team A	6		10		**16**
Team B	9	12	6	2	**29**
Grand Total	**15**	**12**	**16**	**2**	**45**

Table no 9: Shows the shot origin outcome results in both first and second half of the match between India Vs Qatar

Table no 10:

Shows that Team A(India) in the first half of the match they have been analyzed with they have got six shots on goal where zero shot was succeeded and six shots where missed, likewise in the second half of match they have gotten shots on goal and the ten were missed. Team B(Qatar) in the first half of the match they have been analyzed with they have got twenty-one shots on goal where one shot was succeeded and twenty shots where missed, likewise in the second half of match they have got eight shots on goal where the two shot was succeeded and six shots were missed. As a whole Team A got sixteen shots and Team B got twenty-nine shots in total.



	1st Half Goal	1st Half Miss	2nd Half Goal	2nd Half Miss	Grand Total
Team A		6		10	**16**
Team B	1	20	2	6	**29**
Grand Total	**1**	**26**	**2**	**16**	**45**

Table no 10: Shows the shot outcome results in both first and second half of the match between India Vs Qatar

On the whole comparing with both the teams Indian team performance over the selected parameters is not satisfied and it is not at all entering into any minimum criteria in entering the qualifiers it is mandatory to have more insight generation strategical planning and decision making with advanced training will lead to increase the performance with the help of advanced and emerging technologies [8].

III.RESULT

As a result, the analysis done by using Dartfish software which was used to find the details of the match that let the players improve through setbacks, it has been found that in the entire matches played by our Indian team against Qatar and Afghanistan in World Cup Qualifiers there are a lot of areas the team has to work on. Improving the overall performance of the team involves ball control, more coordination between the players, arranging more international matches and tournaments to give players exposure to different styles of play & higher level of competition and conducting camps a month before the matches. Also, the coaches can utilize this analysis to work in the weaker areas of the players to enhance their performance.

IV.DISCUSSION

Discussion on the performance of players:

(Goal keeper) Gurpreet Singh:

He is one of the best goalkeepers and India's first choice goalkeeper. He also plays for Bengaluru FC in the ISL. His height is an added advantage to him. He is the pillar of the Indian team. But in Afghanistan match he made a foul because of which the opposite team was awarded with penalty kick. He has to calmer in our defensive box area.

(Defender) Sandesh Jhingan:

He is playing for Indian team for the last 8 years; he is a strong player he also got offer from foreign club but he could not perform well there so he returned to India here he played well but he could not perform well while facing foreign teams so his performance also below average

Anwar Ali:

He is playing in fullback position for Indian team, he has also played under 17 World cup. He has to improve in heading, surprise long kicks to forward players, endurance and body power.

Subashish Bose:

He is playing in left back position, he needs to run for many overlaps, he should provide more crosses and improve in defending.

Rahul Bheke:

He is playing in right back position; he needs to improve in defending and attend more set pieces as he is a good header.

(Midfielder) Brandon Fernandes:

He is playing in attacking midfielder position, he is good in short passes and must improve in long passes, must provide more passes in opponent area.

Anirudh Thapa:

He is playing in defending midfielder position; he is good in long passes but his contribution in the match was less.

He has to improve in box to box playing.

Lallianzuala Chhangte:

He is playing in right winger position, his performance was average, he must improve in dribbling, play more in opponent area and supply more crosses.

Liston Colaco:

He is playing in left wing position; his performance was below average and must improve a lot in ball control and take powerful shots.

(Forward) Sunil Chhetri:

He is the main striker playing in Indian team, he is a legend of Indian football team and a top scorer. But in the Qualifiers, his performance was average. He did not get any ball passes from midfielders. He has to score more goals to get India Qualified.

Indian team performance

In the World Cup Qualifier matches, the overall performance of the team was average. We have lost in both the matches. We have conceded 5 goals and we scored only one goal in the two matches. So, we have to improve and work in every position, we should not receive any goals and the defending lineup should be strong. The midfielders must work a lot in passing and defending in the entire match. The endurance must be improved. The coach should be tactically superior to the other team in order to identify the player's strengths and weakness and create a more cohesive squad. If India wins against Kuwait in their next match, they can qualify for the next round of world cup qualifiers.

V.CONCLUSION

Video analysis of the entire matches played by our Indian team with Qatar and Afghanistan was analyzed by tagging events with the help of Dartfish and the statistical report for improving the players' performance has been generated. This statistical analysis of the performance is based on ball possession and attacking. Coaches can further utilize these data from each match to result in a better outcome in the upcoming matches. Focusing on the weaker areas of players, ball control and endurance, increasing the number of team camps, playing more international matches and resulting in a better outcome.

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CFD and Wind Tunnel Study on Cricket Ball at Different Seam Angle and Velocity

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Abstract: *This study delves into the intriguing investigation of flow patterns over a cricket ball, employing both computational and experimental methods for a comparative analysis. The work explores about variation of velocities in different angles, here we have used as 4 cricket balls they are dukes cricket balls, SG cricket balls, dukes 3d printed cricket ball and SG printed cricket ball. While comparing all the cricket balls it shows values in the wind tunnel experiment in seam angles of 0°,30°,45°,60°& 90° in a subsonic wind tunnel. Both computational simulations and experimental observations were conducted to analyze the impact of seam angles and velocities on the cricket balls. The results obtained from computational models were successfully validated through experimental data, affirming the reliability of the computational approach in predicting aerodynamic characteristics. Flow visualization techniques further confirm these findings, highlighting the significance of keywords such as drag, seam angles, reverse swing, flow visualization, and computational fluid dynamics (CFD) in understanding the aerodynamics of cricket balls. Overall, this research provides valuable insights into optimizing bowling strategies by considering the interaction between seam angles, velocities, and aerodynamic behavior of cricket balls.*

Keyword*: Ball drag analysis, Reverse swing analysis, CFD analysis, Cricket ball analysis.*

I.INTRODUCTION

This study uses 4 cricket balls: dukes cricket balls, SG cricket balls, dukes 3d printed, cricket SG printed cricket balls are compared with each other. The exploration of aerodynamics in sports, particularly cricket, offers fascinating insights into the physics governing ball movement. The attributable to spinning, causes a cricket ball to deviate from its original trajectory, adding an element of unpredictability to the game. This phenomenon is pivotal in understanding swing, a crucial tactic employed by bowlers to outmaneuver batsmen [3]. A cricket ball's characteristics, including weight, diameter, and construction, significantly influence its behavior on the pitch. Swing, categorized as conventional or reverse, depends on factors like seam position and ball velocity. Scientific studies, pioneered by researchers like Cooke, Alam, Bartlett, Barton, Metha, Sayers, and Hill, have delved into unraveling the complexities of cricket ball swing. The presence of a seam complicates aerodynamic analysis, making it essential to conduct meticulous studies to comprehend swing mechanics fully [8]. Previous research has shed light on the role of pressure differentials and boundary layer separation induced by the seam in facilitating swing, particularly in the initial overs of a match when the ball's surface remains laminar due to shine orientation [10]. This study builds upon existing research by investigating the influence of ball age and release angle on swing [5]. Utilizing wind tunnel experiments on both used and fresh cricket balls, the research explores the effects of ball wear and seam orientation under various velocities and seam angles. By employing both experimental and computational fluid dynamics (CFD) analyses, the study aims to deepen our understanding of swing dynamics, contributing valuable insights to cricket tactics and strategy [6].

II.MATERIAL AND METHODS

Aerodynamics of cricket ball involved in the suction cup with wind tunnel support there are certain dimensions for testing sections the seam has 5 different types of angles. The wind tunnel's peak velocity capability was 40m/s, while the focused-on velocities it has a ranging from 10m/s to 30m/s it can enhance maximum no. of velocity. Four types of models were utilized for experimentation: two original cricket ball and two 3D printed ball equipped with 18 pressure ports [1],[2]. Diagrams illustrating the attached of these models are provided in Figure 1, while outlines the details of the experiments conducted, including seam angles have studied and measurements performed. Pressure measurements 3d ball model Pressure tubes were attached to the ball and connected to manometer tubes. The measurements were taken without any support out at velocities ranging from 11.5m/s to 30m/s, with the setup adjusted manually to align with different seam angles (0°, 30°, 45°, 60°, and 90°). Manometer readings were noted for each seam angle and velocity, which were subsequently used to calculate pressure coefficients (Cp). Force measurements were performed on the dukes' cricket ball using a six-component system. The setup involved a vertical stringer the horizontal connecting upright post in the frames us connected to the component system, which was easily directly attached to the cricket ball via a nut and bolt. Measurements were guidance under various velocities for each seam angle and were reiteration for three different ball conditions rough smooth: both sides smooth, one side rough, and both sides rough. Additionally, separate experiments were conducted for laser smoke flow visualization, force measurements, and pressure measurements, owing to the limitations of available instrumentation and setup. Overall, this experimental setup facilitated a comprehensive analysis of the aerodynamic characteristics of cricket balls, considering various seam angles, velocities, and ball conditions, providing valuable insights into the factors influencing ball behavior during flight.

Fig.1.3D cricket ball mounted in wind tunnel

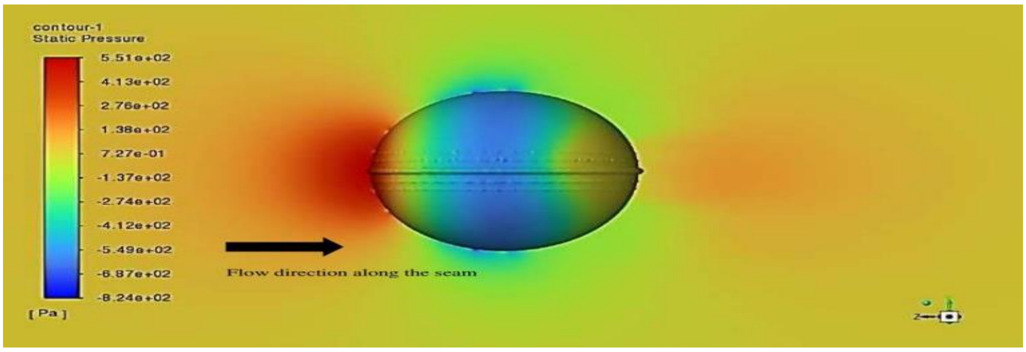


Fig. 2. Cricket ball analysis using Ansys

A combined Computational Fluid Dynamics (CFD) and wind tunnel study on cricket balls at varying seam angles and velocities offers invaluable insights into the intricate aerodynamics governing ball behavior. This discussion highlights the significance of such research and its implications for cricket performance and strategy.

1. Comprehensive Analysis

Integrating CFD simulations with wind tunnel experiments allows for a holistic examination of cricket ball aerodynamics. CFD enables detailed numerical analysis of flow patterns, while wind tunnel experiments provide empirical validation under controlled conditions, ensuring the reliability of the findings.

2. Seam Angle Effects

Seam angles play a pivotal role in determining the aerodynamic forces acting on the ball. Different seam orientations induce distinct pressure differentials and boundary layer separations, influencing the ball's trajectory and potential for swing [4]. Exploring a range of seam angles, from 0° to 90°, the study elucidates the optimal configurations for maximizing swing potential and overall performance.

3. Velocity Influence

The study investigates how variations in velocity impact cricket ball aerodynamics. Changes in velocity affect the magnitude of aerodynamic forces, including drag and lift, thereby influencing the ball's flight characteristics and responsiveness to bowler input [7],[9]. By examining a spectrum of velocities, from low to high, the research provides valuable insights into the dynamic interplay between bowling speed and ball behavior.

4. Validation and Confidence

The agreement between CFD predictions and wind tunnel measurements enhances confidence in the predictive capabilities of computational models. Validation through experimental data ensures the accuracy and reliability of the simulations, reinforcing the credibility of the study's findings. This validation strengthens the foundation for future research endeavors and practical applications in cricket training and equipment design. Insights gleaned from this study have practical implications for players, coaches, and equipment manufacturers. Understanding how seam angles and velocities influence ball flight allows for the refinement of bowling techniques, the development of strategic approaches, and the optimization of equipment design to enhance performance on the field. Moreover, this research contributes to the advancement of cricket coaching methodologies and the formulation of data-driven strategies tailored to exploit the nuances of ball aerodynamics. In summary, the CFD and wind tunnel study on cricket ball aerodynamics across various seam angles and velocities represents a significant advancement in our understanding of the sport. By integrating computational modeling with experimental validation, this research offers valuable insights that can inform player training, strategic decision-making, and the continual evolution of cricket equipment technology.

Statistical analysis

Here, we have analyzed 4 types of balls in different angle which ranges from zero degree to 90 degree to compare and get to know about the benefits of the balls in different angle in aerodynamics perspective. Out of the four balls, we have dukes cricket ball, SG cricket ball and also 3D printed models for both of them.

Table no 1: Shows the ball type and dukes cricket ball comparing with 3d cricket ball absorbing seam angle velocity

Ball type	radius	Height (seam) diameter ratio	Seam angle velocity	Measurement carried out
Dukes cricket ball	36mm	0.32	0°,30°,45°,60°and 90°	Force and smoke flow vis
Dukes cricket ball	36mm	0.20	0°	Force and smoke flow vis
Dukes cricket ball	36mm	0.25	30°	Force and smoke flow vis
Dukes cricket ball	36mm	0.14	45°	Force and smoke flow vis
Dukes cricket ball	36mm	0.12	60°	Force and smoke flow vis
Dukes cricket ball	36mm	0.01	90°	Force and smoke flow vis
Dukes 3d printed ball	36mm	0.31	0°,30°,45°,60°and 90°	Pressure measurement
Dukes 3d printed ball	36mm	0.22	0°	Pressure measurement
Dukes 3d printed ball	36mm	0.19	30°	Pressure measurement
Dukes 3d printed ball	36mm	0.23	45°	Pressure measurement
Dukes 3d printed ball	36mm	0.14	60°	Pressure measurement
Dukes 3d printed ball	36mm	0.01	90°	Pressure measurement
SG cricket ball	36mm	0.31	0°,30°,45°,60°and 90°	Force and smoke flow vis
SG cricket ball	36mm	0.31	0°	Force and smoke flow vis
SG cricket ball	36mm	0.19	30°	Force and smoke flow vis
SG cricket ball	36mm	0.22	45°	Force and smoke flow vis
SG cricket ball	36mm	0.14	60°	Force and smoke flow vis
SG cricket ball	36mm	0.01	90°	Force and smoke flow vis
SG 3d printed ball	36mm	0.31	0°,30°,45°,60°and 90°	Pressure measurement

SG 3d printed ball	36mm	0.18	0°	Pressure measurement
SG 3d printed ball	36mm	0.23	30°	Pressure measurement
SG 3d printed ball	36mm	0.14	45°	Pressure measurement
SG 3d printed ball	36mm	0.01	60°	Pressure measurement
SG 3d printed ball	36mm	0.02	90°	Pressure measurement

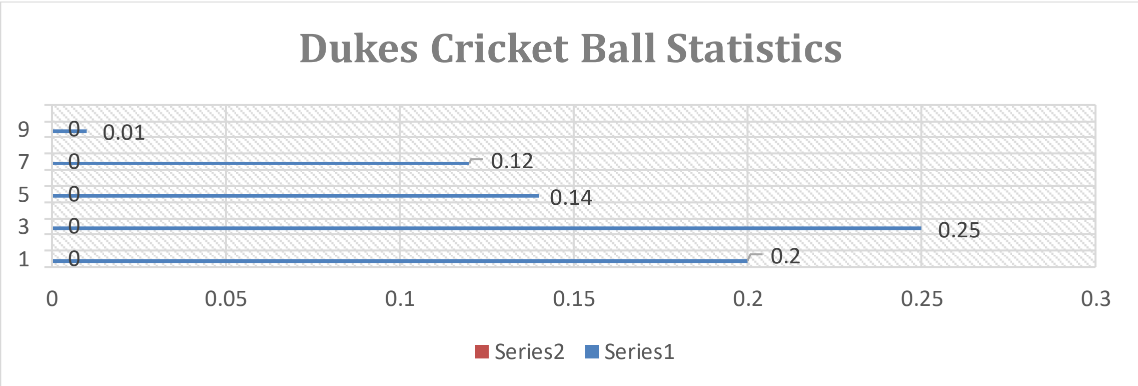
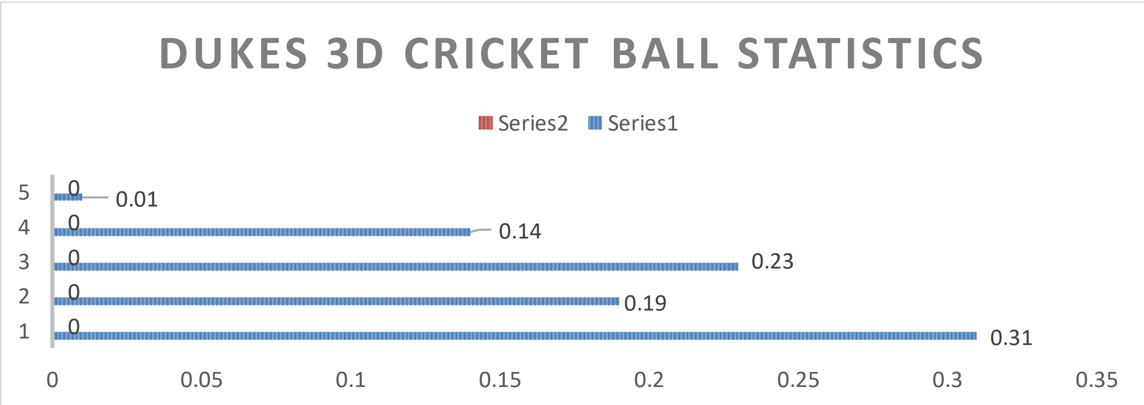


Fig. 2. Cricket ball analysis using Ansys



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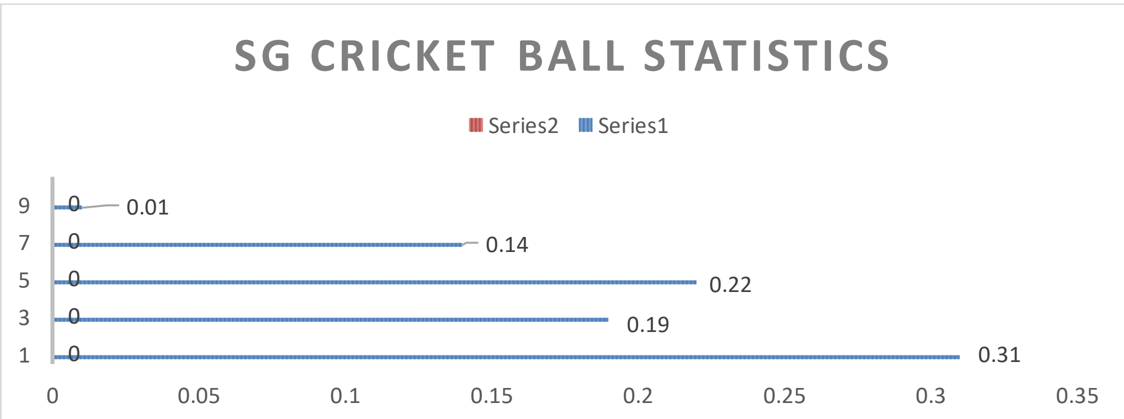

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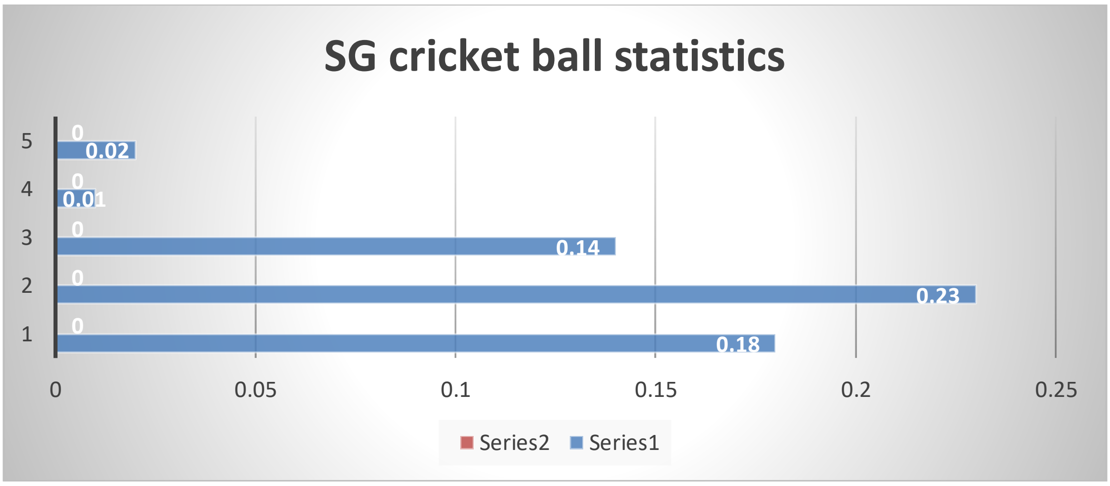

Fig. 2. Cricket ball analysis using Ansys

III.RESULT

Experiment of 4 balls: dukes cricket ball, SG cricket ball, dukes 3D printed ball, and Sg cricket ball are compared to find the force and smoke flow visualization and pressure measurement. We have used 36 mm of all the cricket balls of dukes' balls and sg cricket balls and 3d printed ball to calculate the difference for the study. In these results provide valuable insights into the aerodynamic principles governing cricket ball flight and swing, which can inform strategies for players, coaches, and equipment designers seeking to optimize performance [11],[12]. The study would investigate how seam angle and velocity impact the spin rate and axis stability of the cricket ball. This information is essential for bowlers aiming to control the movement of the ball through the air cfd results with wind tunnel measurements can optimize the balls designs of enhancing this could lead to the developments of balls that exhibit more predictable flights greater swing increased spin capabilities [3].

IV.DISCUSSION

Let's compare the aerodynamics of the dukes cricket balls ,the sg cricket balls and a 3d printed dukes cricket balls across various seam angles 0 degree high seam stability generates swing due to polished surface and pronounced seam in sg cricket ball moderate seam stability ,less swing compared to dukes ball similar to dukes balls depends on materials properties 15 degrees continues to maintain the stability and swing seam acts as an airfoil generating lift 15 degrees sg cricket balls stability decreases slightly swing may vary stability and swing depends on material properties and seam design 30 degrees seam acts a significant aerodynamics elements generating pronounced swing sg cricket balls swing mat reduce compared to lower seam angles swing mat vary depending on the design and material properties 45degrees significant swing seam becomes more prominent in aerodynamics effects sg cricket balls swing decreases the further seam may not have as much impact swing could be influenced by seam design and material properties 60 degrees dukes balls swing continues but decreases compared to lower angles sg cricket balls swing diminishes seams effect may be minimal 3d printed ball swing could vary based on the materials and design 75 degrees minimal swing seams aerodynamics effects decreases sharply sg cricket very little swing seam may not affect the trajectory significantly swing might be negligible on depending on materials properties 90 degrees dukes cricket balls seam has negligible effects on swing trajectory mostly determined by balls spin minimal to no swing seams aerodynamics influence is minimal swing unlikely spin becomes primary factors

V.CONCLUSION

In this study, we conducted experiments comparing the aerodynamic properties of four different cricket balls: Dukes cricket ball, SG cricket ball, and two 3D printed replicas. Through force analysis, smoke flow visualization, and pressure measurements, we found remarkable similarities in the aerodynamic behavior of all balls, regardless of their make or construction. Our results offer valuable insights into the principles governing cricket ball flight and swing, essential for players, coaches, and equipment designers aiming to optimize performance. We investigated how seam angle and velocity influence spin rate and axis stability, crucial factors for bowlers seeking control over ball movement. The correlation between CFD results and wind tunnel measurements suggests potential for optimizing ball design to enhance flight predictability, swing, and spin capabilities. Notably, variations in seam angle, ranging from 0 to 90 degrees, yielded predictable changes in stability and swing characteristics across all ball types. These findings underscore the significance of material properties and seam design in determining ball behavior. While certain seam angles favored pronounced swing, others led to diminished aerodynamic effects. Our study provides a comprehensive understanding of cricket ball aerodynamics, laying the groundwork for future advancements in ball design and player performance optimization.

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Aerodynamics Behavior in High Speed Sports Jersey Fabrics with Different Roughness

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Abstract: *Enhancing aerodynamic performance holds paramount importance in high-speed sports, leading to a growing interest in garments that can positively impact aerodynamic efficiency. Wind tunnel experimentation has played a pivotal role in assessing aerodynamic properties, employing both cylinder and leg models within a closed return circuit tunnel setup. Utilizing a plastic cylinder model, researchers evaluated the aerodynamic properties of various knitted samples, with dummy cylinders introduced to minimize 3D flow effects and ensure adherence to the infinite length hypothesis. By employing the foot and knee as additional dummy components, efforts were made to further mitigate 3D flow effects. These wind tunnel tests encompassed nine knitted single jersey fabrics, predominantly composed of 100% polyester, subjected to speeds ranging from 20 to 80 km/h to simulate real-world sporting conditions. The findings revealed a significant correlation between fabric manufacturing, indicated by the cover factor, and fabric roughness, with discernible impacts on aerodynamic parameters. Notably, consistent aerodynamic behaviors were observed across fabric tests conducted on both the cylinder and leg models, underscoring the reliability of the experimental setup.*

Key Word: *Aerodynamics, Textiles, Roughness and Cover factor*

I.INTRODUCTION

Enhancing aerodynamic performance holds paramount importance in high-speed sports like athletics. Consequently, there has beena surge in interest regarding garments that can positively impact aerodynamic performance in sports. Current research has pinpointed several factors crucial for improving athletes' aerodynamic capabilities:

- The aerodynamic properties of the sports equipment utilized
- The positioning of the athlete's body during activity
- The design and style of the garments
- The fit of the garments worn
- The aerodynamic attributes of the garment surface

Improving the aerodynamics of athletes in motion can be significantly enhanced through meticulous garment design, styling,and fit. This has been evidenced across various sports disciplines such as running, cycling, downhill and cross-country skiing, bobsled, and speed skating. Studies, including one by Laing, have demonstrated that drag reduction of up to 10% can be achieved through strategic clothing choices. Multiple methodologies have been employed to assess the impact of garment design and styling on aerodynamic performance. For instance, Kyle and Caiozzo conducted wind tunnel experiments using materials and wigged-head models, predicting a potential decrease in wind resistance ranging from 0.5% to over 6% by covering the hair and employing elastomeric clothing materials with a snug fit. Similarly, Brownlie et al. compared various garment styles and materials for running, concluding that certain prototypes led to a significant reduction in running time. The importance of garment styling and design, particularly focusing on minimizing aerodynamic drag, was highlighted by Spring et al. in their study on cross-country skiers. Further advancements were made by Brownlie et al. who designed stretch fabric suits specifically tailored to athletes, resulting in notable reductions in aerodynamic drag.

II.LITERATURE REVIEW

The papers included in this literature review offer valuable insights of aerodynamics forces calculated using different factors

1. JulianJ. C.Chua (2011):

This study investigated the aerodynamic behaviour of flapping garments of different looseness ratios (garment length to cylinder circumference) mounted on a horizontal cylinder. The tight fitting garments showed the typical flow transition and a critical flow regime, with Recrit correlating with the roughness of the garments.

2. Viviana Valsecchi (2022):

This study is to investigate and quantify the aerodynamics advantage, the physiological and performance advantage produced by pacemaker drafting in the case of long endurance running. In endurance races, as in manysports, a part of the power produced by athletes is used to overcome air resistance.

3. FirozAlam (2019):

This study is to investigate aero/hydrodynamics understanding of athlete's body orientation and sports textile is paramount for achieving high performance in speed sports. The surface morphology and physical shape determine aero/hydrodynamic behavior and flight trajectory of all speed sports balls.

4. K.SaiAdithya (2020) :

Project focuses on aerodynamics design of a Wind Tunnel to simulate subsonic flows. Our specific aims were to design and construct a user-friendly Wind Tunnel facility, to adapt Wind Tunnel experiments such as flow visualization and measuring lift, drag to DBT (Design, Build and Test) projects, to assess and disseminate results. The review on the use of low speed Wind Tunnel applications shows that Wind Tunnels are very efficient for experimental simulations and flow visualization.

5. Harun Chowdhury (2012):

The results demonstrated that the cycling suit should be selected depending on the cycling position and speed range in order to take the aerodynamic advantage. As the position in the world class competitions are decided with a fraction of time difference, apart from the athletic performance, an efficient sport garment can enhance the overall performance of the athlete. Depending on the nature of the sport, this methodology can be used as a basic design toolto optimise or select proper parameters for the betterment of the outcome.

III.METHODOLOGY

Aerodynamic Test

1.Wind tunnel

The Wind Tunnel was used to experimentally measure the aerodynamic properties on cylinder and leg models. The tunnel is a closed return circuit wind tunnel. The maximum speed of the tunnel is approx- imately 145 km/h. The rectangular test section dimension is 3 m (wide) 9 2 m (high) 9 9 m (long) with a turntable to yaw suitably sized objects. More details about the tunnel can be found in Alam et al. . A zero measurement was taken before each series of measurements in order to eliminate possible errors due to the offset. The aerodynamic resistance was acquired at different incremental speeds from 20 km/h to 80 km/h in order to cover the range of speeds relevant to sports, such as cycling or speed skating. The tunnel was calibrated before conducting the experi- ments and the tunnel's air speeds were measured via a modified NPL ellipsoidal head pitot-static tube (located at the entry of the test section) connected to a MKS Baratron pressure sensor through flexible tubing. Purpose made computer software was used to compute all 3 forces and 3 moments (drag, side, lift forces and yaw, pitch and roll moments) and its non-dimensional coefficients. Thedata stream with 3 forces and 3 moments data at 8 kHz. The sensor was mounted under the wind tunnel floor and was connected to the model with a support. Frequency filtering has been used in order to remove the background noise frequencies and a sampling frequency of 200 Hz was used during the experiments. Samples taken were 20 s long, 3 samples have been taken and averaged. Data varied by a maximum of 5% between two different tests. Based on these initial results, force values were taken as the average of a 1 min run for a single sample.

Figure1. Wind Tunnel

Apparel scale down model:

Height (H)= 0.2m (1:3.5)

Width (W)=0.102m

For a standing subject in running position at constant speed, to neglect body weight effect on acceleration and deceleration, definesprojected area as a function of the athlete's height alone. The projected frontal area 'A' is given by:

A = (0.146×H^2)m^2 (3.11)
Area of actual model =0.7*0.36m = 0.252m^2Area of scale-down model = 0.2*0.10^2
=0.02m^2

Reynold's number of actual models:
Re(actual) = p. v. Lu
= 1.225*5*0.1.81*10^-5 = 2.41*10^5

Reynold's number of scale down model:
Re(scale down) = p. v. Lu = 1.225*17.5*0.21.81*10^-5
= 2.36*10^5

Blockage Ratio:2.7
The frontal area of the object Cross section area of wind tunnel =0.02/0.72×100
= 2.7% (i 5%)

Figure2. Human Apparel Model

Drag Estimation

The Apparel model of height 200mm and width 100mm was tested in a wind tunnel with a test section of 600x600x2000mm at a velocity of 17.5 m/s. Wind tunnel testing is a common method used to study the aerodynamic characteristics of objects in a controlled environment. The test section of the wind tunnel is a confined space where the model is placed, and the airflow is generated using a powerful fan. The velocity of the airflow can be adjusted to simulate various real-world conditions. By measuring the drag force on the model and other relevant data, the aerodynamic properties of the model can be analysed , includingthe co-efficient of drag (Cd).

At V= 17.5 m/sec Strain = 30 ×10^-6

Stress = 30×10^-6x 42x109 N/M^2

=1260×103

M=0.026

Force= M/I = 0.026/0.003

= 0.1113 N

Cd= 2D/0.5*v^2*p*s

=2*0.1113/0.5*1.225*306.25*0.02

=0.023

IV.RESULTS AND DISCUSSION

Velocity	Strain	F1	F2	Cd1	Cd2
5.07	1	0.00371	0.007	0.011	0.022
7.2	4	0.0148	0.0113	0.023	0.017
8.9	7	0.025	0.01855	0.025	0.018
10.5	10	0.0371	0.025	0.027	0.019
12.5	15	0.055	0.0371	0.028	0.0198
14.3	20	0.0742	0.051	0.029	0.02
15.7	26	0.0965	0.07	0.031	0.021
17.5	30	0.113	0.089	0.033	0.023
18.3	40	0.148	0.113	0.036	0.027

Table1. Drag estimation

When an object is streamlined with a low drag coefficient (cd) value, applying additional force can result insmoother fluid or gas flow around the object, thus reducing drag. Conversely, if an object has a complex shape and a high cd value, increasing the force may induce turbulent flow, leading to an increase in the dragcoefficient.

V.CONCLUSION

The wind tunnel test conducted on the Apparel model, measuring 200mm in height and 100mm in width, yielded crucial insights into its aerodynamic behaviour. Within the wind tunnel's test section, precise measurements of drag force acting on the model wereobtained, along with other key data such as the coefficient of drag (Cd). By leveraging the model's dimensions and airflow velocity, the Cd value was calculated, offering opportunities to optimize the design of the apparel model or enhance athlete performance.

Notably, the drag force experienced by the model increased proportionally with airflow velocity, aligning with fundamental principles of fluid dynamics. Overall, wind tunnel testing emerges as a potent tool for unraveling the aerodynamic attributes ofobjects, with potential applications spanning sports and engineering, among other domains.

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Material Optimization in Formula One Seat Fit Based on Structural and Biomechanical Analysis

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Abstract: *F1 drivers have reported that they suffer a long-term lower back pain due to 'Porpoising' effect, it is a series of bounce that is generated due to Aerodynamic downforce. This downforce is part of drag reduction principle that pulls the air underneath the vehicle, thereby creating an incredible speed of 200 to 230 mph. Also at 200 mph speed, the driver experiences a high amount G-forces up to six times during the race. This can be simply avoided by increasing the ground clearance of vehicle but at the same time it also reduces the max speed of the vehicle. Hence, without compromising the speed, Design optimization is done for driver's seat-fit through Computational methods of Biomechanical modelling and simulation for determining the optimum Seat Angle for Postural Ergonomics. As an additional Reinforcement and Shock absorption in seat material to protect driver's spine from the resulting dynamics, Material optimization is done by selecting Graphene as the suitable material over the existing Carbon fiber material. Finite element method was carried out for structural analysis of seat-fit model. The stress, strain and deformation values were found to be lesser in Graphene model when compared to Carbon fiber. The simulation results will provide a solution for eliminating the higher risk of spine injury or pathological condition of a sportsman and thereby improves the sporting performance.*

Key Word: *Motorsports, Computational Biomechanics, Ergonomics, Design optimization, Material optimization, Finite element analysis, Spine Injury prevention.*

I.INTRODUCTION

The lower back pain in F1 drivers is mainly caused due to Porpoising effect & G-forces. The four main factors identified from 4M – method (man, machine, material, method) can be optimized to improve the driver's pathological condition. The factors considered for improvement are Seat angle, Spine biomechanics, Posture & ergonomics, Shock absorption. Since seat angle determines the posture and ergonomics of the driver, and so angle modification approach was carried for optimum results. For Spine biomechanics, the kinematic analysis approach such as trunk flexion and its corresponding kinetics such as compression and shear forces are measured. For further reinforcement, material analysis was carried for various available composite materials from which the Graphene material is suggested to be more resistant to shock than existing carbon fiber material.

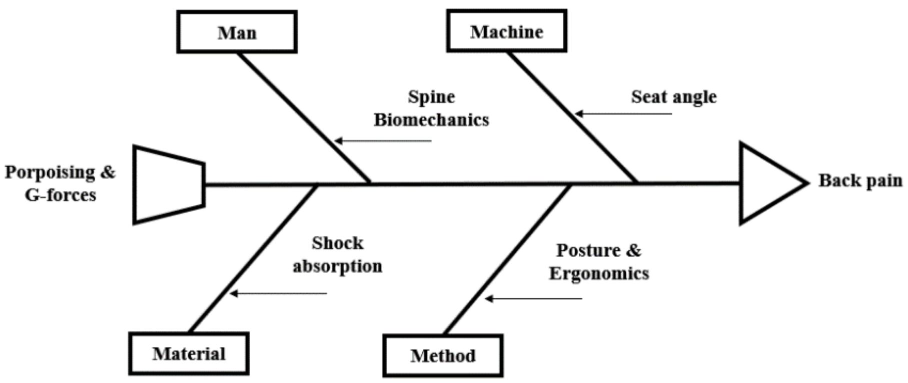


Figure 1. Fish bone representation of problem

1. The Proposing effect

The term 'Porpoising' is referred to a sea-dwelling mammal named as porpoise that's known to bob up and down in the sea surface while its swimming in the ocean. In F1, it's an aerodynamic phenomenon that affects the vehicle by pulling the air underneath for keeping the car close to the ground for achieving high speed in the racing track. The air entered will leave the rear part of vehicle, so in constant motion there a series of bounce is generated causing discomfort to the driver.

The FIA has revised the minimum ground clearance from 75mm to 90mm (75 + 15 mm) after this issue but higher off the ground can prevent porpoising and also creates less downforce, thereby decreasing the speed of a car.

2. G-forces

G-force is a physical phenomenon that is equivalent to one unit of gravity and this tends to be multiplied during the change in direction or velocity. In F1, the drivers experience high g-forces while performing acceleration, cornering and braking. The unit of g-force is 9.81 N. The average G-force in formula one is up to 6G max. In particular, 2G is experienced while accelerating, 5G at braking, 6G at the time of bouncing as well as cornering. The normal human threshold is 9G only for few seconds (measured for fighter jet pilot), where in this condition the body feels 9 times heavier and upward rapid pump of blood from heart to brain is experienced. However, this may lead to negative impact on human health.

II.LITERATURE REVIEW

The papers included in this literature review offer valuable insights into key areas spanning from the ergonomic design of Formula SAE race car cockpits to the optimization of Formula One racing cars and the integration of sustainability principles into automotive seat structures. Additionally, studies focusing on the ergonomics of Formula Student vehicles and truck driver seat comfort highlight the importance of human factors in vehicle design. Furthermore, investigations into advanced materials such as carbon fiber-graphene-reinforced hybrid polymer composites demonstrate the ongoing pursuit of innovative solutions to enhance vehicle performance and comfort.

1. **Mariotti and Jawad (2000):** This paper focuses on the ergonomic design of the Formula SAE race car cockpit. It likely delves into considerations such as driver comfort, accessibility of controls, and overall safety within the cockpit environment. The ergonomic aspect is crucial in ensuring that the driver can operate the vehicle efficiently and safely during races.

2. **Vadgama et al. (2015):** The paper discusses the design aspects of Formula One racing cars, likely covering various engineering considerations such as aerodynamics, materials selection, and performance optimization. Formula One cars represent the pinnacle of motorsport engineering, and understanding their design principles can provide valuable insights for engineers aiming to improve performance in similar contexts.

3. **Kinkead et al. (2016):** This study focuses on the design and optimization of Formula SAE vehicles. It likely discusses methodologies for improving vehicle performance through aerodynamic enhancements, weight reduction strategies, and chassis design optimization. Formula SAE competitions emphasize innovation and efficiency, making such optimization studies crucial for competitive success.

4. **Ahmad et al. (2017):** This paper discusses the ergonomics of Formula Student vehicles, which are similar to Formula SAE cars but geared towards university student teams. Ergonomics plays a vital role in ensuring that the vehicle is comfortable and easy to operate for the driver, which can ultimately impact performance and safety during competitions.

5. **Yuce et al. (2014):** This paper explores the design aspects of automotive seat structures with a focus on sustainability and reliability. Sustainable design practices are increasingly important in modern engineering to minimize environmental impact, while reliability ensures that automotive components meet performance requirements over extended periods of use.

6. **Chimote and Gupta (2013):** This paper discusses an integrated approach to improving truck driver seat comfort using ergonomics and Finite Element Method (FEM) analysis. Comfortable seating is crucial for long-haul truck drivers to prevent fatigue and ensure safety during extended periods of driving.

7. **Georgantzinos et al. (2020):** This study investigates the vibration analysis of carbon fiber-graphene-reinforced hybrid polymer composites using Finite Element Techniques. Such materials have potential applications in automotive components, where reducing weight while maintaining structural integrity and damping characteristics is essential for performance and comfort.

III.METHODOLOGY

The solution for the problem was carried out in two stages. In the first stage, ‘Design optimization and Biomechanical analysis’ and in the second stage ‘Material optimization and structural analysis was carried out. Stage 1 is the corrective action and the Stage 2 is the preventive action approach.

1. Design optimization & Biomechanical analysis

- Seat fit model was designed in CATIA V5 – Part design module. Dimensions were based on FSAE Design rule edition – 2022.
- Human model (Manikin) with average height and weight of general population was assembled on the Seat in CATIA V5 – Human builder module.

- Posture editor in Human builder module was used to accommodate the seat fit with appropriate flexion angles of body segment.
- Load was defined as 75 kg acting downwards at Trunk (considering the average bodyweight of subject drivers).
- Finally, Human activity analysis module was selected, in which "Biomechanical single point analysis" tool was used to calculate the L4-L5 spine compression and shear limits.
- Above procedure was done for iteration of three angle variants such as 60°, 45° and 20° respectively.
- Results was compared for determination of optimum seat angle.

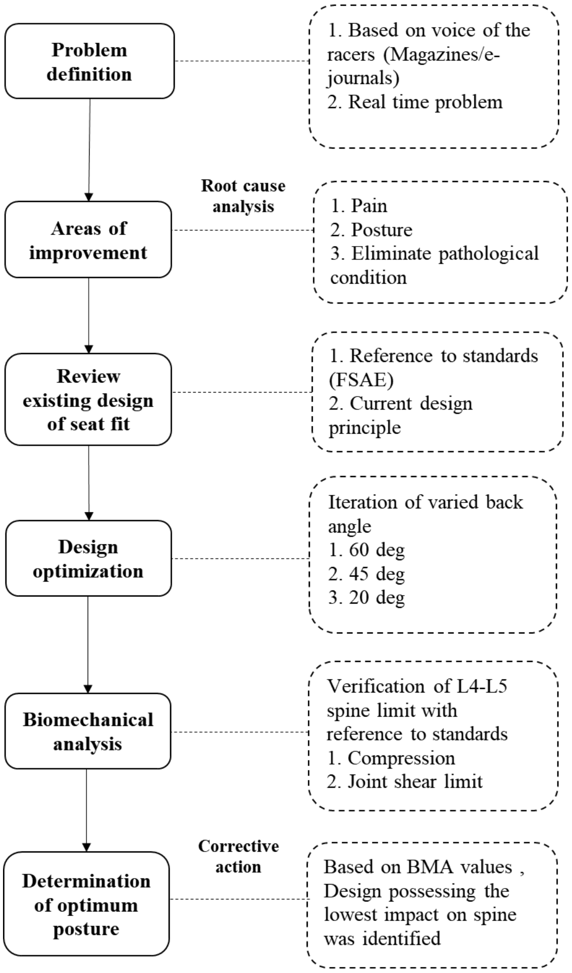


Chart 1. Flowchart for corrective action

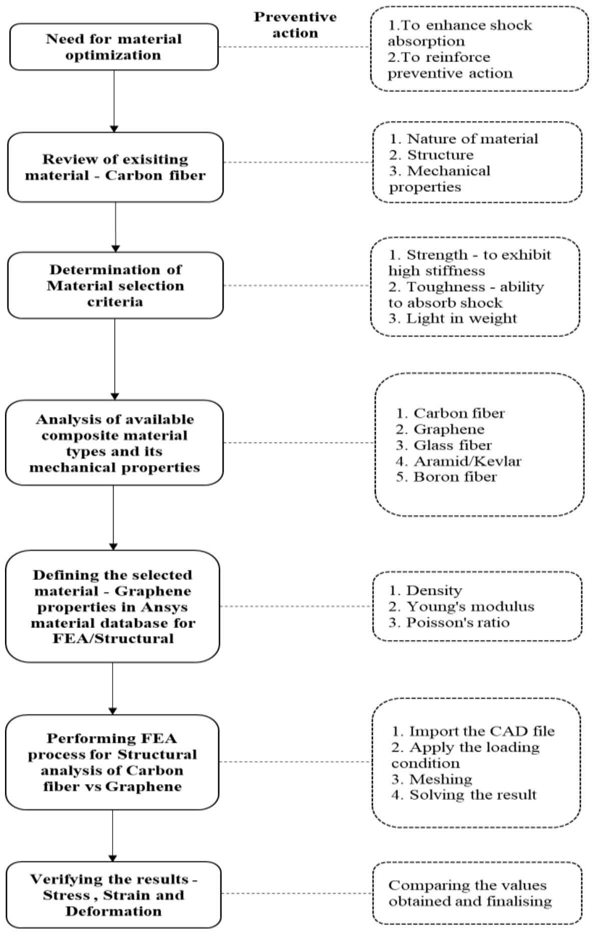


Chart 2. Flowchart for preventive action

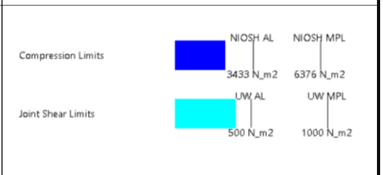
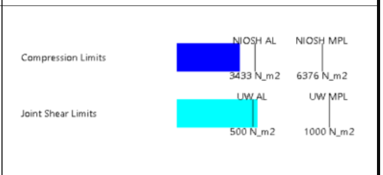
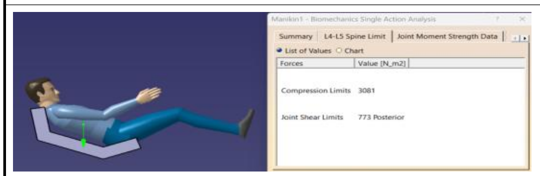
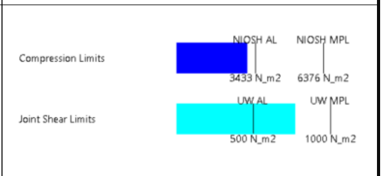
Biomechanical analysis of L4-L5 spine limit	**Safety standards**
	
	
	

Table 1. Biomechanical analysis in CATIA Human Builder & Human Activity Analysis

2. Material analysis & Selection of graphene

The existing material carbon fiber is a composite – reinforced polymer. Hence, other composite types were considered for comparison based on mechanical properties and Graphene was selected for its high strength and toughness characteristics.

S No	Material	Density [kg/m3]	Young's modulus [Gpa]	Poisson ratio	Remarks
1	Carbon fiber	1800	230	0.2	CF is the existing material currently used in F1 seats
2	Graphene	4717	342	0.19	Selected for simulation based on material properties and design criteria (high strength and toughness)
3	Glass fiber	1857	87	0.21	Other types of composites considered for comparison
4	Aramid/Kelvar	1400	140	0.37	
5	Boron fiber	2574	400	0.13	

Table 2. Material analysis based on the mechanical properties

3. Material optimization & Structural analysis

The finite element analysis takes place in three steps,

i. Pre-processing

- Defining the Engineering data (type of analysis)
- Material properties assignment
- Import the CAD geometry

ii. Solving – Mesh & Apply loading conditions

iii. Post processing – Verifying the simulation results

Detailed procedure for this experiment is given below,

- In Ansys workbench > select "Static structural" in the Analysis systems.
- In engineering data > Material database, the following material and its properties has to be defined,

S No	Material	Density [kg/m3]	Young's modulus [Gpa]	Poisson ratio
1	Carbon fiber	1800	230	0.2
2	Graphene	4717	342	0.19

Table 3. Material properties data

- **Import the CAD geometry from CATIA as .igs file**

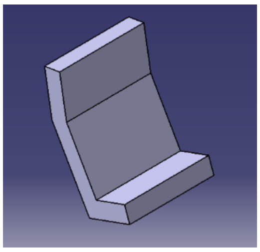


Figure 2. CATIA model of seat

- **Apply meshing to the discretize the solid model in form nodes and elements.**

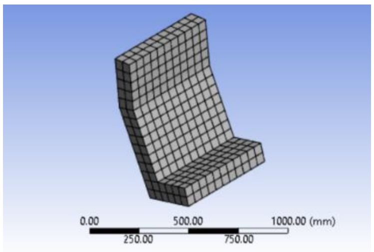


Figure 3. Meshing the model

- **Apply loading condition**

Fixed support: **Point A** – Bottom of the seat.
Force: **Point B** – Region where the driver's spine rest and loading takes place.

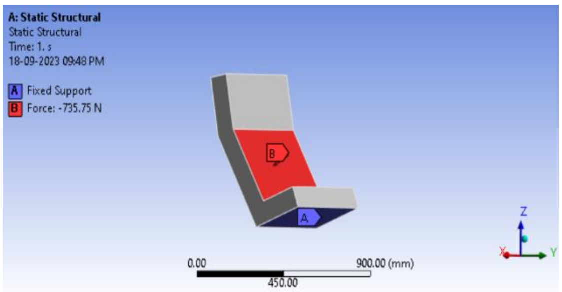


Figure 4. Loading condition

Load criteria:
Bodyweight = 75 kg
G-force = 9.81 N

⇨ 75kg x 9.81 N = -735.75 N ("-"sign indicates load in opposite direction)

- **Verify the results of**

I. Deformation
II. Stress
III. Strain
Following results were obtained for Carbon fiber and Graphene,

Carbon fiber – simulation results

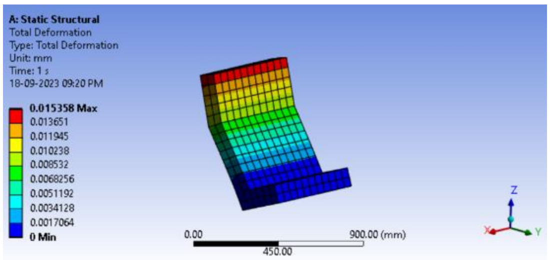


Figure 5. Total deformation

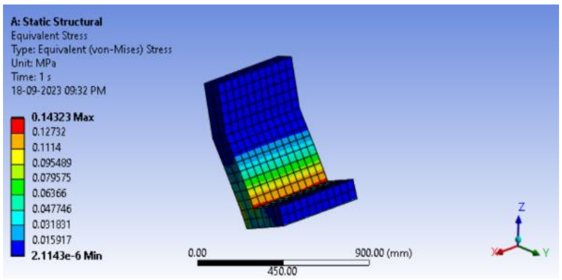


Figure 6. Equivalent stress

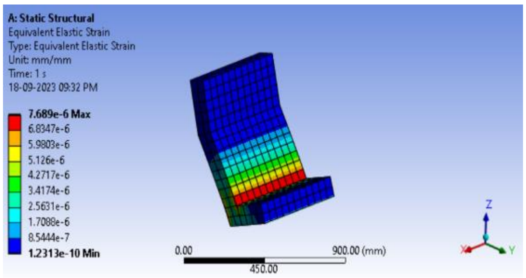


Figure 7. Elastic strain

Graphene – simulation results

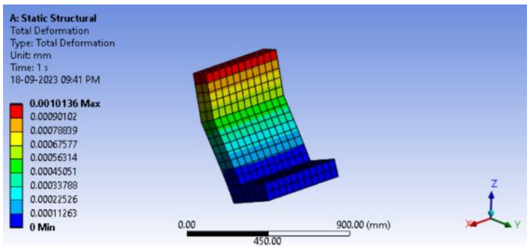


Figure 8. Total deformation

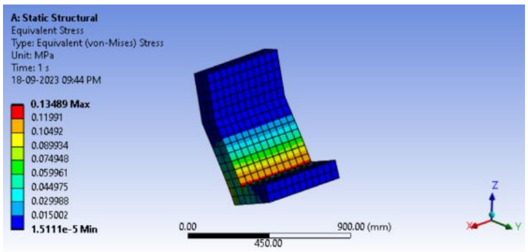


Figure 9. Equivalent stress

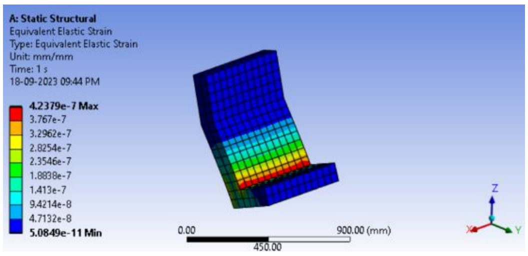


Figure 10. Elastic strain

IVRESULTS & DISCUSSION

In Biomechanical analysis and Design optimization, the compression and Joint shear limits of Lumbar spine - L4 L5 at angle 60° proves to the optimum seat fit posture for the driver. This nearly upright position protects the spine from compression induced shear loads during the porpoising effect and shear forces. Whereas, more flatter position i.e 20° is prone to higher level of load impact.

S No	Angle	G - Force [Taking 1G force = 1xbodweight as ref.]	L4-L5 spine limit (N)			
			Compression	Joint shear	Location	Result
1	60°	75 kg	2185	400	Posterior	Low
2	45°	75 kg	2747	531	Posterior	Medium
3	20°	75 kg	3081	773	Posterior	High

Table 4. Result of Design optimization & Biomechanical analysis

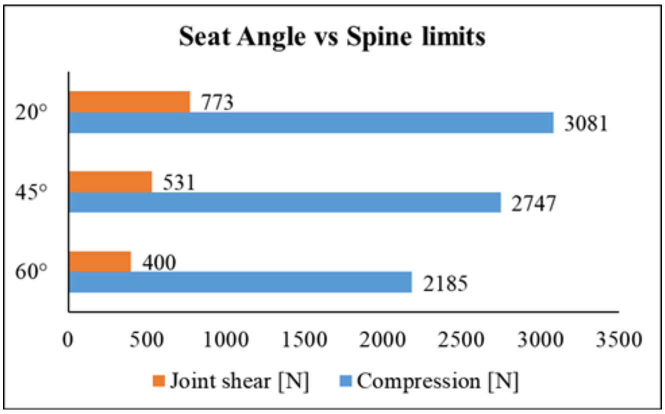


Chart 3. Graphical representation of Spine limits

In Material optimization, Graphene and carbon fiber model was simulated for Structural analysis by finite element method and compared for the values of Stress, Strain and Deformation. The total Stress value of Graphene model was 6% lower than Carbon fiber. Thus, Shock absorption is enhanced further in the selected material.

Load factors	Carbon fiber	Graphene	Result
Total deformation [mm]	0.01	0.001	Values <1 , negligible
Stress [pa]	143230	134890	Reduction of 6% of Stress in Graphene
Strain [mm]	7.689 e-6	4.237 e-7	Values <1 , negligible

Table 5. Result of Material optimization & Structural analysis

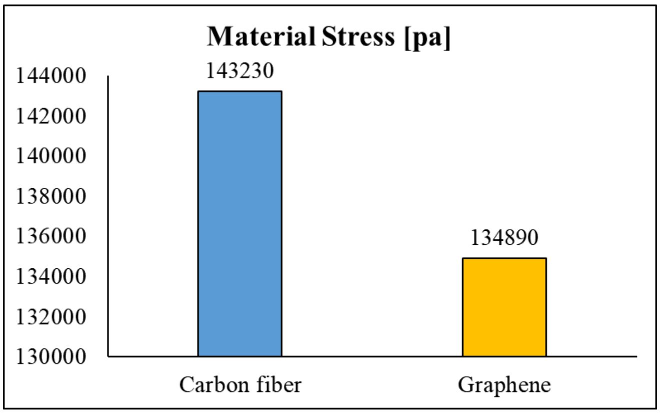


Chart 4. Reduction of stress in Graphene material

V.CONCLUSION

Hence, the simulation results have provided a clear solution for eliminating the higher risk of spine injury or pathological condition of a sportsman and thereby improving the sporting performance.

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CFD Analysis of the Generic Isolated Gable Roof Stadium: Impact of Opening Direction and Roof Angle for Wind Drift in Badminton

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Badminton; wind drift; ventilation; gable roof; computational fluid dynamics

ABSTRACT

Badminton is highly influenced by wind drift due to indoor ventilation, which changes the trajectory of the shuttlecock from the actual. To understand the influence of wind drift over different stadium configuration is studied using Computational Fluid Dynamics (CFD). CFD is an essential tool to assess and understand the impact of wind in the building environment for ventilation comforts. Many studies on natural or cross ventilation on the generic model and stadium infrastructure focus only on the ventilation comfort but limitedly on the wind influence like wind drift in badminton. Therefore, this paper presents a detailed study through computational analysis of the isolated generic model with three gable roof slopes ratio and two opening directions. The simulation is performed in a 3D steady Reynolds-Averaged Navier–Stokes (RANS) approach with the SST k–ω model. Validation is carried out with grid sensitivity study by comparing study of a published work with wind tunnel experiment data on a flat roof model. The results show that the gable roof in the longitudinal direction with a 6:12 and 4:12 sloped ratio performed better than a flat roof with a 6% and 13% volume flow rate higher with almost no wind drift near the ground (h=0.02m). The 2:12 sloped gable roof has a higher volume flow rate in both longitudinal and lateral wind flow than the flat roof, with 26% and 37 % higher but a more drifty environment.

1. Introduction

In sports stadium infrastructure, especially in the indoor arena/stadiums natural/cross ventilation is vital due to sustainability and less maintenance than Heat Ventilation and Air-Conditioning (HVAC). There was a unique challenge in designing the ventilation system for a sports stadium; it needed to provide ventilation comfort for the spectators and players without indoor wind disturbance for the sports activity. In badminton, the shuttlecock is used instead of a ball, a lightweight bluff body that will change from the actual trajectory due to indoor wind leading to a colossal setback for elite badminton players. The wind drift is due to natural ventilation caused by wind flow from doors, ventilation openings/windows and the HVAC system [1-6]. The natural/cross ventilation in the

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building depends on many parameters such as the volume of the building, roof configuration (size and shape), external wind direction and temperature, opening in the building (Size and Inlet-outlet location) and impact of surrounding environments is known from Awbi [7]. There are many studies on an isolated model for cross-ventilation based on the impact of computational parameters, roof geometries and types, leeward and windward opening location and size, symmetrical and asymmetrical opening, and an effect of wind catcher or tower [8-19]. In the case of the stadium, studies are based on ventilation comfort, impact opening types, thermal comfort, pedestrian comfort, pollution dissertation, wind influence around the stadium at different wind directions and impact of the surrounding environment [20-28]. Several studies have been carried out on ventilation comfort in isolated models and sports stadiums, but there has yet to study on badminton wind drift with ventilation comfort [13-24].

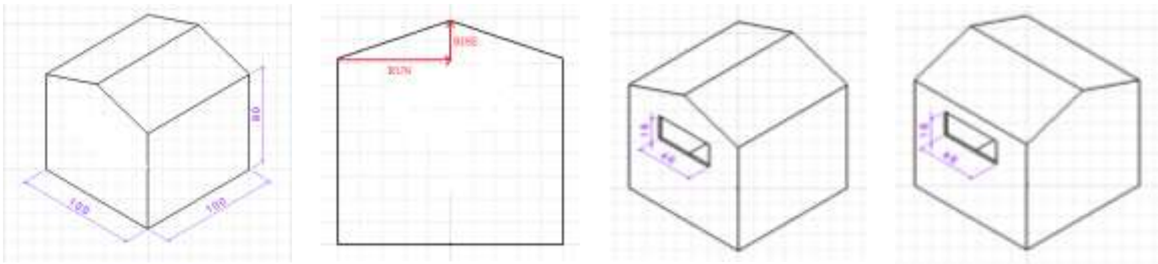
A gable roof is the one of the common roof structures used mostly to construct the badminton stadium with cross ventilation. Studies like peak pressure impact and wind-induced loads at different geometry are studied in gable roofs [8,9]. In the case of an inlet-outlet opening across the building, there were symmetrical and unsymmetrical openings, different heights, and different ratios studied in previous studies [12-19]. However, studies have yet to be conducted on the different gable roof configuration in the longitudinal and lateral opening of the model. Therefore, this paper will investigate the impact of the gable roof slope ratio and with opening direction in a generic isolated environment in Computational Fluid Dynamics (CFD). This paper will employ the coupled approach, where the indoor and outdoor wind flow model is simulated simultaneously in the following CFD studies at the same computational domain [29].

The aim of the study is not only to identify the best ventilation comfort roof configuration or opening direction but also the having a minimum wind drift near the ground. For validation purposes, the flat roof with two opposite openings is studied with the same model geometry and wind flow data from the literature on the wind tunnel experiment by Karava *et al.,* [29]. The study will analyze the seven different models, where one is the flat roof validating model [3].

(L X B X H = 0.1 X 0.1 X 0.08 m^2) with an opening in opposite directions at the top of the building at the height 0.06m from the ground to the center of the opening. The gable roof is studied with three different configurations in two opening directions; in total, six gable roofs are subjected to CFD analysis to understand the ventilation and wind drift among them. The horizontal measurement line between the inlet and outlet is to measure the non-dimensional wind velocity for validating with wind tunnel data taken from Karava *et al.,* [29] and to understand the wind flow between the opening (Inlet to outlet) is influencing the indoor environment which leads to a wind drift. The non-dimensional velocity contour is visualized in the vertical plane in the center and at the horizontal plane (h=0.06m) to visualize the wind flow exchange between the opening and the horizontal plane (h=0.02m) for understanding the wind flow pattern and dominating wind drift areas.

2. CFD Simulation

The simulation is carried out with wind tunnel experiment model dimensions by Karava *et al.,* [29] and computational parameters carried out based on Ramponi and Blocken [15] and Perén *et al.,* [18]. The gable roof is designed above the flat roof model at the different slope (rise/run) configurations (Figure 1(a) and Figure 1(b)) to understand the influences wind drift and ventilation [29]. The three different roof configuration models are developed for the analysis at the slope ratio (rise: run) 6:12, 4:12 and 2:12. The wind flow in all roof configurations is studied in longitudinal and lateral opening in the opposite direction to each other at 10% porosity with opening dimensions L X H = 0.046 X 0.018 m2 (Figure 1(c) and Figure 1(d)).

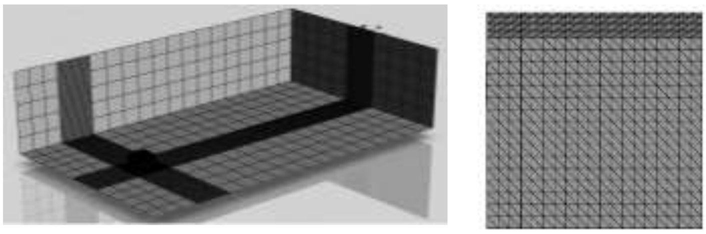


(a) (b) (c) (d)

Fig. 1. (a) Perspective view of the scale down model with dimensions in mm (b) Front view of the model illustrating the run and rise length (c) Perspective view of longitudinal wind flow opening with dimension in mm (d) Perspective view of lateral wind flow opening with dimension in mm

2.1 Domain and Grid Generation

The commercial package ANSYS Fluent user manual is used for grid generation and CFD simulation [30]. The cuboidal domain with a model is constructed in the dimension L X B X H = 1.9m X 1.1m X 0.6m (Figure 2(a)), and the model is located from the inlet plane at three times the height of the model. The structured mesh was generated using the partitioning technique, where the domain is divided into separate volumes, and a fine grid is generated in the model volume. The reference mesh model has 4,31,796 grids cell (Figure 2(b)), and the grid sensitivity will be discussed in subsequent section.



(a) (b)

Fig. 2. Computational grid model (a) Perspective view of grid in building model, ground, side and outlet wall (b) Reference model grid of the side view in longitudinal wind flow opening model

2.2 Boundary Condition and Solver Settings

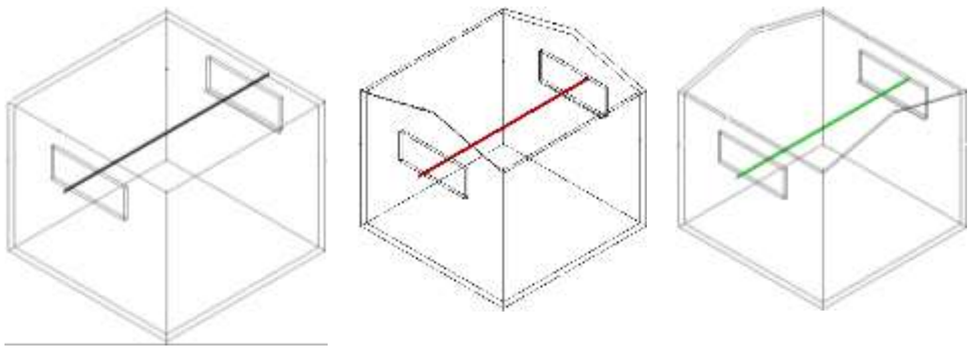
The front plane of the domain is the inlet, where the Atmospheric Boundary Layer (ABL) velocity profile is enabled based on Karava *et al.,* [29] wind tunnel measurements data is referred from Karava *et al.,* [29,31] and according to the logarithmic law Eq. (1), Where U (y) is the velocity-inlet profile, U* the ABL frictional velocity, Ǩ the von Karman constant, y the height of the domain and y_o the aerodynamics roughness length. For turbulent kinetic energy - k(y), epsilon - έ(y), omega - ω(y), is computed based on the reference from Ramponi and Blocken [16] and Perén *et al.,* [18]. The zero static pressure is maintained in the rear plane of the domain, has a pressure outlet, and a zero-velocity gradient is applied to the side and upper wall of the domain. Based on the literature recommendation in the studies by Ramponi and Blocken [15,16] and Perén *et al.,* [18], the model and ground surface impose the roughness height and roughness constant.

$$U(y) = \frac{U*}{K} \ln\left[\frac{(y+y.)}{y.}\right] \quad (1)$$

The simulation is carried out with the commercial CFD package Fluent. The SST k-ω model and 3D steady RANS equation was solved in a combined manner. The pressure-velocity coupling, interpretation and discretization are all in the second-order scheme with the SIMPLE algorithm is used in the previous studies [16,18]. It was assumed to attain the convergence at the scaled residual leveled and reached a minimum of 10^{-4} for continuity and specific dissipation rate (ω), 10^{-5} for turbulence kinetic energy (k) and 10^{-6} for x, y and z momentum is reliably monitored until 10,000 iterations to reach a stationary solution. The turbulence model for the study is selected based on the literature Ramponi and Blocken [15], where the simulation is compared between different turbulence model to understand the impact of turbulence, where the SST k-ω model, SST k- ε model, Sk- ε model, Rk- ε model, RNG k- ε model, Sk-ω model and RSM model. Among all turbulence model, SST k-ω model shows the best performance for a generic isolated cross-ventilation CFD simulation.

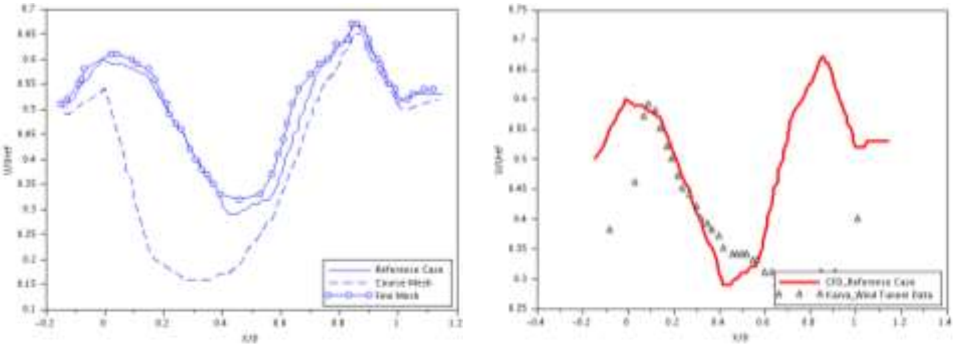
2.3 Grid Sensitivity and Comparison with Wind Tunnel Data

The grid sensitivity analysis is carried out on the flat where the non-dimensional velocity across the horizontal line between the opening (Figure 3(a)) is compared for the reference (4,31,796 cells), course (2,09,796 cells) and fine (6,92,521 cells) mesh model. From the observation, it was found that the course mesh has a huge drop in the non-dimensional velocity (Figure 4(a)) from the windward opening to the middle of the model. There is no significant difference between the reference mesh and the fine mesh which concludes that the non-dimensional velocity parameter (Figure 4(a)) becomes insensitive to an increase in the number of grids. To save the iteration timing and computational power demand, it is optimizing to select the reference mesh for the rest of the roof models. The reference mesh results gave a good argument with Karava *et al.,* [29] experiment data based on their study (Figure 4(b)) from the inlet opening to the middle where the experiment data is lacks towards the outlet opening of the model due to the effect of reflecting and shading, which is similar to previous studies [18,29]. The contour of non-dimensional velocity is measured in the center in a vertical plane (Figure 5(a)) and the horizontal plane at h = 0.06m (Figure 5(b)) to understand the wind flow exchange between the opening. The wind drift area is visualized in the horizontal plane at h=0.02m (Figure 5(c)), and the ventilation flow rate will be computed to understand the impact of the roof slope ratio's.



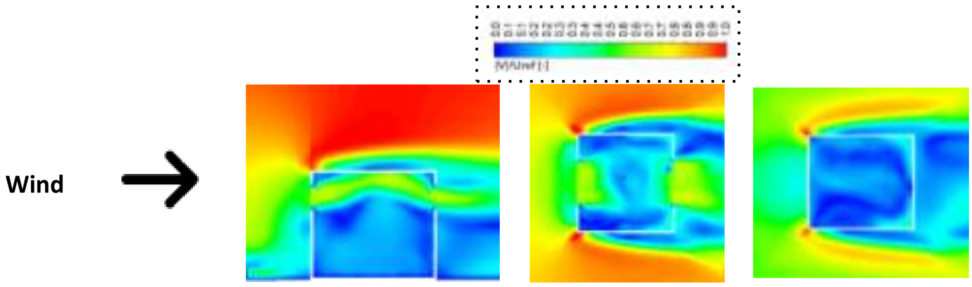
(a) (b) (c)

Fig. 3. Horizontal line between the opening center for measuring the U/U_{ref} (a) Flat roof (b) Gable roof in longitudinal wind flow opening direction (c) Gable roof in Lateral wind flow opening direction



(a) (b)

Fig. 4. (a) Comparison of impact of grid sensitivity in mean wind velocity (U/U_{ref}) between the opening along the horizontal line in flat roof. (b) Comparison of numerical data of reference mesh and wind tunnel data of mean wind velocity between the opening along the horizontal line in flat roof



(a) (b) (c)

Fig. 5. Flat roof non-dimensional velocity ($|V|/U_{ref}$) contours (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

3. Impact of Gable Roof Configuration and Wind Flow

To understand the impact of the gable roof configuration on wind drift for badminton stadium or arena, the analysis is done through non-dimensional contour (Figure 5 to Figure 11), Velocity vector of horizontal plane at 0.02m (Figure 12) and mean non-dimensional velocity in a plane (Table 1). The three configurations in a longitudinal and lateral wind flow at the different slope ratio (rise:run) 6:12, 4:12 and 2:12. In all three cases the inlet to outlet opening distance, location and size maintain to be the same. The velocity contour in the center vertical plane and horizontal plane (h=0.06m and 0.02m) (Figure 6 to Figure 11), Velocity vector at horizontal plane (Figure 12), non-dimensional velocity in the horizontal line (Figure 3(b) and Figure 3(c)) between the opening (Figure 13) and volume flow rate (Figure 14) will be analyzed to compare the gable roof slope and opening direction impact.

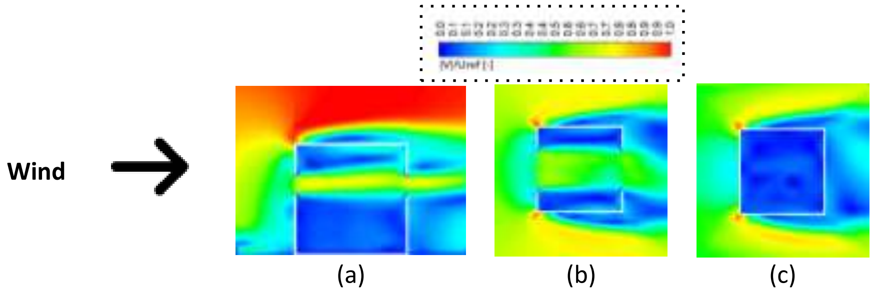


Fig. 6. Gable roof [6:12] non-dimensional ($|V|/U_{ref}$) contours - longitudinal wind direction (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

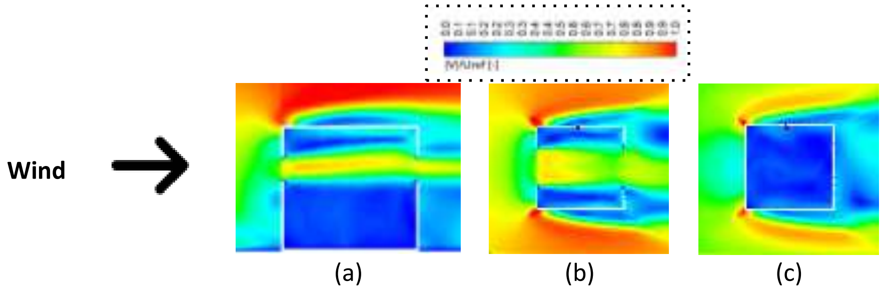


Fig. 7. Gable roof [4:12] non-dimensional ($|V|/U_{ref}$) contours - longitudinal wind direction (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

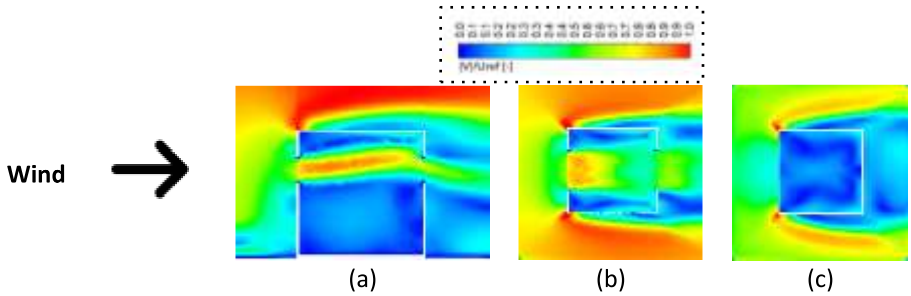


Fig. 8. Gable roof [2:12] non-dimensional ($|V|/U_{ref}$) contours - longitudinal wind direction (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

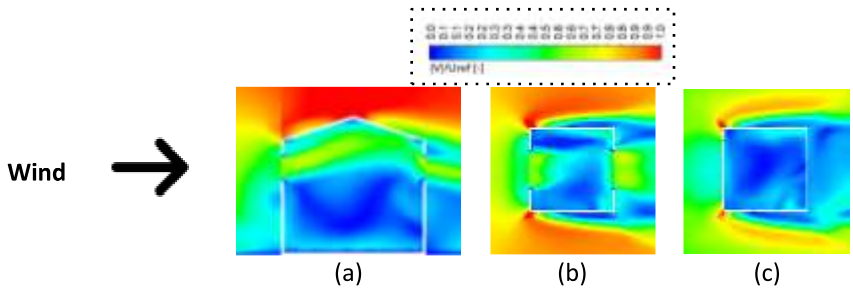


Fig. 9. Gable roof [6:12] non-dimensional ($|V|/U_{ref}$) contours - lateral wind direction (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

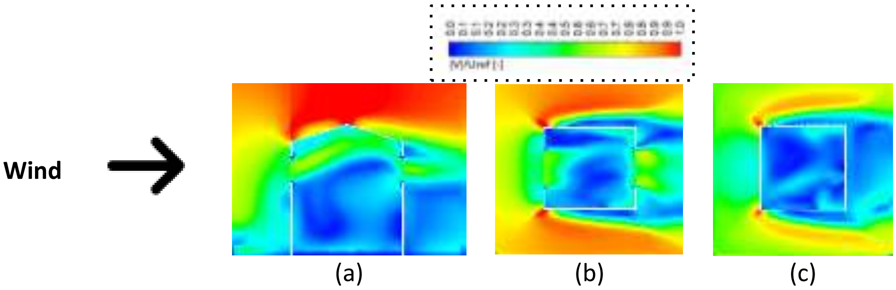


Fig. 10. Gable roof [4:12] non-dimensional (|V|/U_{ref}) contours - lateral wind direction (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

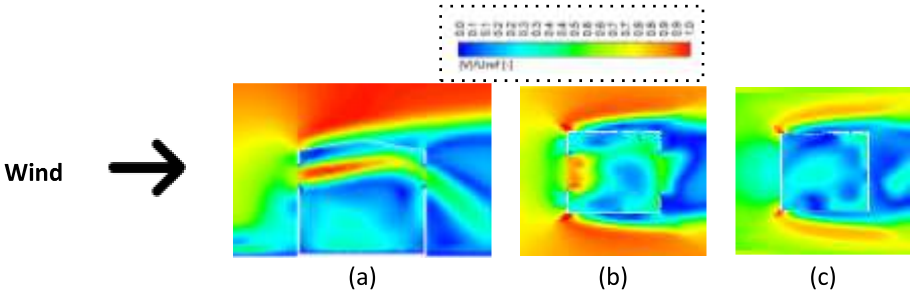


Fig. 11. Gable roof [2:12] non-dimensional (|V|/U_{ref}) contours - lateral wind direction (a) Vertical plane at center of the model (b). Horizontal plane at height = 0.06m from the ground of the model and (c). Horizontal plane at height = 0.02m from the ground of the model

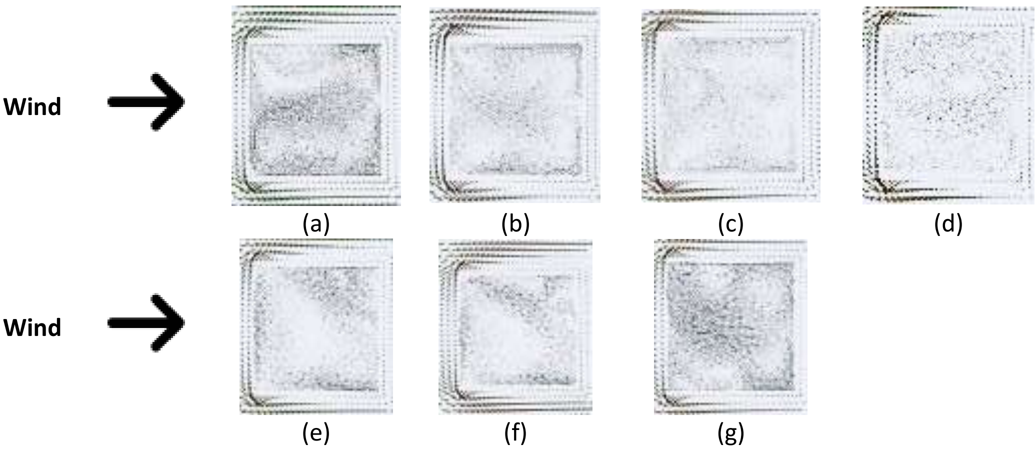
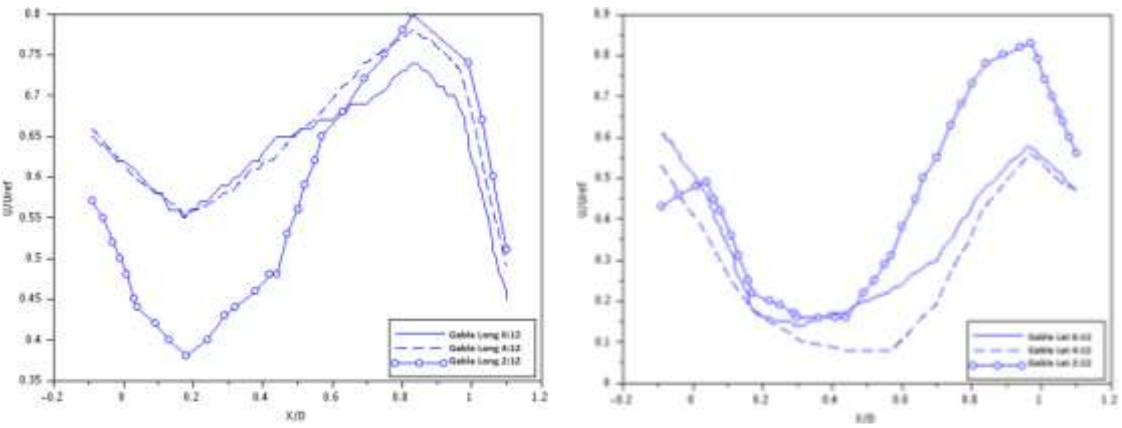


Fig. 12. Gable roof velocity vector at the horizontal plane at height = 0.02 m from the ground of the model. (a)Flat roof, Longitudinal wind direction (b). 6:12 (c). 4:12 and (d). 2:12 and Lateral wind direction (e). 6:12 (f) 4:12 and (g)



(a) (b)

Fig. 13. Impact of roof configuration (a) U/U_{ref} along the horizontal line in gable roof in longitudinal flow direction for different slope ratio (b) U/U_{ref} along the horizontal line in gable roof in lateral flow direction for different slope ratio

Table 1 gives more insight into different gable roof configurations where the mean U/U_{ref} in the vertical (center) and horizontal plane (h=0.06m) between the opening is studied for the exchange of wind flow. The horizontal plane (h=0.02m) mean U/U_{ref} gives insights into the wind drift. In longitudinal wind flow, the 2:12 configuration has a huge drop in the non-dimensional velocity (Figure 13(a)) from the inlet opening to almost the middle of the model due to deviation of flow toward the roof compared to 6:12 and 4:12, where there no huge change except near to the outlet opening. In 6:12 and 4:12, the wind flow exchanged between the opening without deflection from the roof (Figure 6(a) and Figure 7(a)) led to less wind drift near the ground (Table 1), but 2:12 had an increase in dirty area (Figure 8(a)) (Table 1) due to the flow deflection near the outlet opening. All three-roof configuration in lateral wind flow deviates upward to the roof (Figure 9(a), Figure 10(a) and Figure 11(a)), causing a drifty environment near the ground that is almost the same or more than a flat roof. The 2:12 possess a peak mean U/U_{ref} (Table 1) in the horizontal plane (h=0.02m), leading to a more drifty area (Figure 11(c)) than any other roof configuration. Altogether, the longitudinal wind flow performs better than a lateral wind flow with a less dirty region (Table 1). For all wind direction and roof configuration, the velocity vector is visualized in the horizontal plane at 0.02m from the ground to understand the no wind drift area. In 6:12 and 4:12 configurations in longitudinal wind flow (Figure 6(c) and Figure 7(c)) seems to have a better performance which possess a shallow drifty area compared to other configurations including the flat roof.

Table 1
Mean non-dimensional velocity in different plane area at longitudinal and lateral wind flow in gable roof

Model Case	Vertical plane inside the model at center	Horizontal plane inside the mode at h=0.06m	Vertical plane inside the mode at h=0.02m
Reference Case	0.24	0.28	0.12
6:12_Longitudinal	0.23	0.37	0.06
4:12_Longitudinal	0.22	0.39	0.05
2:12_Longitudinal	0.26	0.41	0.10
6:12_Lateral	0.23	0.22	0.10
4:12_Lateral	0.21	0.21	0.12
2:12_Lateral	0.31	0.36	0.20

From Figure 14, We can conclude that the volume flow rate for the gable roof 2:12 in lateral wind flow is the highest among all other roofs, with an increase of 37% compared to the flat roofs. In longitudinal wind flow, 2:12 is highest among 4:12 and 6:12, with an increase of 26% compared to the flat roof. The 4:12 in longitudinal opening direction has a better volume flow rate with a low wind drift area compared to other configurations, with an increase of 13% comparative to the flat roof. Comparing 6:12 and 4:12 in lateral wind flow has no significant difference in volume flow rate but decrease by almost 10% compared to a flat roof (Figure 14). It can be noticed that the lowest slope ratio of the roof will impact largely in the volume flow rate, both a flow direction lower slope configuration gains high volume flow rate.

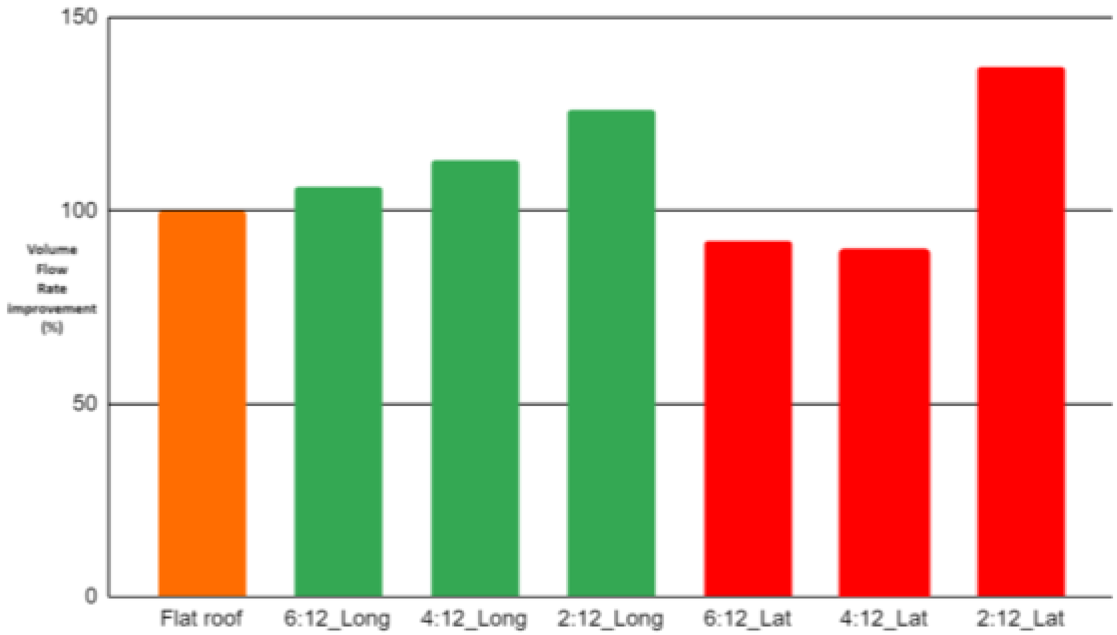


Fig. 14. Influence of roof slope ratio with opening flow direction for gable roof on volume flow rate improvement in percentage comparing with flat roof

4. Conclusion

The above study result is to understand the influence of the gable roof configuration with some limitation. CFD simulation is carried isothermal conditions with a flat roof and three different slopes of a gable roof (6:12, 4:12 and 2:12) in an isolated condition without an internal layout with cross ventilation opposite opening in longitudinal and lateral wind flow direction to understand the dominance of the wind drift (wind velocity near ground h=0.02m) in badminton stadium.

The following conclusion has been obtained from this study

i. The six types of CAD model are developed, where two types of roof type and three types of sloped roof ratio (Figure 1) for the CFD simulation to understand the wind drift and ventilation for the development of badminton stadium.
ii. The grid sensitivity analysis (Figure 2 and Figure 4(a)) is carried out in the flat roof, where the reference case selected for the analysis which perform will computationally with acceptable computational time and resource.
iii. Turbulence model and other computational parameter is selected based on the best practice provided in the literature for the isolated building cross ventilation analysis. Based on the literature recommendation, SST k-ω model perform well to predict the ventilation performance and validated well with experimental data (Figure 4(b)).
iv. The non-dimensional velocity contour at vertical plane at the centre and vertical plane at height 0.06m and 0.02m from ground (Figure 5 to Figure 11); Velocity vector at the

horizontal plane at height 0.02m from the ground (Figure 12); U/U_{ref} is measured in the horizontal line in the centre of the opening (Figure 13); Mean non-dimensional velocity at both vertical plane at height 0.06m and 0.02m from ground (Table 1) and Volume flow rate compared with flat roof (Figure 14) is analysed for all the roof configuration to understand the wind drift and ventilation.

v. In longitudinal wind flow direction, the gable roof with slope ratio 6:12 and 4:12 performs better (Figure 6(c) and Figure 7(c)) with higher volume flow rate than a flat roof (Figure 14) and lower wind drift compared to 2:12, even though it has higher volume flow rate (Figure 14) but has a huge drifty environment (Figure 8(c)).

vi. In longitudinal wind flow direction, a 4:12 sloped roof is recommended because 6:12 has a lower volume flow rate (Figure 14) comparatively, but both have the same lower drifty environment.

vii. In the lateral direction, 6:12 and 4:12 sloped roofs have no significant change in the drift environment compared to flat roof (Table 1) but have decreased to 10% in volume flow rate (Figure 14).

viii. The 2:12 sloped roof in lateral wind direction possesses a more drifty environment (Table 1) with a higher volume flow rate among all roof configurations (Figure 14).

ix. The CFD simulation is carried out in the isolated condition, there is need of analysis with surrounding environment for the better understanding in the wind drift and ventilation.

x. The CFD analysis is carried in the isothermal condition and steady state, where this analysis demand the actual scenario with environmental and weather condition for the more insights to balance both wind drift and ventilation in the Badminton stadium.

xi. The real-time case study will be carried out with CFD and experiment in the Badminton stadium in the future research for more progress in development of lower the wind drift court area with optimized ventilation.

Acknowledgement
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Monitoring Biometric Data of a Player Using a Wearable Device in Real Time for Sports Applications

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Abstract
On-field heart rate and physiological fitness makes the player more active on the ground if his fitness level is maintained from beginning till the last. This is the current demand in the modern sports field. For this reason researchers are developing devices to be incorporated in training sessions to monitor the health parameters and the physical fitness of the players. The aim of the research paper is to present a wearable device to obtain the biometric information that is, the muscle contractions, temperature and pulse rate of a player during his training session. Strain gauges are used to predict the muscular contractions in non-invasive way to forecast the muscle strain for every shot during sports activity. The designed wearable system includes the integration two strain gauge sensors placed on human arm, along with the temperature and pulse sensor encapsulated into a separate module. The developed system measures the strain, temperature and pulse rate in real time and updates the player with these details instantly. A dedicated user interface is developed so that the player and the coach can review the health details instantly in his mobile or laptop. The prototype is powered with a 10,000 mAh rechargeable battery.

Keywords Wearable device · Biometric data acquisition · Sports training · Strain gauge sensor · Non-invasive

1 Introduction

Sports always play a major role in human life and with the advent of new technology it is gaining importance in recent years. Low cost and miniaturization of devices led embedded system to monitor the sports activities and biometric applications. In [1] sensors are used to monitor the physiological variables such as strain, force, vibration, muscle activity, temperature and heartbeat rate. Monitoring the real time details of a player helps to improve his performance and access his physical parameters instantly as in [2]. Sometimes

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overstrain might lead to injuries to the player. Early signs of injury to soft-tissues are readily detected, letting coaches relieve players before serious problems arise. A muscle contraction sensor was developed to measure muscle contractions in a non-invasive way [3]. It was implemented and tested by analyzing the values in time domain with the actual force developed by the muscle. Connaghan et al. [4] the vital signs of the player such as temperature, heart beat are captured in real time to know the fatigue and endurance of the player during his practice sessions. The wireless communication has enabled wearable devices embedded with sensors and wifi to easily communicate the physiological information to the user via smartphone or his laptop [5].

A wearable system was designed that can detect a particular movement or they support only the fitness metrics like heart rate, calories burnt, etc., but do not provide information on the muscle force that cause strain [6]. But the proposed wearable device measures the arm strain encountered in a particular stroke and also measures the on field body temperature and heart rate of the player during the training sessions. So this would help to understand the mechanics of human movement and motor control. The physiological responses like heart rate, oxygen uptake, respiratory exchange ratio, energy expenditure of batsmen were determined during a simulated One day International century match [7, 8]. The pulse rate variation and blood oxidation content were measured by a wrist wearable device without disturbing the user in any way [9]. Monitoring the physiological parameters like respiration rate and volume changes is possible with low power piezoelectric sensors like resistive strain gauge [10]. These sensors can be combined with Bluetooth units in wearable device and measure the parameters continuously.

A methodology was proposed to measure strain using strain gauge sensor where the data acquisition is done by low cost microcontrollers [11]. The results obtained were satisfactory and was verified by using finite element analysis software. The strain gauges were used to detect muscle contractions and showed a better result compared with electromyography sensors [12]. Continuous excessive strain in ankle joints will lead to tear in ligaments. The strain was measured by applying various degrees of stress to the ankle joint and stated the maximum strain rate [13]. The strain gauge sensors were used to find the muscle contractions, which were directly related to change in length of the sensor during muscle contractions [14].

Based on above related work discussed, this paper focuses on developing a wearable device which measures the strain encountered by a cricket player while playing various strokes during his training session and also measuring other basic parameters like heart beat rate and temperature.

2 System Architecture

The magnitude of vibration on the muscles during various strokes may lead to strain and overload the players. In games such as cricket the delivery speed of the ball is greater than 150 kmph for fast bowling. The batsman has to release a proper shot to encounter the ball coming with such high velocity. There are possibilities for the arm to get strained. Measuring the muscle activity at this point gains importance. A system is proposed to measure the strain, temperature and heart beat rate of a cricket player. From these details the information about the physical state of the player can be derived. Figure 1 shows the design of the proposed system.

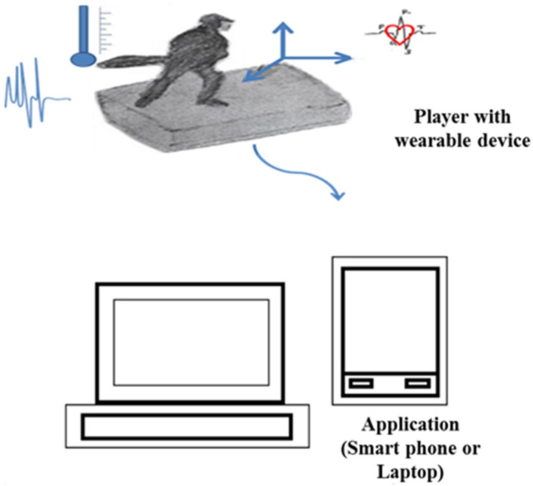


Fig. 1 Architecture of the wearable system for biometric data acquisition

The proposed system consists of three modules: (1) Wearable sensor module for recording strain, temperature and heart beat rate. (2) Processor module and (3) User Interface module to access real time details. All complex process is performed in the processor. The individual modules are presented in detail.

2.1 Hardware Design

The system hardware is designed to measure the player's biometric information. The wearable device is placed on the players gloves to acquire the data. Strain gauge sensors are to be placed on the either side of the elbow for recording muscle contraction while playing various shots.

The heart beat sensor is placed on the fingertip and temperature sensor is placed on the wrist of the player. The sensor placement does not disturb the player's performance. Figure 2 shows the placement of wearable device on the players arm. This data acquisition module operates solely measuring biometric data of the player in real time. The strain gauges which are well known for their accuracy, light weight, flexibility and low sampling frequency are considered a great interest for strain measurements on the human body. Basically the training lasts for 2–4 h, so the module is powered by Lipo rechargeable battery with a specification of 10,000 mAh battery which can lasts for 2 days and it is easily rechargeable so it can be used for prolonged time. Figure 3 depicts the block diagram representation of the proposed wearable device hardware.

The processor employed is a 64 bit RISC ARM cortex A-53 processor. Since the input from the strain sensor is too low it is amplified by HX711 amplifier and is connected to the processor via I2C bus. Also the temperature and pulse sensor is the other input to the processor and they are connected through ADS 1115 an analog to digital converter (ADC). External memory can be connected to the processor. With the inbuilt wifi module data can be transferred to the user form the processor. The strain gauge sensor along with its amplifier, heart rate sensor and temperature sensor are integrated into a separate module to avoid misplacement and can be easily replaced in case of damage. The module is fabricated separately to hold the sensors. Conductive tracks for ADC, amplifier, resistors and interface with the processor are designed and laid out on

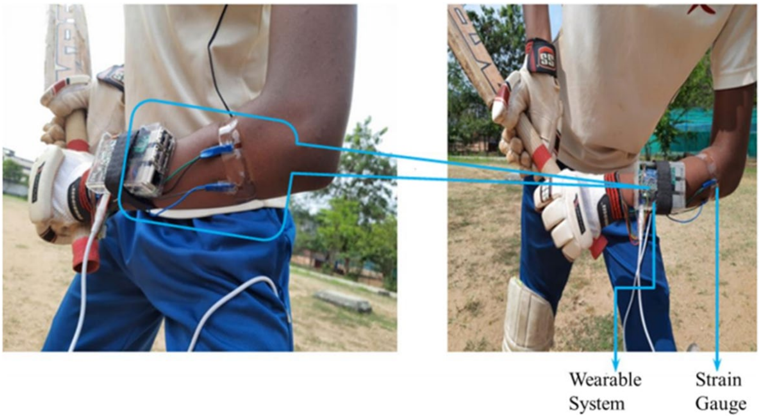
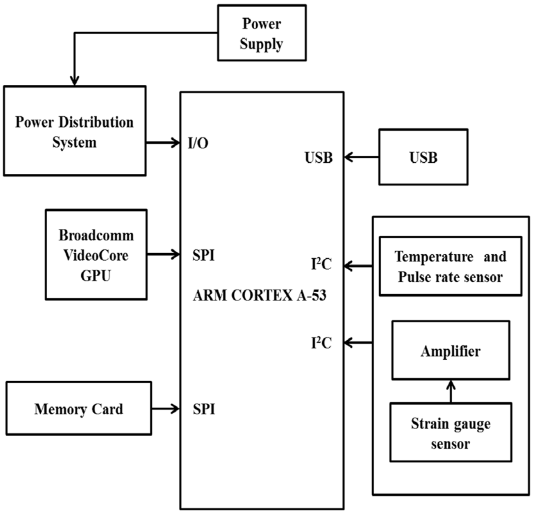


Fig. 2 Biometric data acquisition device position

Fig. 3 Block diagram representation of the proposed wearable device



the printed circuit board. This board is then interfaced with the processor. So the circuit remains undisturbed and the sensors can be replaced easily in case of impairment.

Figures 4 and 5 shows the hardware setup and the fabricated printed circuit board.

3 Biometric Data Acquisition

This section discusses the details regarding acquiring biometric data like strain, temperature and heart beat rate. The performance of the proposed system was tested on cricket players. Figure 6 shows the workflow model.

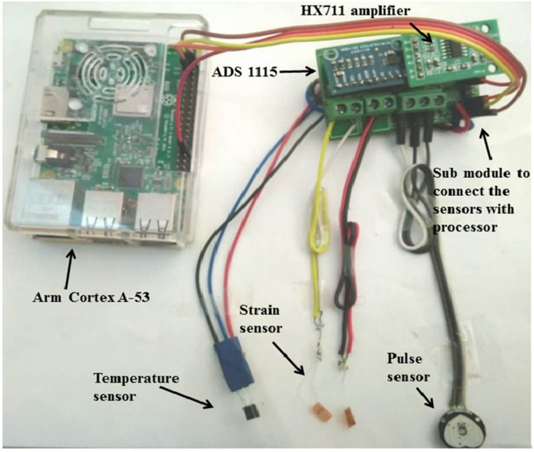


Fig. 4 Hardware setup of the wearable device

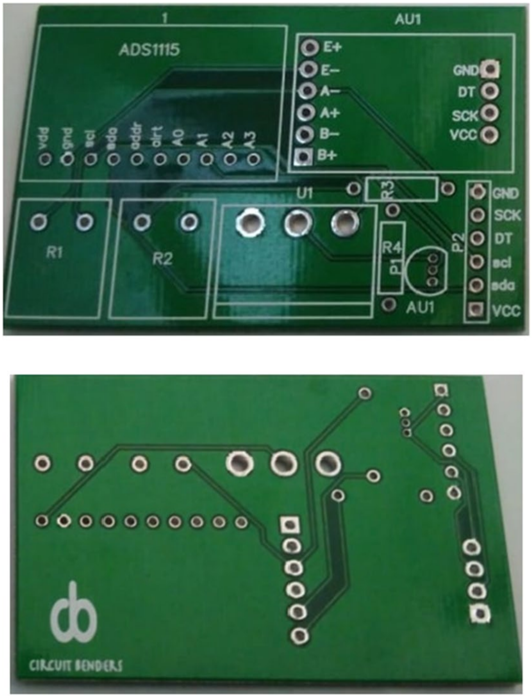


Fig. 5 Submodule -fabricated PCB front and back view

Strain in muscles might happen due to repeated activity in a particular portion of the body. During training sessions due to eagerness and involvement the player might overstrain his muscles without knowing that his body is strained too much.

It is now essential to concentrate on the health aspects of the player during their sports activity. So the system aims to measure the temperature and heart rate of the player. Table 1 gives the characteristics of the wearable prototype system.

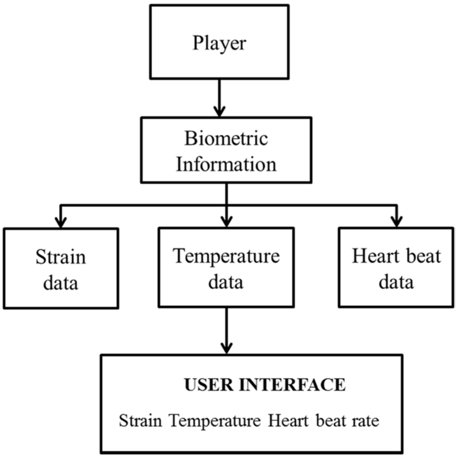


Fig. 6 Work flow model of Bio-metric data acquisition

Table 1 Characteristics of moniotring system

Sensors used	Strain gauge sensor—350Ω, Gauge factor—2 Pulse sensor—+3 V/+5 V Temperature sensor—−55 to 150 °C
Sensed parameter	Strain in arm muscles, Heart beat rate, Body Temperature
Connectivity	Wifi
Dedicated user application	Yes
Real time bio-feedback	Yes
Method	Non-invasive
Battery	Lipo rechargeble battery—10,000mAh
Wearable	Wrist worn
Easy replacement of in case of sensor damage	Yes, a separate hardware for the sensor module

3.1 Strain Measurement

Strain gauge sensor can measure strain in human arm. These low-powered piezo-resistive sensors can be integrated with the processor and Wi-Fi units, and thereby can be useful in monitoring the strain in sports activity, in everyday training sessions. Strain measurements can predict the location of injury and the performance of the safety wear being used by the batsman etc. In this paper, we demonstrate that it is possible to measure strain in arm using a wearable strain sensor placed directly on the arm of the player. Strain in the arm is increased when the elbow was moved into greater degrees of rotation and inversion.

This paper presents a method for measuring strain by using a strain gauge sensor and data acquisition is performed by a low power 64-bit processor with RISC architecture. Figure 7 shows the signal conditioning is done by Wheatstone bridge and discretized by HX711, which is an analog to digital converter (ADC) connected external to the processor. Figure 8 shows the strain for three different cricket shots obtained from the proposed wearable device.

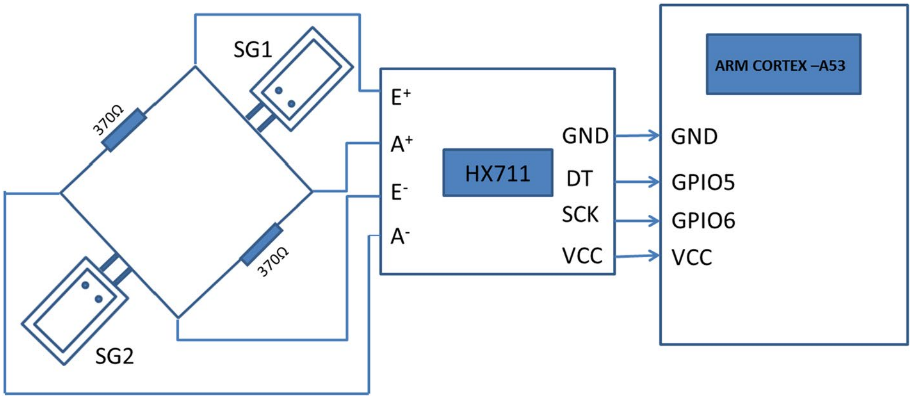


Fig. 7 Interfacing diagram of strain gauge with the processor

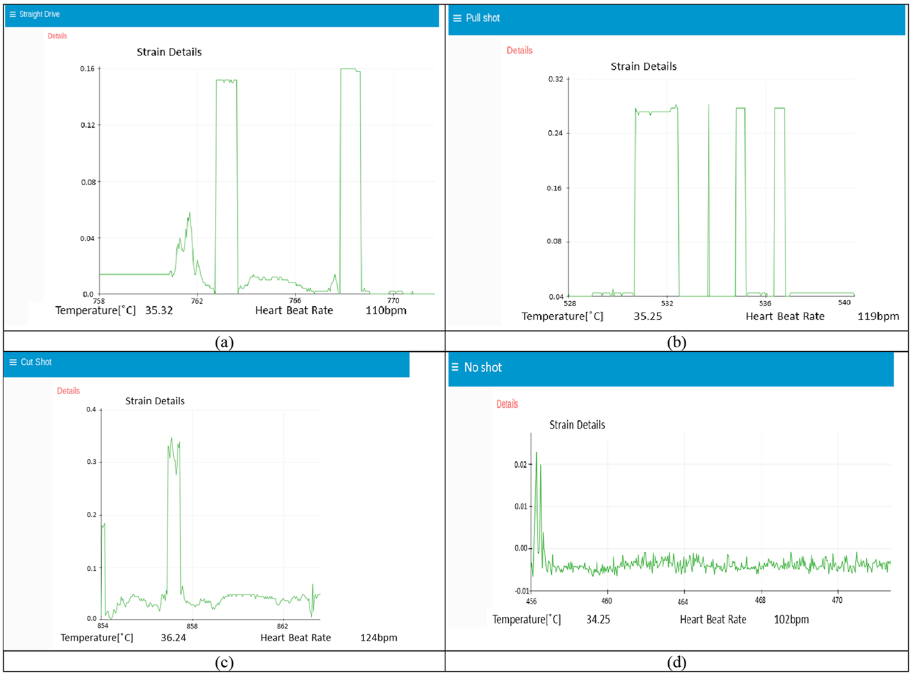


Fig. 8 Strain, temperature and heart beat rate seen in application for **a** straight drive, **b** pull shot, **c** cut shot and **d** no shot respectively

3.2 Heart rate Measurement

The pulse sensor has a light sensor on one side and an amplifier circuit on the other side. The LED on the front side of the sensor is placed on the wrist of the player. The emitted light will fall on the vein directly and the rate of blood flow can be monitored form which the heart beat can be calculated. The analog output form pulse sensor is interfaced

Table 2 Heart beat values of the players

Heart beat rate	Time (s)	Heart beat rate	Time (s)
118	200	120	1000
119	400	118	1200
119	600	112	1400
121	800	114	1600

Table 3 Skin temperature measurements

Skin temperature (°C)	Time (s)	Skin temperature (°C)	Time (s)
35.25	200	36.03	1000
35.42	400	35.52	1200
36.26	600	36.41	1400
36.44	800	36.43	1600

to the processor through ADS1115 ADC module via I2C communication since the processor accepts only digital inputs. Table 2 gives the heart beat rate values of player at different time intervals.

3.3 Temperature Measurement

Skin temperature is important in many research and applied settings and using sensors affixed directly to the skin surface is common for this purpose. LM35 temperature sensor provides a good support for direct skin contact continuous temperature measurement and measures the body temperature (in °C). The scale factor is 0.01 V/°C.

LM35 sensor which is placed on the wrist is connected to the processor through one of the channels of ADS1115 ADC module and the output format is adjusted to get a working thermometer in Celsius. Since continuous temperature output is not necessary, the temperature was recorded for every 10 s. Table 3 gives the temperature changes of a player at various time instances. The main finding of this study is, the skin temperature readings were changing constantly, as batting is performed for extended period. The reasons for such temperature variations are different levels of activity during practice, sweating rate, stress level etc.

4 Results and Discussion

4.1 Software Design

An interface between the system and the user is made and the app is designed using Tkinter and Node-RED supported by python. The strain details along with temperature and heart beat rate of the player is monitored and the updates are given instantly. The recorded data can be accessed both by the player and the coach. Figure 8 shows the strain details of shots like straight drive, pull shot and cut shot in cricket, the temperature and heartbeat of the player in his mobile or laptop.

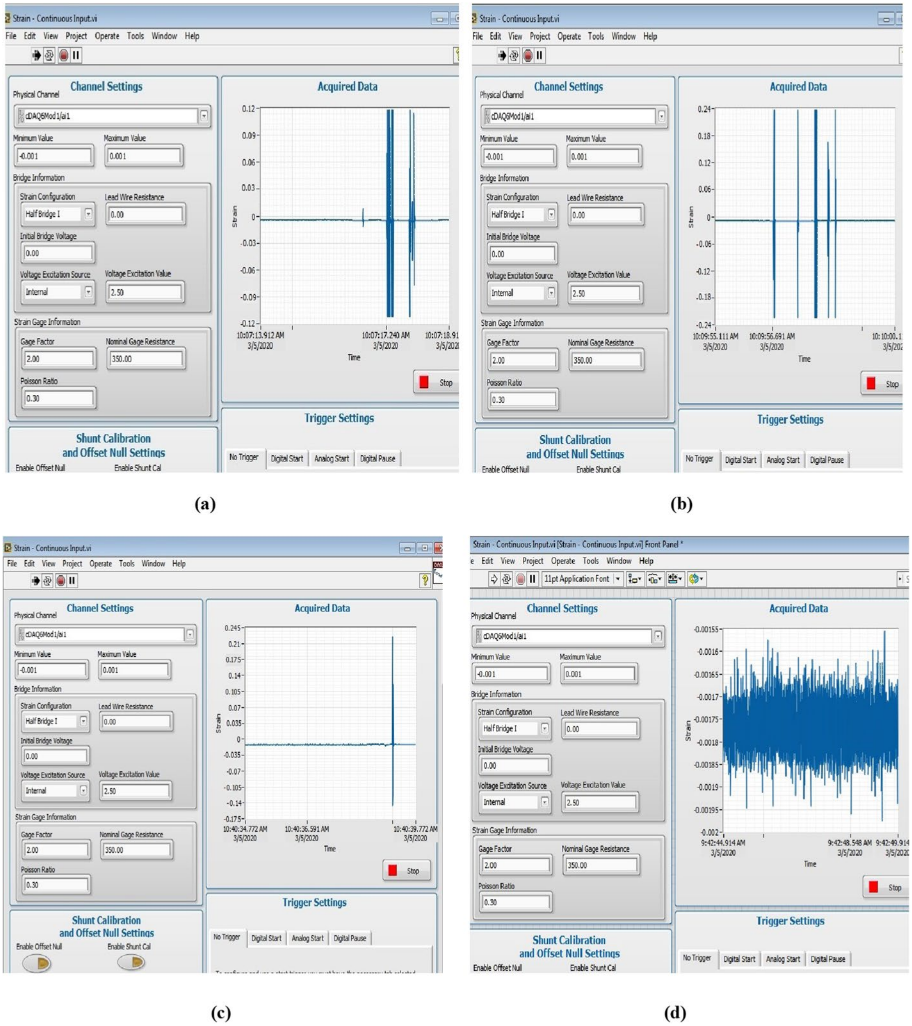


Fig. 9 Strain measurements from data acquisition device **a** Straight drive, **b** Pull shot, **c** Cut shot, **d** Still pose

Table 4 Comparison of strain measurements

Shots	Wearable device	Data acquisition device	Error
Straight drive	0.15	0.12	0.03
Pull shot	0.27	0.24	0.03
Cut shot	0.32	0.2	0.12

Table 5 Comparison of proposed system with other existing systems

References	Sensor	Objective	Physiological parameters	Application(general/sports)	Real time bio-feedback	Dedicated user interface	Result
[15]	Carbon nanotube Strain sensor	To measure the knee flexion and knee extension muscle strength	Muscle strain in knee	Sports	No	No	The torque– angle graph of the CNT sensor may be more informative in knee assessment than that of the dynamometer
[16]	Strain gauge sensor	To develop a wearable bio-instrument for detecting the contractions of subject's biceps muscle	Muslce contractions for the movement	General	Yes	No	Detection of the small skin deformations by strain gauge sensors
Proposed	Strain guage sensor, Pulse and Temperature Sensor	To introduce a wearable device to measure the biometric information of a player during his training session	Strain in the arm muscle while playing, heart beat rate in bpm and body temperature in degree celcius	Sports	Yes	Yes	The wearable prototype acquires the biometric information in a non-invasive manner and with an interactive user interface provides instant updates about the physiological information of the player

4.2 Strain Measurement Accuracy

In order to verify the results obtained using the wearable device, a verification of the same is done using LabVIEW and NI data acquisition devices. For the hardware, the half bridge strain gauge which is placed on the human arm is connected to NI 9236 module that includes the necessary signal conditioning to perform the strain measurement including, applying excitation voltage and completing the half bridge strain gauge. It's then connected to the computer using USB.

Figure 9 shows the strain measurements of the batsman for straight drive, pull shot, cut shot and still pose obtained from NI data acquisition devices. Still pose is recorded when the batsman is not performing any shot. The results obtained from wearable device are in agreement with the results obtained from NI data acquisition devices and demonstrate that the proposed system has satisfactory accuracy.

Table 4 gives the comparison on the performance of the wearable and data acquisition device. It is inferred from the table that the wearable device performs in a better way with a maximum strain error of only 12%. Table 5 shows the comparison of the proposed system with the existing system.

5 Conclusions

A wearable miniature device to find the strain encountered by the player along with measuring heart rate and temperature is developed. The designed wearable prototype acquires the biometric information in a non-invasive manner. The interactive user interface provides instant updates about the physiological information of the player.

With required break and relaxation the player might know when it's time to push for athletic activity. In future intelligent data algorithms can be developed to predict the strain while playing. Extensive collection of input data is required to predict the internal forces generated during dynamic movements. The prototype developed should be realized as a miniaturized commercial market available wearable device. These are challenges which have to be addressed in the upcoming research.

Author Contributions The authors have equal contribution.

Funding No funding received.

Data Availability All data generated or analysed during this study are included in this article itself.

Code Availability No.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Informed Consent Sensors such as strain gauge, temperature and pulse sensor were just placed on the body and it is a total non- invasive placement. The participants were well informed about the sensors.

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Design and Development of a Prototype Shuttlecock Feeder and Evaluation of Various Shot Parameters

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Abstract*—Badminton is one of the most popular racket sports globally, and player training through the feeder machine is important in improving elite player performance. The purpose of this study is to create a prototype shuttlecock feeder machine and evaluate various shot parameters. The machine components were CAD modeled and simulated using Fusion 360 software and 3D printed. The printed spare models are assembled into a shuttlecock feeder machine, which consists of three major components, 1. shuttlecock magazine, 2. shuttlecock loader; and 3. Shuttlecock ejector. The Arduino microcontroller is used to control the speed of the ejector motor, feed the shuttlecock into the ejector through the servo motor. For different shots, the rotating table turns clockwise and anti-clockwise using the servo motor. With this shuttlecock feeder machine, the nine-type trajectory shot has different shot parameters. Finally, the shot parameter data will be used for the development of the artificial Intelligence based feeder machine to compete with elite players to improve performance and for biomechanical analysis.

Keywords—Badminton, Player performance, Shuttlecock feeder machine, shuttlecock trajectory, 3D Printing, Arduino.

I. INTRODUCTION

Racket sports like badminton are quite popular, and competitions are held in the men's, women's, and mixed divisions in singles and doubles [1]. The three primary indicators of performance for professional badminton players are stamina, quick recovery for the following stroke, and reactions to the opponent's strikes. To increase performance, the coach will teach the player in the traditional manner by having them perform different shots and play against various opponents [2]. A feeder machine is now commonly used in sports like tennis, cricket, and others to train elite players [3][4]. In badminton, the sport is played with a shuttlecock with conical shaped feathers stuck in the perimeter of the hemisphere rubber cork. There is a need for some special mechanism to simulate the trajectory of the shuttlecock rather than the ball in the feeder machine firing like a cannon in most of the other sports feeder machines. From the literature, we found that most of the shuttlecock feeder machines are developed in embedded or Bluetooth controlled [5]. The shuttlecock gains momentum through the rotor wheels, which are revolved by the high-speed motors [6][7]. This paper attempts to develop the shuttlecock feeder machine, and to identify the drop location of the different shot trajectory simulations using a feeder machine where this prototype will be used to enable the artificial intelligence computer vision system. This technology will train the elite player to improve their performance and to identify the player's court zone or shot weakness.

II. CAD MODELING AND 3D PRINTING

The shuttlecock feeder machine is constructed of three primary components: 1. shuttlecock magazine, 2. shuttlecock loader, and 3. shuttlecock ejector. The shuttlecock magazine is a clear hollow cylinder made of plastic that connects to the bottom of the loader and is used to load the feather. After pulling the shuttlecock from the ejector, the shuttlecock loader will have a continuous servo motor in the vertical bar that spins to bring the shuttlecock down to the ejector one at a time. The shuttlecock will be moved between the high-speed rotating motor coupled with the wheel by the trigger on the loader. The motor speed control interfaces with the Arduino microcontroller and controls its speed using the PWM (pulse width modulation) concept. and its duty cycle is varied from minimum to maximum. The motor wheel will provide the shuttlecock with momentum to change its trajectory. [8].

The base support of the feeder machine is constructed with wooden blocks and panels. The circular wooden panel is supported in the 180^0 rotating pins and controlled by the 15kg servo motor through the vertical shaft. The circular panel is supported with a two high speed motors which is connected to the 3D printed wheel and 3D printed trigger between the wheel will push the shuttlecock to fire shots between the rotating wheel. Behind the motor set up the aluminium frame column is fixed to support the horizontal 3D printed rotating loader. Above the loader, the magazine is 3D printed with a bottom exit and the top surmounted with transparent plastic foil. Refer the assembled model of the shuttlecock prototype in the Figure 1. Shuttlecock Feeder machine. [9-13]

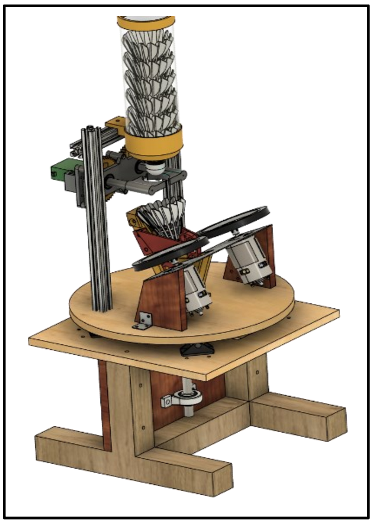


Fig1. (a). CAD Model [9]

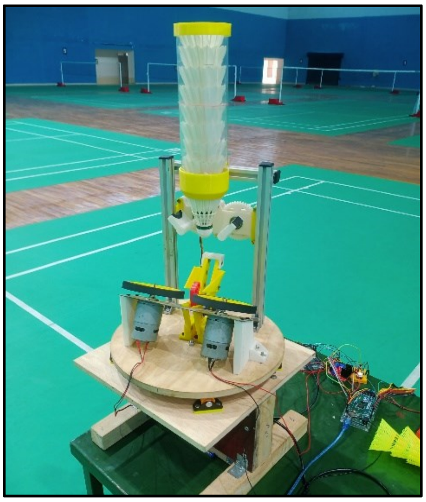


Fig 1. (b). Prototype Model

III. TRAJECTORY EXPERIMENT SET UP

The Shuttlecock feeder machine is mounted on the stand, at 1.10 m height and 1.30 m distance from the net (Figure 2). The shuttlecock feeder machine servos and the high speed motors are controlled by the Arduino microcontroller. The code is embedded with a button to control the motor and servos to identify the timing, necessary motor speed, and angle of ejection for different shots [14]. The court is divided into nine zones with three shots, a drop, offense, and defense in left, right, and center, as shown in Figure 3 [15]. Two high speed cameras are used to record the experiment, camera 1 records the trajectory of the shuttlecock, and camera 2 records the drop location of the shuttlecock in the court. In DARTFISH Live S software, Notational analysis is used to locate the two co-ordinates of the feeder machine and shuttlecock in different locations under various shot conditions for feather and plastic shuttlecocks (Figure 4) [16]. To determine the average drop position and beginning shuttlecock speed from the feeder machine in each of the nine situations, a total of 12 trial shots are simulated. [18][19].

Distance co-ordinate between two points,

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

$$D_{average} = [\frac{d_1 + d_2 + d_3 + \cdots \ldots\ldots\ldots + d_{12}}{12}]$$

where,

D = Distance between the feeder machine and shuttlecock drop location

x_1, y_1 = Feeder machine coordinates

x_2, y_2 = Drop location coordinates

$D_{average}$ = Mean or average distance between the feeder machine and shuttlecock drop location.

d_n = No of Trial shots

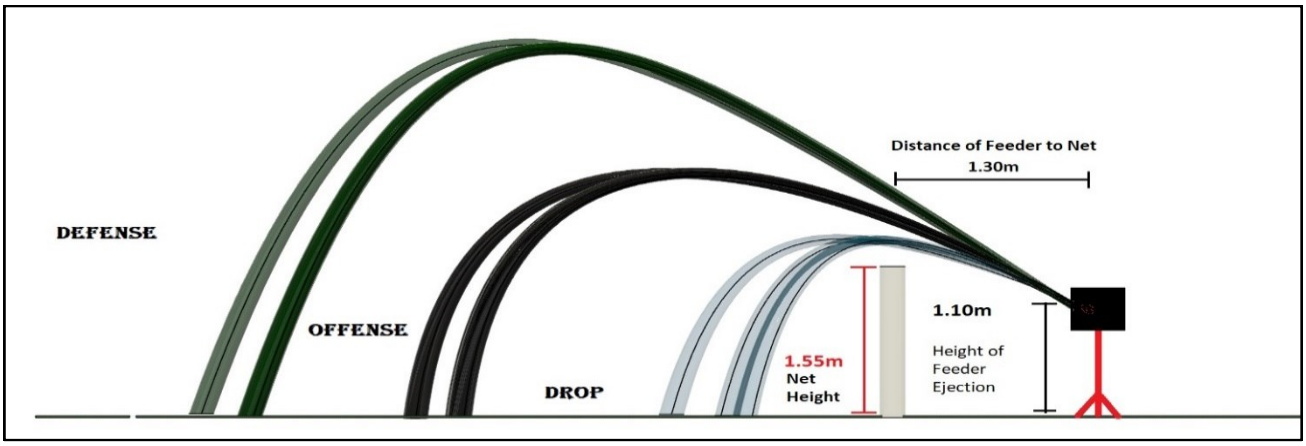
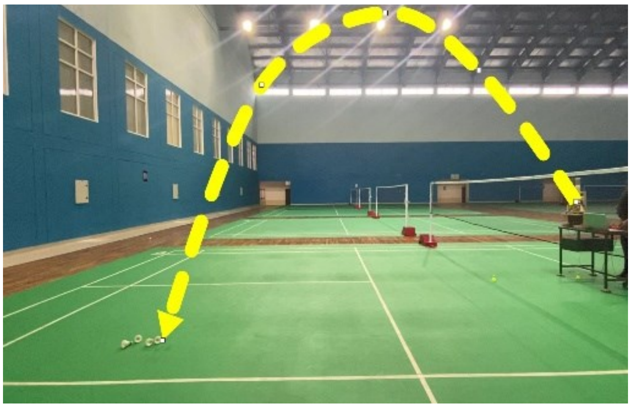


Fig 2. Schematic representation of experimental setup [9]



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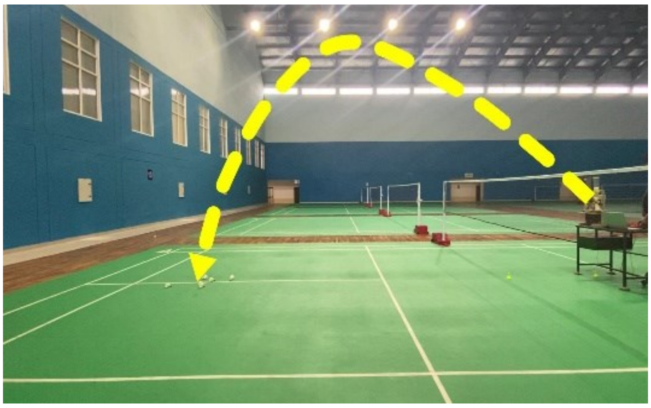

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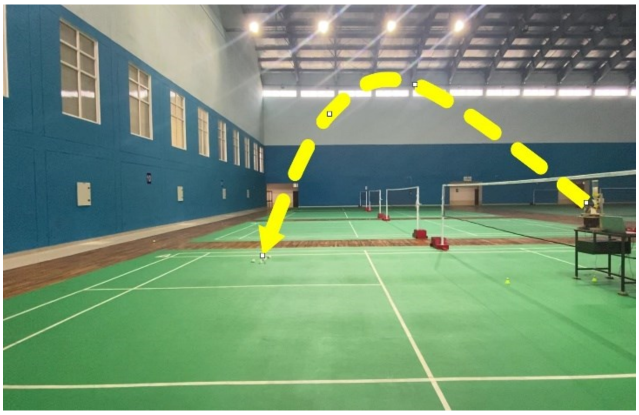

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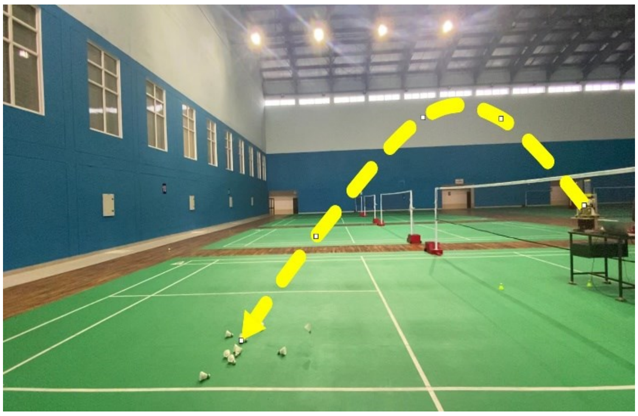

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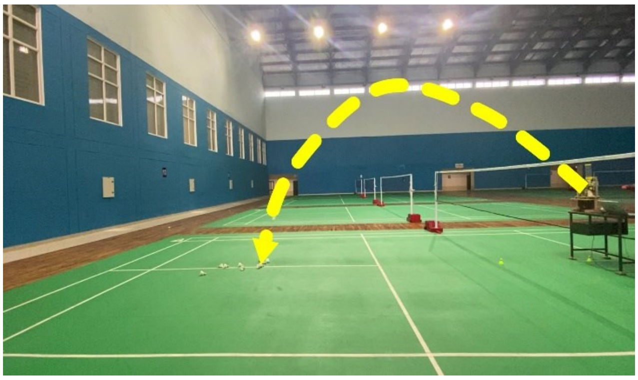

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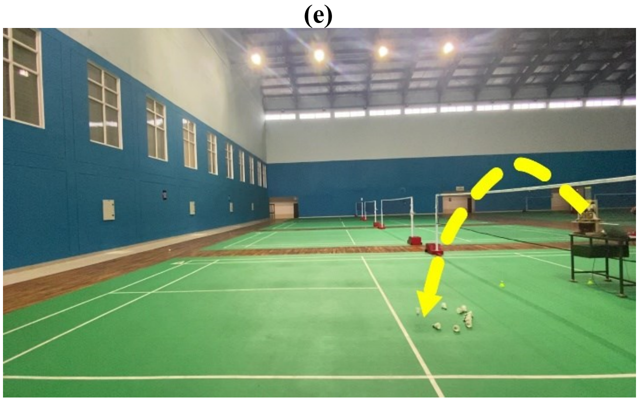
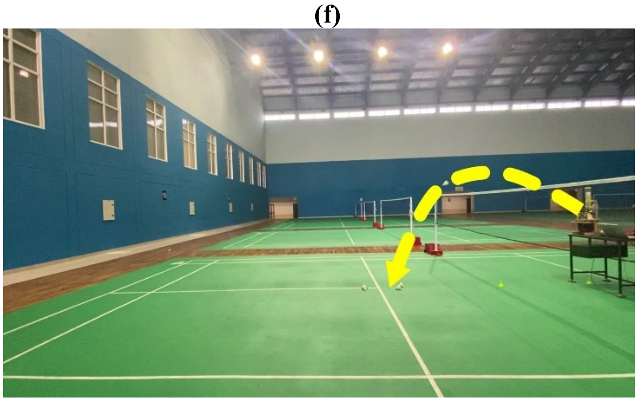


(g)



(h)

(i)

Fig 3. Shuttlecock trajectory from the shuttlecock feeder in various conditions (a). Left Defense (b). Center Defense (c). Right Defense (d). Left Offense (e). Center Offense (f). Right Offense (g). Left Drop (h). Center Drop (i). Right Drop. [16][17]

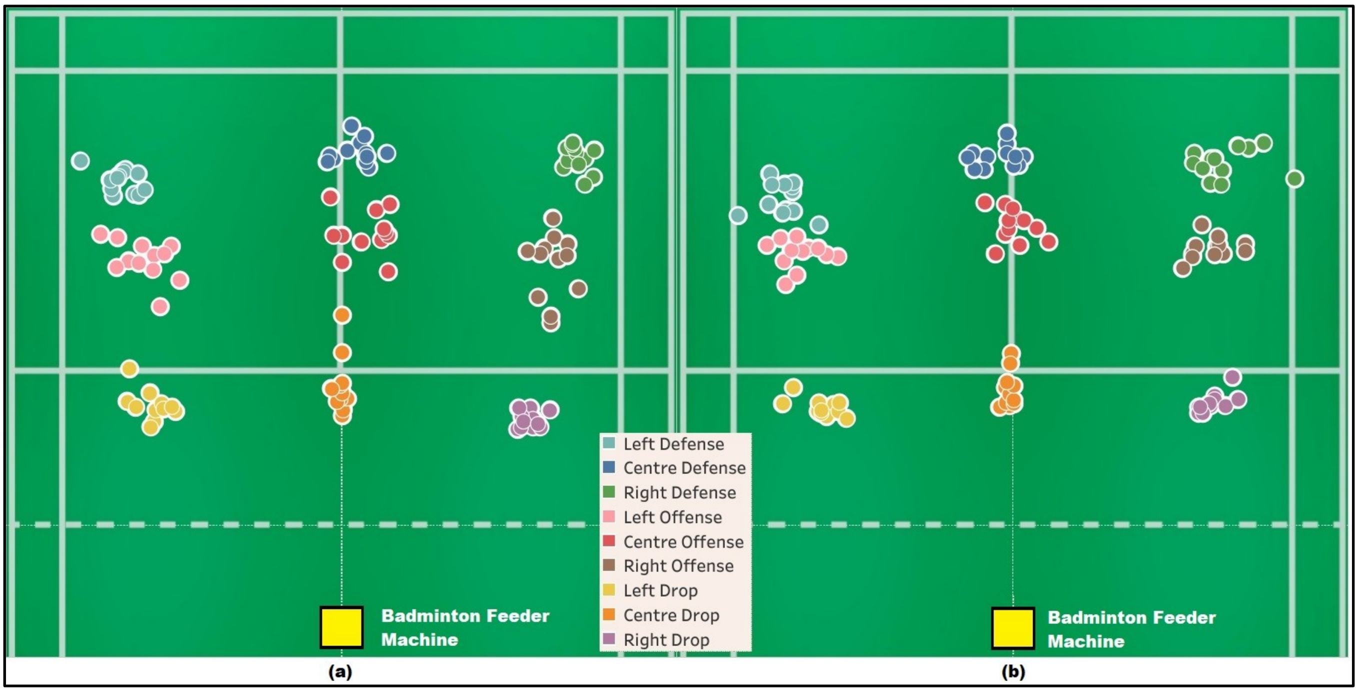


Fig 4: - Drop location of the map zone for various badminton shots (a). Feather Shuttlecock (b). Plastic Shuttlecock. [20]

IV. Results and Conclusion

TABLE 1 Evaluation of Various Shots Parameters

Shot Type	Motor speed in %	Average initial speed of shuttlecock (m/s)	Average Distance Between the Feeder Machine and Drop Location (m)	
			Feather Shuttlecock	Plastic Shuttlecock
Center Defense	100%	10.11 m/s	6.15	6.08
Left Defense			6.06	5.82
Right Defense			6.43	6.31
Center Offense	50 %	6.03 m/s	5.11	5.2
Left Offense			5.07	5.2
Right Defense			5.05	5.22
Center Drop	30%	3.35 m/s	3.11	3.06
Left Drop			3.33	3.32
Right Drop			3.18	3.43

The drop location for different badminton shot coordinates is obtained from the DARTFISH (figure 3), which is interpolated with a tableau. There is no huge significance in the change in the motor speed for both a feather and plastic shuttlecock. The defense shot average distance varies from 6.15m to 6.47m for the feather shuttlecock and 6.08m to 6.31m for the plastic shuttlecock. The offense shot average distance varies from 5.05m to 5.11m for the feather shuttlecock and 5.2m for the plastic shuttlecock. The Drop shot average distance varies from 3.11m to 3.33m for the feather shuttlecock and 3.06m to 3.43m for the plastic shuttlecock. The motor speed for the defense is 100%, the offense is 50% and the drop is 30%

Table.1 have the detail of the motor speed, Average initial speed of shuttlecock and average distance of the drop location for both a feather shuttlecock and a plastic shuttlecock. The distance from the shuttlecock drops location to the feeder machine is calculated from equation 1 and the average is taken from the 12 simulated trajectories for the various badminton shots for both feather and plastic shuttlecock. The average initial speed of the shuttlecock in the defense shot is 10.11 m/s, offense shot is 6.03 m/s and drop shot is 3.35 m/s.

This machine data will be used for Artificial Intelligence (AI) based shuttlecock feeder machine database to simulate the different badminton trajectories depending on the location of the player and challenge level for both feather and plastic shuttlecock. This work will be foundational and importance for the AI shuttlecock feeder machine.

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Validity and Reliability Analysis on Video-based Self-learning of Yoga in Children

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Abstract. *The ongoing pandemic situation has affected almost everyone in some way. Particularly, children were very much affected mentally and physically due to continuous lockdowns imposed in several countries. Furthermore, they are in a position to sacrifice their useful period of learning new things from school or skill development centers or both. However, with the rising availability of an enormous number of educational videos on video-based websites like YouTube, it seems self-learning of new skills is not a big problem anymore. To examine the validity and reliability of one such assertion, five popular yoga training videos from YouTube were taken and experimented with children to test the possibility of self-learning of yoga. Two-dimensional video analysis of virtual yoga instructors and children from two different age groups practicing yoga poses were executed by using advanced smartphone cameras and video analysis software tool kinovea. The extracted key-frame images were subjected to semi-automated annotations of various angles between the body parts of the instructors and the participants. And mathematical modeling was used through comparison of angle measurements with statistical MAE (Mean Absolute Error) calculation of angle variations, differences in annotated body shape features, side-by-side time/frame rate measurements, and minor errors identification to conclude that self-learning of yoga is only partly valid and is less reliable for children.*

INTRODUCTION

The necessity of learning new skills has increased in this pandemic situation. Parents and school teachers are concerned about the new skill learning need of children and so advise them to involve in skill-developing extracurricular activities. Yoga is a unique activity in improving a child's physical strength and mental health. Practicing yoga has spread all over the world [1]. The very purpose of yoga is to reach a unified state of consciousness through a balanced mind and body [9]. The growing tension and stress of the daily life of an adult are becoming a major problem nowadays [6]. Children of this generation may experience the same in the future ahead. Yoga can self-regulate the practitioner and is an important factor in characterizing one's success throughout their life [10]. Various other health benefits are improved musculoskeletal health condition, development in motor skills, physiological improvement, cardiopulmonary, respiratory benefits, etc., [5]. In recent times, preferences are given to practice yoga at home rather than going to the gym because yoga falls under lightweight exercises that do not require any equipment for practicing. Smooth movement with changing angles of different body parts is a part of it [4].

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There were eight different multiple intelligence capabilities found commonly in humans. Bodily-kinesthetic is one among them. To test kinesthetic performance, usually, a posed picture is shown to the subject under study and will be asked to remain in shown pose for 20 seconds. Then experts will analyze the poses. But understanding the pose from a photo is very difficult for young children [7]. Practicing yoga seems to be easy; but practicing on your own, on regular basis is a difficult task [9]. Spending additional time to practice yoga or exercise on their own than the actual training time is essential. But one must see how far it is good to practice without a teacher/trainer nearby. Without a trainer, the learner would not evolve fully [11]. A yoga teacher is integral part of yoga learning because the teacher uses physical touch adjustments, verbal cues, or even offers direct immediate demonstrations to provide a better teaching-learning process [8].

The experience and standard of self-learning should match that of conventional learning [1]. Assessing the physical activity of yoga or exercise is very important as it is directly related to health [3]. Despite the multiple benefits that yoga can give to people, injuries related to yoga practice have been reported by many western media [2]. Poor postures of yoga poses may harm ligaments, muscles [11], bones, and joints of different body parts [4]. So quantifying yoga is important and can be used to create a universal model for yoga [3]. There are other methods available to evaluate the execution of yoga poses such as simulators, sensors, etc., [1]. Video proves to be a very good medium for synchronous yoga and meditation by seeing and hearing the partners who are in a far distant place [8]. The curiosity to know how the children self-learn anything from videos resulted in carrying out this work. The previous works considered so far have not considered home-based self-learning of yoga and analysis through videos available in web. Angular measurements using semi-automated annotations, timing of execution of yoga poses while transition from one pose to the other, body shape feature annotations from the images were analyzed in this work.

RELATED WORKS

Many works found in literature extensively analyzing the different forms of self-learning of yoga in children and adults using video/image processing and analysis. This section summarizes them in brief. A yoga assessment method was proposed by [1] to detect the different poses for self-learning purposes. Multiple body parts are detected using a simple computer web camera. Angle variation between the instructor and the practitioners was calculated using this system and corrective action was taken from the observed differences. They provided performance range regions to classify the performance from perfect to bad. Different age group practitioners were analyzed by computer vision methods and used open pose detection and estimation method.

Video feedback and video self-evaluation procedure are proposed by [2] to improve the yoga pose accuracy. They used several rating methods and questionnaires for support. The intervention effects were analyzed using multiple baselines. Task analysis was performed by the yoga instructor for the score-related information. The physical activities involved in yoga using the content analysis method were described in [3] and a comparison of three different video categories related to yoga was analyzed. They identified the pose, rate of a pose, and different categories of poses that vary from style to style.

A mobile app was developed by [4] for yoga training through video chat. Detection models were introduced using human key points for training assistance during yoga practice. Pose skeletons are used to estimate the illegal yoga poses and vocal instructions and feedback were given for corrective action. Similarly, [6] created a mobile app to study meditation practices. Wearable sensors, a smartphone camera, computer vision, and pattern recognition along with competence management are used to perform the objective assessment of yogic meditation.

Microsoft Kinect is used by [5] to find different yoga poses and their accuracy to help practice yoga. Yoga pose analysis of children was performed by [7] using Microsoft Kinect along with a robot. Authors of [8] introduced online chat-based meditation and yoga sessions for participants living in different parts. The proposal of [9] focused on home-based yoga learning with assisting technology. Biofeedback and the respiration detection method are proposed for yoga breathing exercises. The researchers of [10] proposed a qualitative exploratory research method in revealing the embodied experiences of children in a classroom coaching for 8 weeks. A self-learning system using a computer was introduced by [11] and the system rectifies poor yoga poses thereby preventing injury.

EXPERIMENTAL SETUP

This section details the used methodology, the samples considered, the hardware and software tools used, the measurements involved, and the procedure followed in this study.

Methodology

Video analysis was carried out with a TV, Front view, and side view camera setup as shown in Figure 1. The video of instructors was played on the TV. The participants were allowed to face the TV to clearly see the instructor performing. Every day, the play-pause-perform-play cyclic method is used to show each yoga pose one by one and children performed all poses. Continuous recordings were made for the whole duration of the study. None helped children nor gave any time-to-time instructions/comments on their performance. The semi-automated annotations [18] were used using a software tool.

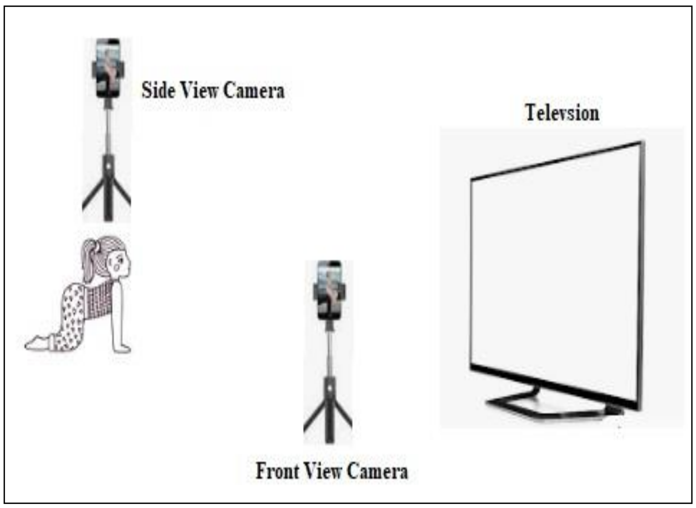


FIGURE 1. Proposed Experimental Setup

Samples and Duration

The analysis was executed on children from two age groups and differing gender. The first child is a 7-year-old male, and the second child is a 13-year-old female. These children have not been involved in any yoga training activities before, and they were new to this skill set. Upon getting willingness from them and consent from their parents, they were allowed to participate. They are inspected for ten consecutive days with one session on each day performing all the yoga poses considered in this study. This duration of inquiry is required for children to get involved with the skills via video and for this work to discover the consistency in performance and error rate day by day.

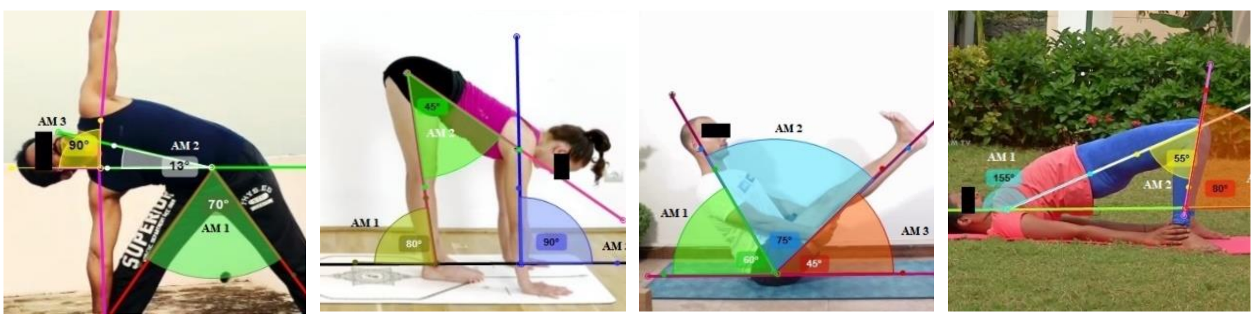
Yoga Poses and Angle Measurements

For the motive of experimentation, different yoga poses from five popular instructional videos on YouTube was taken. Considering the children's age, only simple and moderate difficulty level poses are taken. The videos are trimmed, avoiding unnecessary portions, and then merged to form an overall video duration of 2 minutes and 15 seconds. The videos are arranged in an order such that each was played without any in between breaks. Table.1 shows six yoga poses from four different categories that are adapted for the study.

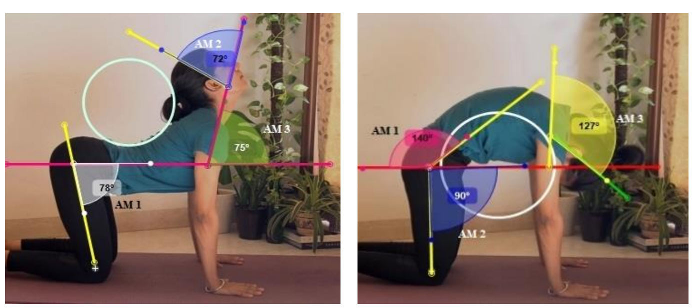
TABLE 1. Yoga Asanas/Poses Considered in the Study

Asana/Pose Category	Asana/Pose Names	
	Name in Sanskrit	Name in English
Standing	Trikonasana	Triangle pose
	Ardha Uttanasana	Standing half forward bend pose
Sitting	Navasana	Boat pose
Lying Down	Setu Bandha Sarvangasana	Bridge pose
Kneeling	Bitilasana	Cow pose
	Bidalasana	Cat pose

The extracted keyframes from the instructors' videos are subjected to angle measurements using kinovea. Each pose is designated with three angles marked as AM (Angle Measurement) AM 1, AM 2, and AM 3. Figure 2. (a) to (d) shows the six different yoga poses of instructors from various categories and their respective angle measurements. To study the body shape features, annotations are shown particularly in Figure 2. (d). The angles are taken arbitrarily between any two body part joints, neck, shoulder, and middle of the head. It is unnecessary to calibrate lengths of body parts to perform the required angle measurements and it has no significance as for as the analysis is concerned. The angle measurements are accurate as the orthogonality of cameras is always preserved from the children's position.



a. Standing Poses b. Sitting Pose c. Lying Pose



d. Kneeling Poses

FIGURE 2. Various Categories of Instructor Yoga Poses with Annotations of Angle Measurements

Equipment and Tools Used

The two advanced smartphone cameras used are Infinix hot 8, a triple rear 13 MP AI camera equipped with a depth sensor for capturing the front view, and Lenovo K8, a 13 MP rear camera for capturing the side view of the poses. To analyze the performance, kinovea freeware version 0.8.15 was chosen. There were many instances kinovea proved to be a great alternative to costlier analysis systems. Kinovea is simple, yet powerful low-cost, open-source two-dimensional video/motion analysis software in measuring kinematic parameters. The authenticity of kinovea is tested in [12][13] comparable with that of AutoCAD and proved to provide accurate measurements on different distances and angle ranges.

In [14], the Smartphone-kinovea combination was used to perform analysis on jumping height. High-end laboratory-based motion analysis is used to examine the accuracy of kinovea and it proved to be valid and reliable. Gait analysis of healthy subjects was analyzed using a 3D motion system and kinovea. Measurements using kinovea demonstrated to be good [15]. The reliability and validity of a high-speed Smartphone camera-kinovea pair used to measure parameters related to velocity-based training were investigated by [16] and concluded that this combination can be used as a low-cost counterpart for measuring such parameters. The knee joint movement was extensively studied by integrating HD video camera and kinovea combination against the use of a costlier motion analysis method. The drop jump movement analysis using this combination proved to be the best option. [17]. A kinovea-based performance study was made by [19] for elite men's high jump athletes through annotations of body shape features and angle measurements of the body with respect to ground and between their body parts.

Procedure

The recordings of the participants were deployed in kinovea to extract the keyframes and perform angle measurements. Some sample angle measurements of participants were shown in Figure 3. Thus, a dataset was created for 10 days having 120 (10 days * 6 Poses * 2 children) keyframes with 360 (120 frames * 3 AMs) angle measurements. A typical single day (Day 1) angle measurement made is shown in Table. 2 for reference.

FIGURE 3. Sample Angle Measurements of Participants From Different Days of Study

TABLE 2. Angle Measurements of a Single Day

Day 1 Angle Measurements				
Asana/Pose Name	**Measurement Notation**	**Instructor**	**Child 1 (7Yr M)**	**Child 2 (13Yr F)**
Triangle Pose	AM 1	70°	68°	53°
	AM 2	13°	0°	9°
	AM 3	90°	119°	95°
Standing Half forward bend pose	AM 1	80°	99°	94°
	AM 2	45°	52°	53°
	AM 3	90°	94°	93°
Boat Pose	AM 1	60°	29°	44°
	AM 2	75°	100°	81°
	AM 3	45°	51°	55°
Bridge pose	AM 1	155°	153°	148°
	AM 2	55°	48°	50°
	AM 3	80°	76°	78°
Cow pose	AM 1	78°	78°	80°
	AM 2	72°	53°	79°
	AM 3	75°	85°	71°
Cat pose	AM 1	140°	160°	139°
	AM 2	90°	83°	68°
	AM 3	127°	144°	119°

Statistical analysis was performed with the available data by calculating the magnitude (absolute value) of the observed angle error of both children compared with that of the instructors. Then, calculations of the MAE of both children were made for each day. Finally, the total MAE of individual children for all six yoga poses for each day was estimated. This estimate gave the idea about the error rate, mistakes committed, and indirectly, their performance level on each yoga pose every day. Considering that angle measurements alone are insufficient, the frame rate comparison of one instructor video was deeply analyzed. This single video showed two poses: cow and cat. The instructor took some time to do the pose transition from cow to cat in a particular frame rate or time duration. The aim is to find the cognitive level of children in perceiving timing details of a yoga pose activity from videos. The videos of the instructor and children are run side-by-side in the two-playback screen feature available in kinovea. The work area is selected such that, both the instructor and children started doing the pose simultaneously. The portion of the pose transition of the instructor from the whole video and the pose transition recordings of participants were compared as shown in Figure 4.

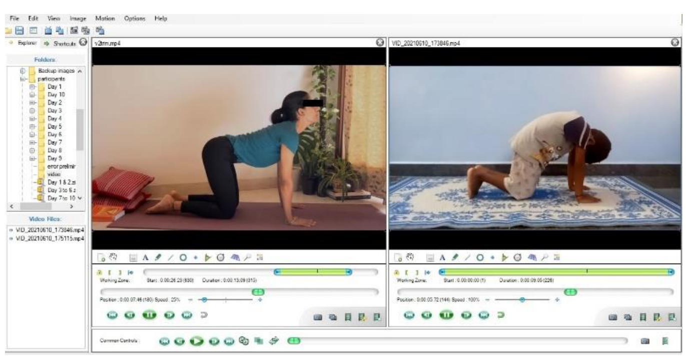


FIGURE 4. Pose Transition Duration Measurement

Finally, some important minor variations in the poses of children compared to the instructor and even among themselves were noted, while executing the poses. These differences could be so vital in deciding the reliability of the self-learning of yoga. In addition, two yoga poses with distinct shape features were compared and are very significant. The convex and concave shape variations on the back of the instructor for cow and cat pose are observed. This feature is compared with the back portions of participants.

RESULTS AND DISCUSSION

This section presents the results gathered from the analysis and interprets them. Firstly, for the determination of angle variations, the MAE magnitudes of all angles of both children for all the yoga poses were noted daily. For simplicity, the first, middle, and end day measurements and their MAE of angles for all the yoga poses are shown in Figure 5. The video-based angle analysis indicated that the error is high and fluctuates initially and then starts to decrease day by day. This decrease in angle error and thus the performance improvement can be noted. The errors show that the children took some time to conceive the video content and the nature of yoga pose instructions given. Once they are familiar with the video instructor's guidance and poses, they start to perform with a lesser error every following day. And the learning ability of the elder child is mostly better than the younger child.

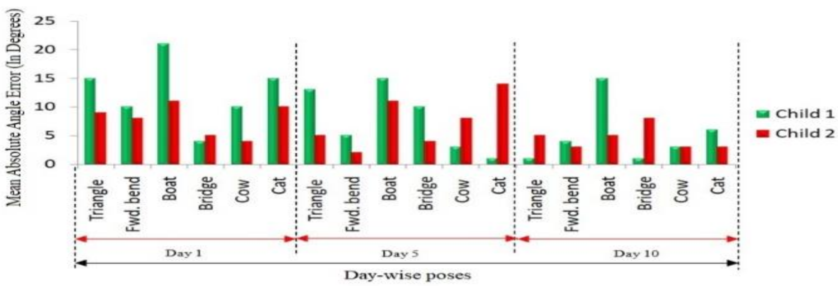


FIGURE 5. Day-wise Poses Versus MAE of Angles

Table. 3 shows the total MAE of all poses for all days. The values are plotted, and day by day angle error graph was obtained as shown in Figure 6. The initial fluctuation in values indicates their understanding ability in due course of time. In the later stages of analysis, the error starts to reduce but is not negligible enough to consider that they are fully successful in executing the poses perfectly.

TABLE 3. Total Mean Absolute Angle Errors for All Poses Together

Days of Study	Total Mean Absolute Error of Angles	
	Child 1	Child 2
Day 1	75°	47°
Day 2	46°	51°
Day 3	54°	59°
Day 4	53°	41°
Day 5	47°	44°
Day 6	55°	48°
Day 7	38°	38°
Day 8	38°	36°
Day 9	36°	30°
Day 10	30°	27°

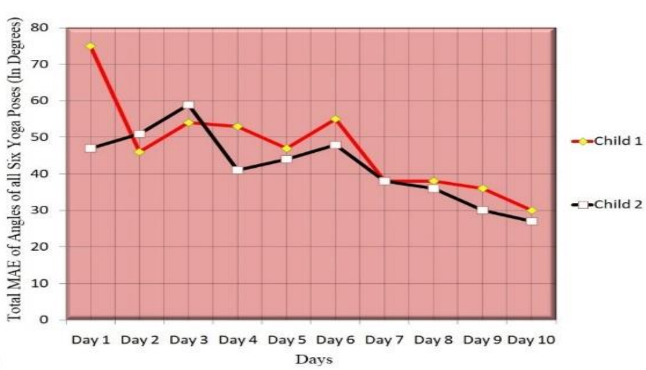


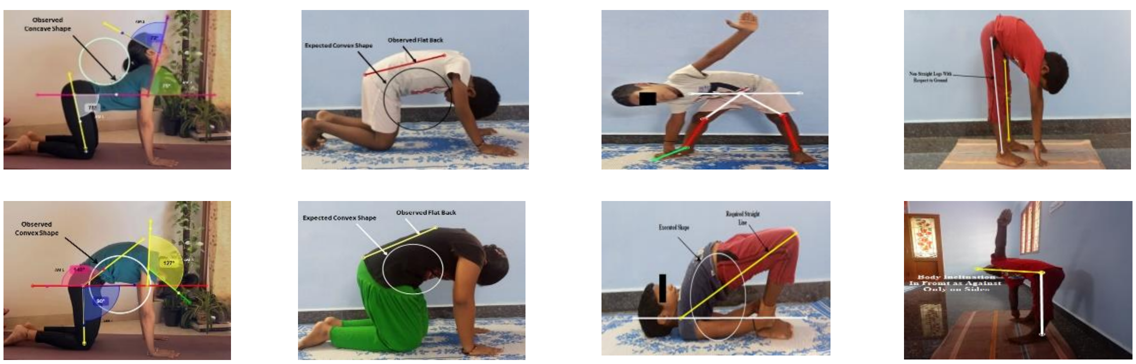
FIGURE 6. Day-wise Total Angle Errors of All Poses

Secondly, the findings from a side-by-side comparison gave the timing error committed by participants. Table. 4 shows the frame numbers and corresponding timing of the pose transition period on Day 10. Both children were unable to follow the exact timing followed by the instructor even after 9 days of practice. The instructor is slow in changing the pose, whereas the children do it quickly.

TABLE 4. Pose Transition Timing Data Comparison

Performer	Cow to Cat Pose Transition	
	No. of Frames	**Duration (in Sec)**
Instructor	315	13.09
Child 1	226	9.05
Child 2	198	9.25

Thirdly, the extraction of some keyframes during video analysis gave the minor, but crucial errors that are non-observable by bare vision, which decides the reliability of the self-learning process without the presence of a trainer/coacher nearby or a proper feedback system. These errors include non-straight lines of legs and toes, bending knee points, tilting body in front as against expected bending only on sides (observed from side view camera), unable to stand firm with combined legs closure together, etc., Furthermore, the shape features gave more insight into some yoga poses. For example, the cow and cat pose require a sharp curve on the lower back. The cow pose requires the back to be in a concave shape and similarly, the cat pose requires the back to be in convex shape when observed from outside and these shape features are missed by the children during the performance. The identified errors are annotated and shown in Figure 7 (a) and (b).



(a) Comparison of Body Features with Instructor

(b) Non-Straight Line Body parts of Participants

FIGURE 7. Cat-Cow Pose Performance Comparison and Errors Committed by Participants

Lastly, observation was made on different yoga poses performed by children have different error occurrences. The pose-wise average error for a single day was listed in Table. 5. From the table, it is clear that the boat pose is the most difficult yoga posture for both children. Likewise, Triangle and cat pose shows moderate difficulty level.

TABLE 5. Pose-wise Average Error

Pose Name	Pose-wise Average Angle Error on Each Day (In Degrees)	
	Child 1	**Child 2**
Triangle pose	7.7	9
Standing half forward bend pose	5.1	3.9
Boat pose	14.6	10.3
Bridge pose	6.3	5.6
Cow pose	4.9	5
Cat pose	8.6	8.3

Self-learning practiced without proper guidance and care while selecting the type of minute-detailed yoga poses for children may lead to possible injury and pain. Selection of yoga training videos suited for adults to children will be inappropriate due to the skill level and possibility of maximum error. Also, the different age groups of children understand every yoga poses differently. The instructor audio explains the benefits of doing a particular yoga pose while posing, and this does not allow the children to follow the actual pose duration, leading to timing errors. Parents or a mentor must ensure their presence during self-learning to monitor and minimize all the errors indicated in this study. Care must be taken in the prevention of even the smallest errors as children's ignorance may lead to irreversible problems.

CONCLUSION

In this study, the two-dimensional video analysis was performed on six different yoga poses of two children for several practice sessions using the video analysis tool kinovea along with statistical analysis to test the validity and reliability of self-learning of yoga from public videos available on the web. Many features of the analysis tool were used to completely study the performance of children as compared to that of the virtual instructors. The results show the difficulty in children to follow all details from the yoga training videos during the self-learning process and commit consistent mistakes in angles between different body parts, missing body shape features, timing imperfections, and other minor faults. Though there is a sign of progressive improvement in the skill level day by day, the errors outperform the improvement in skill level. So, this work concludes that the self-learning of yoga is only partly valid for children because of visible skill improvement day by day, but less reliable considering all the problems associated with it and the safety concerns of children. Smartphone cameras were used for capturing and assessed only a small number of samples and can be regarded as a pilot study. In the future, a similar kind of large-scale systematic study with advanced high-speed cameras or motion analysis systems will be considered. Furthermore, this work can be extended to other sports/games as well to understand the self-learning ability in children.

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Original Article

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Multi-sensor fusion based optimized deep convolutional neural network for boxing punch activity recognition

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Abstract

Recent advancements in deep learning have significantly enhanced the recognition of player activities in sports by enabling automatic feature extraction. In our proposed work, we focus on recognizing six distinct punches in the context of boxing. We incorporate the sliding window technique during the pre-processing stage to transform the time-series data obtained from Inertial Measurement Unit (IMU) sensors in a boxing punch activity recognition system. Our approach influences a sensor fusion-based Deep Convolutional Neural Network (DCNN) classification model to identify various boxing punches accurately, achieving an impressive *F*1 score. The system demonstrates proficiency in distinguishing similar activities, such as jab and hook punches where the existing systems made misclassifications due to subtle variations in arm flexion that differentiate the two. Through experimentation, we identify an optimal window size for boxing punch activity recognition, which falls within the range of 15–20 frames (equivalent to 0.15–0.25 s). This window size selection results in a notable reduction in inference time. To evaluate our proposed model, we conduct comparisons with a standard DCNN and an optimized DCNN model. Our proposed optimized DCNN model demonstrates enhanced recognition accuracy, achieving an impressive 99%, coupled with an improved *F*1 score of 87%. Furthermore, the model displays a remarkable reduction in inference time, clocking in at less than 1 ms. Overall, our research contributes to the field of sports-related player activity recognition by employing the power of deep learning. By expertly combining these techniques, we achieve remarkable accuracy, precision, and efficiency in recognizing various boxing punches.

Keywords

DCNN, deep learning, wearable, combat sports, boxing, punch recognition, inertial sensors, micro inertial measurement unit, sensor fusion, sliding window technique

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Introduction

Boxing, often referred to as the "noble art," holds its roots as an ancient combat sport that involves stand-up fist fighting. Notably, boxing made its entrance in the Olympic Games in St. Louis in 1904, marking its inclusion at the field of international sporting competitions.[1,2] The significance of adopting proper punching techniques and adhering to standard punching postures cannot be understated, as they strongly influence an athlete's boxing prowess and potential career trajectory.[3,4] This finding underscores the pressing necessity of harnessing emerging technologies to automate the identification and comprehensive analysis of boxing punches.

Innovative technologies are revolutionizing boxing training, offering invaluable assistance to coaches. This innovative model enhances our understanding of its applicability, promising significant advancements in sports. It serves as a crucial resource for coaches and athletes, enabling close monitoring and the potential to boost performance in any one-on-one bouts.

Presently, available technology for boxing training falls into two main categories. image/video-based and sensor-based technologies. Research involving image/video-based technologies for analyzing human motion has been in existence for around four decades[5–7] and it

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utilizes visual data for in-depth analysis of activity recognition, employing techniques such as motion tracking, gesture recognition, and advanced computer vision methods. This visual data provides coaches and athletes with profound insights into activity recognition, allowing for thorough scrutiny of critical parameters like speed, angle, and impact, ultimately enabling highly targeted feedback and skill refinement.

However, challenges persist within the domain of image/video-based technology. These encompass the intricacies of video image processing, computational demands associated with the analysis, obstacles in real-time monitoring of image capturing motions, substantial financial investment required for acquiring high-precision cameras, and need for meticulous manual placement of cameras in optimal positions well in advance of an event to ensure comprehensive coverage and minimize blind spots. IMU sensors are involved in many sports related studies such as boxing,[4] tennis,[8] running,[9] volleyball,[10] and cricket,[11] and in daily human activities[12] such as keystroke recognition,[13,14] and skill assessment,[15] due to the limitations inherent in image/video based technologies.

Activity recognition using sensors involves four phases: data acquisition, pre-processing, feature extraction, and activity recognition.[16,17] While traditional segmentation has been a machine learning pre-processing technique, deep learning challenges its necessity. Some research suggests using segmentation with deep learning for activity recognition.[18] Ebner et al.[19] experimented with variable window sizes (2, 2.5, and 3 s) at 50 Hz, finding decreased accuracy with larger window sizes. Banos et al.[20] proposed a 1.2-s interval for an optimal balance between recognition speed and accuracy in Human Activity Recognition (HAR) using conventional machine learning models.

Prior research emphasizes the impact of window size on recognition speed in activity recognition. This finding motivates the combination of deep learning's automatic feature learning property with a sliding window approach in the pre-processing stage to find the optimal window size for enhanced recognition speed. This study aims to analyze the effect of sliding window size within a deep learning architecture, using evaluation metrics like accuracy and $F1$ score ($F1$ score is a metric used to assess the performance of a classification model, particularly when dealing with imbalanced datasets). Overlapping sliding window frame sizes for analysis range from 200, 100, 50, 25, 20, 15, 10, and 5, corresponding to sampling rates of 2, 1, 0.05, 0.20, 0.15, 0.10, and 0.05 s at a sampling frequency of 100 Hz. The primary goal is to identify the window size that minimizes latency and processing costs.

Feature extraction is crucial for identifying valid attributes from IMU sensor data, minimizing classification errors, and reducing computational complexity,[21] especially in deep learning. Feature extraction methods include manual and automatic approaches. Manual feature extraction requires domain expertise and is labor-intensive,[22] while the automatic approach uses deep learning algorithms to autonomously learn features. Deep learning algorithms are widely used due to their effectiveness in capturing local dependencies within data across various domains.[23–26] Deep learning methods, particularly DCNNs, excel at recognizing complex activities, leading to robust HAR systems.[27,28] Successful in various domains, DCNNs prove equally effective in time series classification.[21,29]

Using a single sensor for sports activity recognition presents challenges due to the increased complexity of movements. This approach introduces challenges, including difficulties in differentiating between activity classes with similar punch types in boxing, such as a jab and hook. The subtle variations, particularly in the latter stages of a flexed arm movement, make accurate activity recognition a challenging task. Additionally, individual variation among athletes executing the same punch type introduces complexities that complicate the recognition process. Though researchers have achieved notable advancements in recent years by employing data from single sensors,[30–32] relying on a single sensor for the activity recognition task has proven to be unreliable due to the inherent limitations of most sensors. These limitations arise from factors such as sensor deficit, restricted spatial coverage, occlusion, imprecision, and uncertainty.[10]

To address the challenges associated with using a single sensor and enhance recognition performance (mainly gauged by metrics like accuracy, precision, recall, $F1$ score, sensitivity, and specificity) research suggests employing multiple sensors at diverse body locations[33] to enhance accuracy. Utilizing multiple sensors for the recognition of human activities is logical because other sensors can complement the information overlooked by one sensor. Additionally, the imprecision inherent in a single sensor can frequently be offset by other sensors exhibiting similar characteristics.

This paper aims to address the challenges outlined above in the field of activity recognition and classification and demonstrates the significance of sensors positioned on various parts of the body in contributing to the comprehensive recognition of activities with high accuracy and $F1$ score.

The key contributions of the proposed study are outlined as follows:

1. A novel DCNN Classification Model: The research introduces a novel DCNN classification model. This model is specifically designed for real-time applications and aims to accurately recognize various boxing punch types.
2. Data Fusion Model Utilizing DCNN: The study employs a data fusion approach that utilizes DCNN architecture. This model effectively combines data obtained from sensors positioned at three distinct body locations. The goal is to enhance the system's ability to differentiate between activities that might exhibit similar patterns.

3. Optimal Window Size Exploration: The research delves into the exploration of an ideal window size for activity recognition. By investigating the relationship between window size and recognition accuracy, the study provides insights into how small a window size can be while still effectively detecting boxing punches.

In essence, these contributions collectively serve to advance the field of boxing activity recognition by proposing an innovative deep learning model, incorporating data fusion techniques, and shedding light on the optimal window size for improved accuracy in identifying boxing punch types in real-time scenarios.

Literature review

Deep learning is making progress in various applications such as image processing and artificial intelligence. In recent years, it has become increasingly popular in sensor-based HAR due to the prevalence of smart devices with embedded sensors. The evolution from traditional machine learning (ML) algorithms to deep learning in sensor-based HAR is evident, particularly in solutions dealing with big data,[34] treating HAR as a time series problem. Numerous research studies utilize deep learning for feature extraction and activity classification, with applications extending to real-world scenarios. Li et al.[35] proposed a Support Vector Machine (SVM) based model for recognizing gymnastic movements, while Rustam[36] introduced a deep stacked Multi-Layer Perceptron model for HAR. Other studies by Plotz et al.,[37] employed Deep Belief Networks (DBN) for feature extraction, although these networks may not fully leverage the local dependencies in time series data. Alsheikh et al.[38] presented a deep model based on Restricted Boltzmann Machines and DBN, incorporating multiple network layers and a Hidden Markov Model (HMM) for activity recognition. Chowdhary et al.[39] proposed a posterior-adapted decision fusion method utilizing SVM, Binary Decision Trees, and deep neural networks (DNN) for activity recognition. Their approach involved assigning weights to each activity class based on prior knowledge of model predictions, followed by using the weighted average for the final prediction. Thus DCNN, with its convolutional layers, was highlighted in the above mentioned literatures for its ability to extract unique features from sensor data, aiding in the identification of various activities and capturing local dependencies in time series data.

Mutgeki et al.[34] proposed the iSPLInception model, employing the Inception-ResNet model for HAR. Mutgeki et al. conducted parallel convolutions with diverse kernel sizes within each inception module and aggregated the outcomes. In contrast, Li et al.[40] suggested a structure combining CNN (Convolutional Neural Network) and LSTM (Long Short-Term Memory) for concurrent activity recognition with multimodal sensors, while our study specifically utilized wearable sensor data to focus on identifying similar activities. Mekruksavanich and Jitpattanakul[41] presented a four-layer CNN-LSTM model for smartphone-based HAR, comparing it with three LSTM variations. The existing studies primarily focus on HAR, and notably, there is a visible absence of research classifying boxing sport activities using deep learning techniques. This absence underscores the motivation for our research and highlights its distinctive nature.

Regarding sensor fusion technique, many studies concentrate on basic activities, accurately recognizing similar activities poses a significant challenge. Munzer et al.[42] introduced a CNN-based sensor fusion approach, where each dimension (x, y, and z) of the sensor was fused into individual convolutional layers for feature extraction, incurring computational costs. Our work differs notably, albeit sharing similarities with the work by Hirawat et al.[43] Instead of sending individual sensor channels to the initial layer, we considered sensors at each body position, employing an optimized DCNN model for improved feature extraction. Our study uses separate convolutional layers to extract features from sensors at different body positions. The x, y, and z coordinates of each sensor are fused into distinct convolutional layers for feature extraction, and subsequently, all extracted features are merged into the same convolutional layer to capture temporal dependencies. Batch normalization is applied to expedite convergence, resulting in superior performance compared to the work by Khan et al.[33] Existing techniques have their limitations and employ various sample generation and validation processes, making direct comparisons challenging.

In previous studies,[44,45] the data segmentation procedure for feature extraction in wearable sensor input involved breaking down data measurements into smaller fragments or sliding windows. Feature extraction is a crucial aspect of HAR, aiding in the identification of essential features from sensor data, leading to reduced classification errors and decreased computational complexity.[21] The choice of window size in segmentation has been widely discussed due to its impact on recognition results concerning data size and time span.

While conventional ML methods commonly use window size variation for evaluation, some authors propose window size segmentation as a pre-processing step for HAR with deep learning (DL) methods. For instance, Mairittha et al.[18] conducted data labelling for an activity recognition system using inertial mobile sensing, employing a 5.12 s window size (at 20 Hz) in both simple-LSTM and hybrid CNN-LSTM with overlapping, representing around 100 frames.

On a different note, Ebner et al.[19] introduced an innovative approach involving analytical transformations and artificially constructed sensor channels for activity recognition, utilizing window sizes of 2, 2.5, and 3 s at 50 Hz, equivalent to 100, 125, and 150 frames, respectively, without overlapping. Their findings suggested that variations in accuracy based on window length were hardly noticeable, with a slight tendency toward decreasing accuracy with larger widths. Another study evaluating the impact of window size on HAR for 33 fitness activities[20] explored different window sizes ranging from 0.25 to 7 s in 0.25-s steps, without a defined sampling rate, using four conventional classification models. The conclusion drawn was that the interval of 1–2 s provides the best trade-off between recognition speed and accuracy.

Subsequently, Niazi et al. proposed the simultaneous use of multiple window sizes with a novel multi-window fusion technique.[46] Various researchers have also experimented with dynamic window size approaches.[47] As noted by Baños et al.,[47] there is no clear consensus on the preferable window size for HAR. The dilemma arises from the trade-off: while decreasing the window size enables faster activity detection, a small window size may lead to classification errors. Determining how small a window can be while retaining the advantages of decreased size and maintaining accuracy is a key consideration for improving activity recognition and its associated applications.

The proposed research deals with the above research gap that exists in the study of activity recognition in boxing, determining the study with validation results in accuracy, precision, *F*1 score, and recall which shows that the proposed paper outperforms all the above literature.

The proposed system of measurement

Multiple sensors for activity detection offer distinct advantages compared to single-sensor devices, including enhanced noise reduction, reduced ambiguity, and the integration of input signal data.[48] This study introduces a novel data fusion methodology aimed at capitalizing on these advantages. The proposed technique involves extracting unique features from three separate IMU sensors. The process begins by placing IMU sensors at three different positions on the player's body—specifically, on both wrists and at the upper back. The data from each sensor is then individually passed through convolutional layers to extract features tailored to the characteristics of that particular sensor. Subsequently, the extracted data from all three sensors is integrated into the classification layer, as depicted in Figure 1. The implementation of this data fusion approach displays tangible enhancements in the overall performance of the activity detection device.

During measurement, the athletes were asked to wear the sensors on both of their wrists beneath the boxing gloves and the in-clavicle belt as it positions the third sensor on their upper back. For the study, after a 10-min warmup session, each player was asked to perform six types of punches considered for the study, which were recorded over a span of 10 h. Ten players with varying skillsets were involved in the study. First, all six punch types were thrown by the players in a random manner, followed by successive sets with 30 s of rest recorded. Notably, the design of these wearables, including armbands and clavicle belt, ensures minimal hindrance to the athletes' movements. Figure 2 offers a depiction of a jab punch representation with a set of signals obtained from the player during the study.

Hardware platform

The SparkFun Razor 9 Degrees of Freedom (DOF), illustrated in Figure 3, is a preprogrammed sensor designed for automatic logging of IMU data. Each SparkFun Razor 9 DOF unit comes equipped with an IMU capable of recording data from a triple-axis accelerometer, gyroscope, and magnetometer and stores the data on a microSD card or transmits it wirelessly to a PC for subsequent computational analysis.

The sensor offers a comprehensive range of options for full-scale acceleration and angular rate, with options of $\pm 2/\pm 4/\pm 8/\pm 16$ g for acceleration and $\pm 125/\pm 250/\pm 500/\pm 1000/\pm 2000/\pm 4000$ dps for angular rate. Additionally, the magnetometer within the sensor is sensitive enough to detect down to 0.4 mg, with an accuracy of $\pm 0.5°$. The significance of the acquired data lies in its interpretation to derive meaningful insights. Therefore, the section responsible for transmitting signals must be provided with a substantial amount of energy, as it remains active throughout the data transmission phase, spanning from the sensor to the DL layers for processing and inference. To validate the feasibility of the proposed work for real-time sensor utilization, considerations must be given to energy consumption, size constraints, and weight limitations. Consequently, a low-capacity Li-ion battery (3.7 V, 2000 mAh) has been incorporated.

For the analysis of sports motion activity features, a high sampling rate of 100 samples per second is necessary.[49,50] However, when examining the expected battery life of a 9 DOF wearable device sampling data at 100 Hz and equipped with a 2000 mAh battery, the duration would not surpass 10 h.[51] This constraint poses challenges for real-time applications, even with the application of compression algorithms.[52] The implementation of compression algorithms can lead to a notable improvement in battery life. Furthermore, the utilization of on-board processing capabilities can minimize transmission overhead by storing data in burst sequences that tap into the internal memory's buffering capacity. This approach has the potential to extend the battery life to approximately 2 days.[53]

Selection of neural network model

The emergence of deep learning has brought about a transformative shift in the signal processing

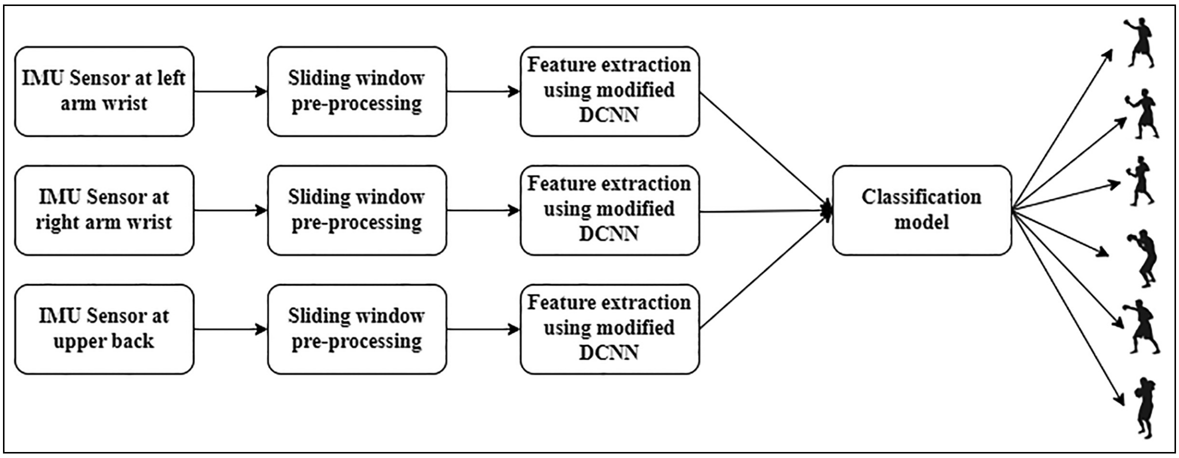

Figure 1. The system architecture.

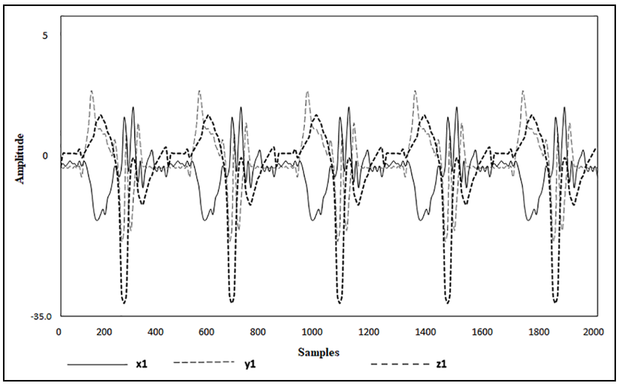

Figure 2. IMU signals representation obtained from a participant.

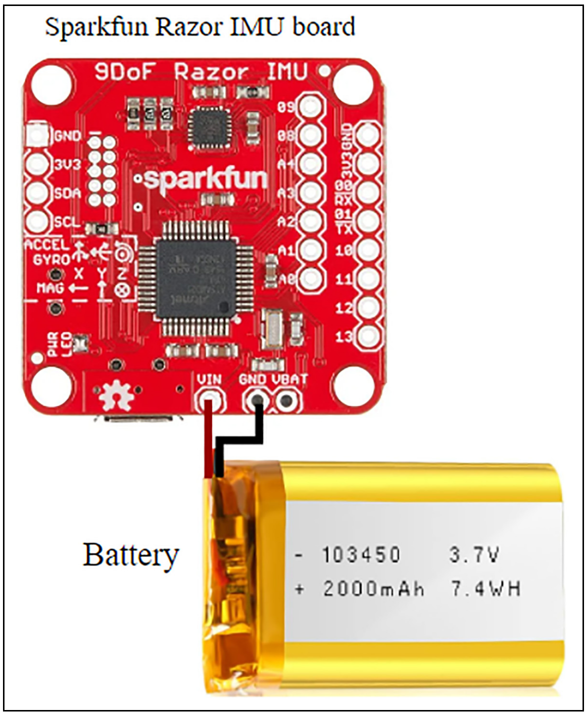

Figure 3. The wearable sensor hardware including 9 DOF IMU.

environment and feature extraction techniques. Prior to the advent of deep learning, the conventional approach involved manual feature extraction, which entailed generating domain-specific attributes.[54] Subsequently, machine learning models were trained on the processed data. However, this method has certain limitations. It demands the processing of acquired data signals and necessitates domain experts labeling the data for both data collection and analysis of raw data. Moreover, model-fitting features are required for each new dataset, further complicating the process.

The classical machine learning approach has many additional drawbacks. These include the challenge of developing a generalized model capable of accommodating diverse movements performed by distinct individuals. With the objective of justifying the computational complexity inherent in deep learning and recognizing the potential of deploying deep learning models on affordable, portable wearable devices for automatic feature extraction, the proposed research endeavor centers on the development and training of a neural network. The neural network is devised to conduct predictions while conserving resources to the fullest extent, thus ensuring its portability on low-cost embedded devices.

In this context, the study introduces a streamlined deep learning network personalized to recognize boxing punches. Notably, the research establishes the efficacy of deep learning in sports activity recognition compared to conventional neural network techniques, an assertion verified by existing literature.[50] The basic aim of this study is to offer an efficient and automated means of recognizing boxing punches using deep learning technology, facilitating real-time recognition while keeping computational demands in check.

Dataset and sliding window creation

The dataset used for the experiments was derived from three 9 DOF IMU sensors, with two sensors placed on each player's wrist and one on the upper back. The deep

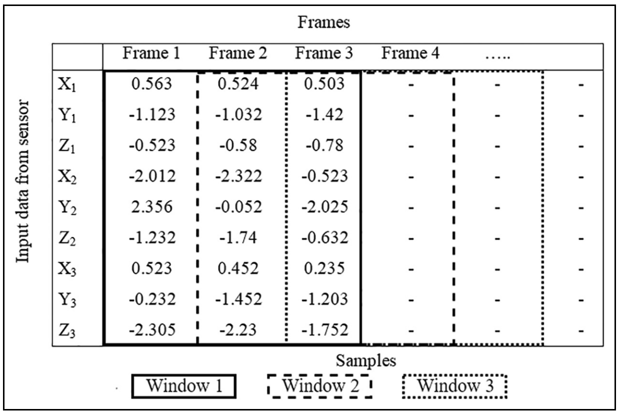

Figure 4. Sliding window schematic over the sensor data.

learning model is evaluated by splitting the data into testing and training sets. The training system involves raw data from eight athletes, and the data from two athletes was used for prediction. The IMU dataset with 261,790 samples was used for testing and 79,361 samples for validation.

There are two primary methods for creating sliding windows: one is based on segmenting sequences into frames, and the other is based on segmenting the time following the data sequence into fixed intervals. These windows can be further categorized as overlapping or non-overlapping, as well as fixed or adaptive. Fixed windows maintain a consistent size throughout the sequence, while adaptive windows adjust their size based on specific criteria linked to movement. Additionally, windows are considered overlapping when the subsequent window retains part of the previous sequence or when there is an overlap between adjacent windows, as described in studies by Ma et al.[54] and Dehghani et al.[55]

In the context of the study, 9 DOF IMU sensor signals were collected. Peaks in acceleration are indicative of punch impacts. To identify the acceleration peak related to punch impacts and reduce noise and motion artifacts arising from individual and environmental factors affecting the sensor data, a preprocessing stage involves applying low-pass and high-pass filters. To handle potential data dropouts and insufficient information below the 2-s frame, cubic spline interpolation is employed to resample data. The resampled values are then normalized between the ranges of -1 and 1. In this research, a sampling frequency of 100 Hz is utilized, translating to 100 samples of X, Y, and Z acceleration values for each second. The signal is segmented into 2-s sliding windows with a 50% overlap between consecutive windows. This window size and overlapping ratio are inspired by prior work,[34] striking a balance between covering the most relevant activities and minimizing time delays for real-time implementation.

To delve into the components of a sliding window, it is important to understand that a sequence is a larger sample that might comprise one or more single samples. Each observation within the sequence corresponds to a time step, forming the "window size." Furthermore, a feature pertains to the input of the sequence, such as X_1, Y_1, Z_1, X_2, Y_2, Z_2, X_3, Y_3, and Z_3, which represents a single time interval (Figure 4). The progression of a new phase occurs as the window traverses through the sample.

For the smallest sliding window size of five, the resulting input matrix becomes quite large, specifically (261,785, 5, and 9), as depicted in Table 1. This matrix is obtained by dividing the total number of samples by the number of time steps, encompassing all observed data columns. As the window size expands, the total number of samples decreases, reflecting the subtraction of the window size from the overall count.

This study adopts fixed overlapped sliding windows, which involves segmenting all available samples into windows of size "n." The dataset was collected at a consistent sampling rate of 100 Hz using a window size of 100 frames, corresponding to a duration of 1 s. To ascertain the optimal window configuration, the study experiments with reducing the window size to shorter lengths (20, 15, 10, and 5 frames), equivalent to time spans of 0.20, 0.15, 0.10, and 0.05 s, respectively.

The choice of a shorter sliding window is strategic, as it facilitates real-time data processing, aligning with the objective of embedding the inference process within the sensor node. This approach streamlines the model's real-time data processing capability by integrating the inference step directly into the sensor node. Consequently, the study generates a dataset comprising 261,790 instances, and the comparison of these instances with their corresponding activities is outlined in Figure 5.

Spatial feature extraction

The utilization of deep learning models capitalizes on their inherent ability for automatic feature extraction directly from raw data. This advantageous trait of automatic feature extraction within the deep learning architecture forms the foundation of the proposed research's methodology for recognizing boxing punches. Specifically, in the context of deep learning strategies, DCNNs stand out for their capacity to not only automatically extract features but also perform classification tasks on input activity data.[50] The convolution operation involves moving a one-dimensional filter across the sensor data signal, a process illustrated in Figure 6. This DCNN architecture effectively extracts distinct features from the time series data, particularly excelling in efficiently handling segments with shorter lengths within a comprehensive dataset.[56,57]

In time series data, DCNN plays a crucial role in capturing local dependencies by correlating adjacent signals, a feature that this paper influences for extracting local features. This work employs the Rectifier Linear Unit (ReLU) activation function, a choice made to remove non-linearity introduced during the

Table 1. IMU window sizes distribution for training the model with 261,790 samples.

Window size			
5	10	15	20
(261,785, 5, and 9)	(261,780, 10, and 9)	(261,775, 15, and 9)	(261,770, 20, and 9)
Window size			
25	50	100	200
(261,765, 25, and 9)	(261,740, 50, and 9)	(261,680, 100, and 9)	(261,680, 200, and 9)

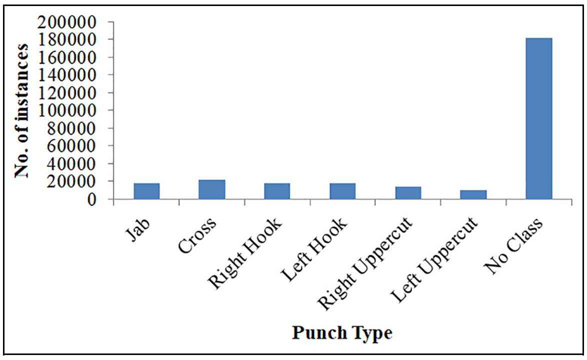

Figure 5. Composition of data (261,790 instances).

convolutional layer's operation. The pooling layer, responsible for dimensionality reduction in the data and consequently reducing the network's computational parameters, employs the max-pooling method, which is preferred based on superior results compared to average pooling. Given that DCNN is a multilayer architecture, as depicted in Figure 7, the input data passes through a sequence of layers, including fully connected layers and a softmax layer, following the convolutional and pooling stages. During the training phase, hyperparameters are tuned to establish the relationship between the input IMU sensor data and the output activity classes.[58]

Optimization of DCNN model and data fusion approach

Given their strong performance, DCNNs are commonly employed for feature extraction. The optimization of the model is performed using the practice methods suggested by Castanedo.[59] Data fusion entails the incorporation of information from multiple sources.[60] In scenarios involving complex behaviors, a single sensor often falls short, necessitating sensors in multiple body locations. To address this sensor shortage, the present study proposes a sensor fusion approach wherein three sensors placed at different body locations (one sensor at each wrist and a sensor at the upper back) contribute their respective x, y, and z coordinates to distinct convolutional layers for feature extraction.

Because the features from each sensor are independently extracted, the incorporation of the sensor fusion technique leads to a higher number of trainable parameters compared to the DCNN architecture without this fusion approach. The outcomes, as detailed in the results section, demonstrate enhanced accuracy in recognizing related activities, such as distinguishing between a hook and a jab. In the context of recognizing boxing punch actions, this research employs a deep classification architecture like DCNN with sensor fusion and sliding window techniques.

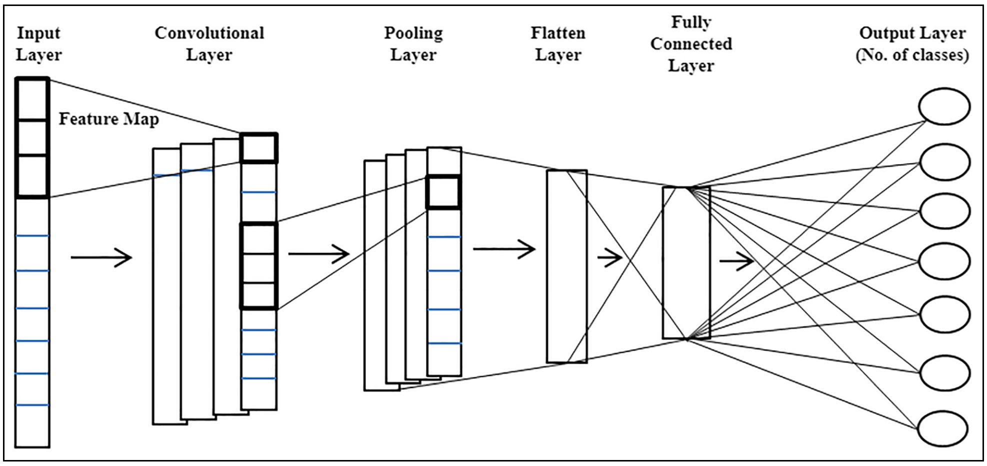

Figure 6. A 1D convolutional architecture for spatial feature extraction.

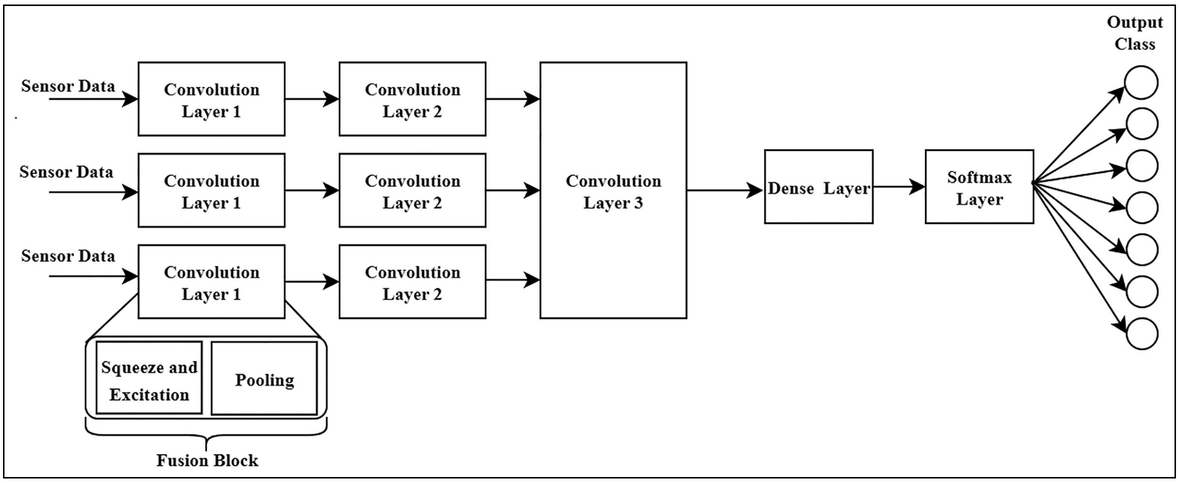

Figure 7. Architecture of the optimized DCNN model used in our experiments for boxing punch recognition.

Table 2. Comparison of DCNN accuracy for different fully connected layers.

Convolution layer count	Fully connected layer count	Accuracy (%)
2	1	92.80
3	1	94.20
3	2	93.80
4	1	93.60
4	2	93.20

Figure 8. Figure showing learning rate affecting *F*1 score.

DCNN without optimization is employed as a reference point to compare outcomes. The hyperparameters for each structure were determined through an iterative process involving different ranges of values using the hit and trial method. To assess their impact on recognition accuracy, we examined different counts of convolutional layers. The configuration that yielded the highest accuracy consisted of three convolutional layers and one fully connected layer and can be referenced in Table 2. Initially, increasing the convolutional layers improved the recognition performance, but this trend reversed after three layers. This decline is attributed to the model's inclination to memorize overfitting data as additional layers are added. Although such models perform well with training data, their performance deteriorates with test data. To mitigate this discrepancy between training and test data, a dropout strategy is employed by randomly deactivating neurons during training to counter overfitting. During forward pass, this technique temporarily isolates these neurons, preventing weight adjustments during backward passes.[61] In this experiment, a dropout rate of 0.2 is utilized to counter overfitting, corresponding to a 20% dropout rate. The learning rate plays a crucial role in adjusting network weights during gradient descent optimization. Smaller learning rates result in slower convergence, while faster rates might lead to non-convergence issues.[62]

For our proposed approach, the learning rate is selected from the range of 0.0001–0.01, while all other hyperparameters remain constant. The effect of learning rate over window size is depicted in Figure 8 and it shows that the learning rate of 0.001, at which the *F*1 score remains high in a batch size of 64, and was trained for 50 epochs. Opting for a larger batch size accelerates the training process but demands more memory. Conversely, a smaller batch size consumes less memory but results in slower training, facilitating rapid model convergence.[63] Among kernel sizes like 3, 4, 5, and 7, the kernel size of three displayed promising performance and was selected for the final experimentation. The outcomes of hyper-parameter setting were presented in Table 3.

The network's task is to discern distinctive features within data sequences to classify them into the predefined boxing punch categories. In our proposed methodology, a sequential architectural model is adopted. This model encompasses multiple layers, including convolutional, max pooling, dense, and dropout layers. These layers work cohesively to extract distinctive features from the data.

Thus, our DCNN fusion model comprises three convolutional layers with a kernel size of three having 128,

Table 3. Hyperparameter settings for the model.

Hyperparameter	Experimental values	Selected values
CNN layers	1–6	3
Kernel size	3, 5, and 7	3
Feature maps	256, 128, 64, and 32	128, 64, and 64
Pooling size	2, 3, and 4	2
Dropout	0.2, 0.3, 0.4, and 0.5	0.2
Optimizer	RMS Prop, Adam	Adam
Learning rate	0.0001–0.01	0.001
Batch size	32, 64, 128, and 256	64

64, and 64 filters respectively. Following the shorthand notation from Srivatsava et al.,[63] the network can be represented as $C\ (128) - C\ (64) - C\ (64) - D\ (256) - S$m. Here, $C\ (F_l)$ signifies the number of feature maps in the convolutional layer $F1$, $D(n)$ denotes the units in the dense layer n, and Sm represents the softmax layer.

A softmax activation function is used for the output layer and is represented by equation (1).

$$q_i = \frac{e^{k_i}}{\sum_{a=1}^{n} e^{k_a}} \tag{1}$$

Equation (1) defines the softmax activation function employed in the output layer. It calculates the probability q_i of obtaining a normalized sum of all exponentials from a real input vector's elements, k_i. This function transforms the network's non-normalized output into a probability distribution.

The activation function ReLU was used for all layers, including the output layer. This choice of activation functions defines the structure of the final model. The specific hyperparameter configurations for the proposed model are detailed in Table 3. The model was implemented using Keras with a Tensorflow backend. The testing and training of the model were performed on hardware consisting of an Intel Xeon E-2224G processor (3.5 GHz) and 32 GB of RAM. The research presented in this study includes outcomes from a deep learning model (DCNN) with an optimum sliding window to identify boxing punches with similar movements. The DCNN model was assessed with sensor data fusion and sliding window variations.

Performance metrics and evaluation

Sparse categorical cross-entropy was chosen as the loss function to evaluate the performance of the proposed model. Considering the multi-class nature of the network's output, the study encompassed seven distinct activity classes (cross, jab, left hook, right hook, left uppercut, right uppercut, and no hit). The activation function employed was the ReLU. The optimization algorithm utilized was the Adam's algorithm, a stochastic gradient-based optimization algorithm.

Performance metrics

The evaluation of the enhanced DCNN model, enhanced through sensor data fusion, was conducted using two key metrics: accuracy and the $F1$ score. Accuracy represents the ratio of correct predictions to the total input samples. While accuracy is commonly used for evaluation in situations without class imbalance,[64] this study recognized that the instances of "jab" and "cross" motions were more abundant compared to "hook" or "uppercut" motions, creating a class imbalance scenario. As a result, the evaluation incorporated the $F1$ score as a metric, which is sensitive to class distribution and is not influenced by imbalanced classes. $F1$ score, on the other hand, combines precision and recall. Higher values of accuracy or $F1$ score indicate better model performance.[65] The $F1$ score takes into account the proportion of samples in each class.

Furthermore, the evaluation also considers the model's inference time, which is the time taken to generate a response. Inference time is very important in real-time application, including sports activity recognition, for reasons including real-time decision-making where immediate responses are required for an action. The parameters used to compare performance are accuracy, precision, recall, and $F1$ score. With accuracy, DCNN performance was evaluated considering all the class outcomes. While $F1$ score, precision, and recall give an accurate indication of how DCNN recognizes a particular class. The formulas to calculate the above mentioned evaluating factors are given below.

$$\text{Accuracy} = \frac{\text{true positive} + \text{true negative}}{\text{true positive} + \text{true negative} + \text{false positive} + \text{false negative}} \tag{2}$$

$$\text{Precision} = \frac{\text{true positive}}{\text{true positive} + \text{false positive}} \tag{3}$$

$$\text{Recall} = \frac{\text{true positive}}{\text{true positive} + \text{false negative}} \tag{4}$$

$$F1\ \text{score} = 2\times \frac{\text{precision}\times\text{recall}}{\text{precision} + \text{recall}} \tag{5}$$

Evaluation

One of the essential stages in the design of each system is the process of evaluation. In the context of HAR, this evaluation has traditionally been carried out using a method known as k-fold Cross-Validation (CV). In a k-fold CV, the overall dataset is divided randomly into k equal subsets. The model is then trained on $k-1$ of these subsets, with the remaining one reserved for testing.[66] It is important to note that in this process, the test set can potentially contain data from the same subjects as the training set. This approach is commonly referred to as subject-dependent CV in the literature.

It is assumed that the data are independent and identically distributed,[67] meaning that all data points are independently drawn from the same distribution. However, this assumption may not persist when dealing with data from human subjects for two main reasons. First, there is substantial inter-subject variability in how activities are performed,[68] which means that data samples from the same subject are likely to be more similar than samples from different subjects. Factors contributing to this variability include sex, gender, age, and experience. Second, there is a temporal dependence between activities performed by the same subject. For instance, data samples collected in a short time interval, such as during the same training session, are likely to be more similar than samples collected further apart in time due to factors like fatigue and training. Therefore, k-fold CV may lead to an overestimation of the performance of HAR recognition systems.

This overestimation becomes even more pronounced when k-fold CV is used with overlapping sliding windows, as the overlap between adjacent windows introduces additional dependencies between data points. A more detailed discussion on the challenges of k-fold CV in HAR can be found in Dehgani et al.[69] To address these issues, an alternative approach is subject-independent cross-validation (subject-independent CV),[70,71] where the data has been split by subject. In this method, during each iteration, the model is trained on all eight players except two, then used for testing. This approach effectively removes the intra-subject dependencies present in a subject-dependent CV.

Results

Classification accuracy

The classification accuracy of the model describes how well the model performs in classifying the different punches in boxing. The performance assessment of the proposed model involved a thorough analysis across various hyperparameter configurations. The findings indicate that increasing the number of convolutional layers does not necessarily enhance the model's performance. Instead, it elevates the complexity of the extracted features, which might lead to overfitting. The heightened number of layers amplifies the neuron's memorization capability, causing the system to excel during training while performing inadequately on unseen data. To counter this inadequacy in performance, a dropout rate of 20% was implemented. Through dropout, neurons are randomly selected and purposefully excluded from weight updates during the adjustment process. $F1$ scores for the activity classes were recorded and evaluated, considering different hyperparameter settings. The outcomes, highlighted in bold, showcase improved performance. Notably, the results in Table 4 underscore the effectiveness of the proposed model in accurately classifying activity classes that appear similar, such as "jab" and "hook."

Table 4. The weighted $F1$ score for six different punches using convolutional machine learning model algorithm using proposed DCNN.

Activities	DCNN	Optimized DCNN
Jab	84.14	89.27
Cross	82.27	89.35
Right hook	84.63	86.24
Left hook	80.39	85.52
Right uppercut	83.25	86.36
Left uppercut	81.03	85.34

The comprehensive performance analysis presented in Table 5 unmistakably demonstrates that the optimized DCNN surpasses other classification algorithms for similar activities. This optimized DCNN outperforms its baseline counterpart, as each player's execution of various activities involves unique movements that generate distinct sensor readings. In the optimized DCNN model, the data from each sensor is subjected to a separate convolution layer, facilitating the extraction of features specific to that sensor. These distinct features are then further processed in subsequent convolutional layers to capture additional distinctive attributes.

In terms of model accuracy, Table 5 shows that the accuracy is significantly improved to 99% by employing optimized DCNN. Across all classes of boxing punches, the proposed optimized DCNN demonstrated superior performance compared to the basic DCNN models. Consequently, the overall efficacy of the optimized DCNN is indeed remarkable.

The conducted study's outcomes highlight the substantial advancements achieved in recognizing similar activities. This progress is attributed to the incorporation of sensor fusion techniques within the optimized DCNN architecture, coupled with the utilization of the sliding window pre-processing method. As a result, the potential applications of the optimized DCNN model extend to other combat sports (karate and taekwondo), and sports involving hitting actions (cricket, tennis, and volley ball), broadening the scope of the proposed device for diverse sports activity classifications.

Confusion matrix

The values along the diagonal of the confusion matrix represent the true positive rate, indicating activities that have been accurately classified and are depicted in Table 6. As mentioned earlier, the optimized DCNN model is notably focused on enhancing the classification of similar activities such as jabs and hook punches. These specific activities exhibit heightened classification performance. Nevertheless, there are instances of misclassifications among activities that look similar, which

Table 5. Overall performance of the models for IMU sensor dataset.

Window size Model	5 Accuracy	F1 score	10 Accuracy	F1 score	15 Accuracy	F1 score	20 Accuracy	F1 score
DCNN	0.96	77.47	0.99	78.67	0.99	80.45	0.99	82.11
Optimized DCNN	0.95	82.12	0.67	84.20	0.99	87.24	0.99	89.84
Window size	25		50		100		200	
Model	Accuracy	F1 score	Accuracy	F1 score	Accuracy	F1 score	Accuracy	F1 score
DCNN	0.99	88.33	0.99	92.43	0.99	91.62	0.94	95.42
Optimized DCNN	0.99	90.25	0.99	91.36	0.99	99.84	0.99	96.28

Table 6. Confusion matrix showing IMU dataset using proposed DCNN model.

	Jab	Cross	Left hook	Right hook	Left uppercut	Right uppercut	Null class
Jab	97.8	0.35	0.65	0.04	0.06	0.03	0.05
Cross	0.35	96.5	1.49	0.02	0.01	0.13	0.13
Left hook	0.15	0.27	95.2	0.17	0.01	0.03	0.24
Right hook	0.07	0.07	0.75	95.7	0.04	0.03	1.91
Left uppercut	0.12	0.05	1.02	0.62	96.8	0.06	0.42
Right uppercut	0.03	0.08	0.07	0.13	0.02	95.5	0.24
Null class	0.03	0.05	0.09	1.83	0.08	0.08	94.9

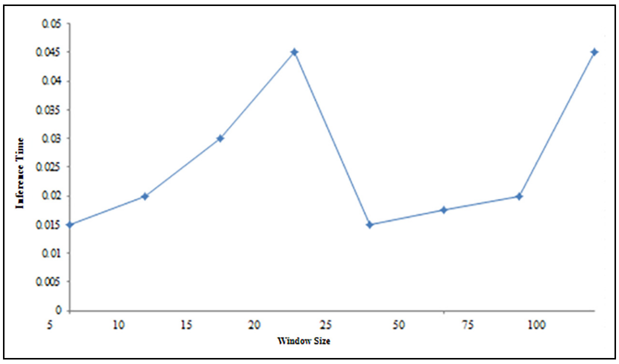

Figure 9. Window size impact over inference time.

can be attributed to the relatively limited number of training samples available for these particular activities.

Optimal window size creation for boxing activity

The ideal window size that yields better accuracy with quicker response time is the objective of interest in the proposed work and had been found using the proposed deep learning model. Testing involved evaluating the model's performance using varying window sizes: 200, 100, 50, and 25 samples. However, no significant change was observed in terms of accuracy and *F*1 scores across these sample sizes (Table 5). The inference time remained consistent at approximately 0.5 ms, considering a sampling frequency of 100 Hz.

Subsequently, the model was reevaluated using shorter window sizes: 20, 15, 10, and 5 sample sizes. Among these, the window size of 15 frames exhibited enhanced accuracy and *F*1 scores while also achieving an optimal inference time of under 0.1 ms (Figure 9).

The accuracy reaches an impressive 99%, and the *F*1 score surges around 87% for the window size of 15 frames. These findings are presented in Table 5 and illustrated in Figure 10. The accuracy and *F*1 score for a window of less than 15 frames are lower than for a window of 15 frames, and the accuracy and *F*1 score for a window of more than 15 frames is higher at the expense of processing time. Table 7 showcases the precision and recall metrics achieved by the optimized DCNN algorithm proposed in our study for different window sizes. Notably, when employing a window of 15 frames, we attained a commendable precision rate of approximately 87% and an impressive recall rate of around 89%. Furthermore, in Table 8, we present the sensitivity and specificity results of our proposed DCNN architecture. For the same window size of 15 frames, our model demonstrated a remarkable sensitivity of 89% and an impressive specificity of 93%.

To assess the computational efficiency of our model, we conducted inference time measurements on an ACER Predator HELIOS 300 laptop equipped with an AMD Ryzen 7 5800H processor and NVIDIA GeForce graphics, boasting 16 GB of RAM. Remarkably, our model exhibited consistent performance, with inference times consistently below 1 ms for all window sizes. It is worth noting that there is an observable trend in the graph, indicating that as the window size increases, the inference time also experiences a corresponding increase.

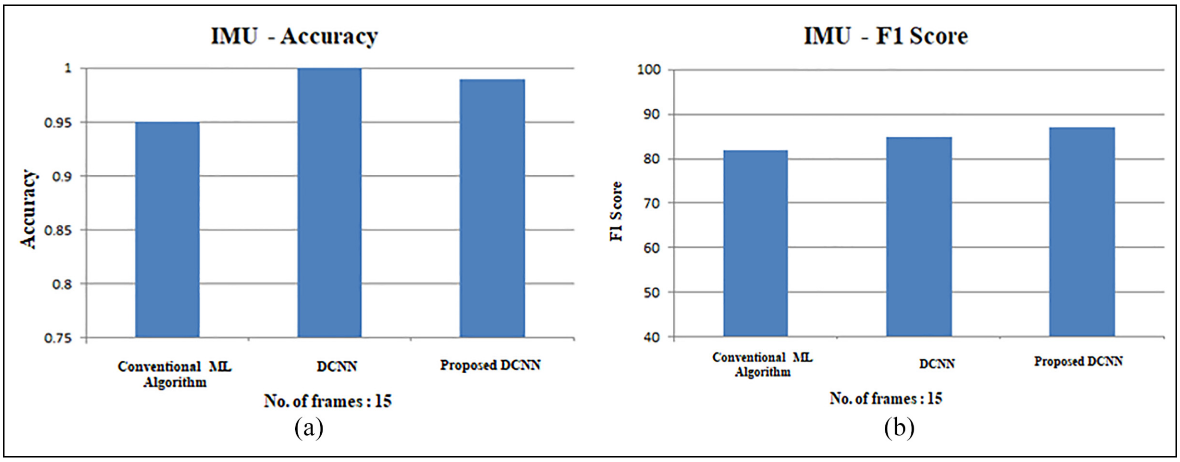

Figure 10. Bar graph showing accuracy (left) and *F*1 score (right) for the window size 15 in the conventioanal ML model, DCNN, and the proposed model.

Table 7. Table showing precision and recall for various window size.

Window size (samples)	Precision	Recall
5	82.10	84.34
10	84.75	87.16
15	87.34	89.01
20	88.13	90.52
25	88.52	92.42
50	94.24	94.35
100	98.97	98.92
200	95.72	95.54

Table 8. Table showing sensitivity and specificity for various window sizes.

Window size (samples)	Sensitivity	Specificity
5	82.24	90.23
10	83.33	91.16
15	89.1	93.62
20	90.12	94.24
25	92.23	95.62
50	95.64	96.34
100	98.93	98.91
200	95.84	97.41

In summary, our findings suggest that employing a sliding window of 15 frames, implemented based on data sampled at a frequency of 100 Hz, and with sensor fusion techniques represents the optimal choice for achieving an impressive accuracy level of 99% and an *F*1 score of 87%. Importantly, this choice also ensures minimal inference time, making it suitable for various boxing punches. Despite the similarity between certain movements, such as the jab and hook punch, our proposed DCNN exhibited impressive capabilities in distinguishing between them accurately.

Discussion

The research findings that deal with sports activity classification using sensor fusion and/or sliding window procedures using machine learning algorithms are listed in Table 9. Adelsberger et al.[72] utilized a 1.5-s window around the detected peaks in the input signal to identify weight-lifting thrusters. They achieved a 94% accuracy rate with their SVM-based model. Anand et al.[73] introduced seven-shot windows for different stages of a shot in tennis, badminton, and squash games. They aimed to capture relevant features in these windows for classification. Their experiments included Logistic Regression (LR) and Bidirectional Long Short-Term Memory (BLSTM) algorithms, with BLSTM showing improved accuracy in hitting events with a classification accuracy of 94.6%.

Connaghan et al.[74] employed a 3D acceleration vector computed within a window around the largest magnitude to detect shots in tennis. They used a binary classifier and achieved an overall recognition accuracy of 90% using the Naïve Bayesian (NB) classifier. Groh et al.[75] developed an event detection method using accelerometer signals, segmenting them into 1-s windows with a 0.5-s overlap in snowboarding. They calculated 54 features and applied classification algorithms like NB, Partial C4.5 Rule Learner (PART), SVM with a radial basis kernel, and *k*-Nearest Neighbor (KNN). Using NB and SVM, they achieved an overall recognition accuracy of 97.8%. In a study, Groh et al.[76] proposed peak detection in accelerometer signals for tricks in snowboarding. They used a window-based thresholding approach and experimented with NB, KNN, C4.5, and SVM classifiers. SVM yielded 90.3% accuracy for grind classification, while KNN outperformed the others with 93.3% accuracy for Airs classification. Jensen et al.[77] used HMM for detection and AdaBoost (AB) for classification in golf putt analysis. They employed sliding windows of 1.5 s with a 50% overlap.

Table 9. Performance comparison in various literatures applied to boxing punch type classification.

Research paper	Study	Recognition model	Accuracy (%)	Sliding window size	Sensor fusion
Adelsberger and Tröster[72]	Weight-lifting thruster	SVM	94	1.5 s	–
Anand et al.[73]	Tennis, Badminton, Squash, and Golf	LR, Bidir-LSTM	94.6	–	–
Connaghan et al.[74]	Tennis	NB	90	–	Accelerometer, Gyroscope, and Magnetometer sensor fusion
Groh et al.[75]	Tennis	NB, PART, SVM	97.8	1 s window with 0.5 s overlap	miPod sensor system
Groh et al.[76]	Tennis	NB, KNN, SVM, C4.5, KNN + SVM	93.3	50 samples (0.25 s)	Accelerometer, Gyroscope, and Magnetometer sensor fusion
Jensen et al.[77]	Golf	HMM	Not available	500 samples (1.5 s) with 50% overlap	–
Jensen et al.[78]	Swimming	AB, LR, PART, SVM	86.5	1, 0.5, and 3.5 s with overlap	–

Jensen et al.[78] segmented swimming events using sliding windows ranging from 1 to 3.5 s with a 0.5-s increment. They classified swimming strokes using AB, LR, PART, and SVM, achieving a maximum accuracy of 86.5% with the SVM classifier.

Our research outperforms the previously mentioned sliding window techniques in the sports genre. Our model demonstrates superior performance, as indicated by various metrics. For a window size of 100 frames (1 s), the $F1$ score reaches a peak of 99%, while for a window size of 15 frames (0.15 s), it remains high at 87%. Notably, the window size of 15 frames achieves the highest accuracy with minimal inference time. Additional metrics, sensitivity, and specificity, exhibit values of 89% and 93%, respectively, for the 15-frame window.

Comparing the inference times, we observe that for the 100-frame window, DCNN takes 0.091 ms, and the optimized DCNN takes 0.045 ms, which is twice as fast. Interestingly, at the 15-frame window, the optimized DCNN is four times faster than at the 100-frame window. Efficiency is gauged by multiplying accuracy with the $F1$ score and further dividing by the inference time. In a 15-frame window, both DCNN and the optimized DCNN achieve an accuracy of 99%. However, the accuracy diminishes in a 50-frame window, possibly due to overlapping frames.

In conclusion, our proposed approach showcases how sensor fusion-based Deep Learning methods, combined with sliding window techniques, can effectively classify boxing strikes. The results are promising, highlighting excellent accuracy during both training and testing, along with quick inference times under 1 ms. These outcomes hold potential for real-time boxing strike classification and extend to using a 9 DOF IMU sensor for diverse sports movement classification and HAR. Nonetheless, our work does have limitations. The fixed data acquisition frequency could impact the results; varying the frequency might yield different outcomes. Additionally, the scope of classified movements in our study was limited. Future research could encompass a broader range of boxing movements and combination strike classifications. Moreover, experimenting with different frequencies to determine suitable window sizes for systems like depth and video cameras for human activity classification remains a promising avenue for exploration.

Conclusion

The objective of this proposed work is to develop a deep learning-based technique for sensor data fusion utilizing an optimized overlapping sliding window. The pre-processing steps aim to enhance the recognition capability of boxing punches while reducing the computational complexity in a 3 DOF IMU sensor-based approach. This approach effectively captures time-series data, accommodating a diverse range of data types.

In this method, each IMU sensor's data undergoes a separate convolutional layer to extract distinct features relevant to body-worn sensors. These extracted features are then merged using the subsequent convolutional layer. The pre-processing involves employing an overlapping sliding window technique, which influences the costs associated with deep layer techniques.

To determine the most suitable window size, various window sizes are compared, and the optimal fit is identified for the proposed model. It has been observed that larger sliding windows enhance accuracy, but at the expense of increased processing time. Hence, selecting an optimal window size is crucial to strike proper balance between accuracy and inference time. The proposed specialized data fusion-based deep learning architecture, employing an overlapping window of 15 frames, achieves high accuracy (above 90%), an impressive $F1$ score (above 80%), and minimal inference time (below 0.1 ms). Frame sizes larger than the selected size does not improve the accuracy further, while smaller frame sizes decrease the $F1$ score.

Due to the imbalanced class distribution, the $F1$ score is used as a performance metric. The results show that the sensor fusion approach enhances boxing punch recognition performance, achieving 99% accuracy in classifying similar actions like a jab and a hook punch, where the classification model, DCNN, falls short. The confusion matrix indicates challenges in identifying similar activities, suggesting potential improvement through additional sensor data fusion techniques. The $F1$ score of 87% demonstrates the capability of the sensor data fusion approach to classify a wide array of activities.

In alignment with the study's objective, the proposed architecture incorporates an overlapping sliding window pre-processing technique and sensor data fusion convolutional layer, achieving accurate and precise recognition of various boxing punches with minimal inference time. This low inference time makes the proposed study suitable for real-time sports activity detection. However, the study's limitation is its exclusive focus on wearable sensor technology for activity recognition. For more complex or multiple punch recognition tasks, additional data sources like HD cameras and GPS systems can be considered in future work. Moreover, the experiments were conducted at a fixed 100 Hz frequency; exploring other frequency ranges and varying sliding window ranges are avenues for future consideration.

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Ethics

The study was approved by the ethics committee of Tagore Medical College and Hospital (Ref. No. IEC-TMC 19/2023, 11/01/2024).

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