CHAPTER 4- RESULTS AND DISCUSSION

The results of the present research are presented and discussed in this chapter, phase-wise as follows

PHASE 1

Nutritional Status Assessment, Tracking Energy Expenditure, Haemoglobin Estimation, Fitness Assessment and Morbidity Injury Profile

PHASE 2

A- Survey on the composition of commercially available protein supplements and sports drinks and

B- Development, supplementation and impact evaluation of a cocoa flavanol-rich drink on muscle recovery

PHASE-3

Assessment of nutrition awareness among participants and study the impact of Nutrition health education intervention

PHASE 1

NUTRITIONAL STATUS ASSESSMENT, TRACKING ENERGY EXPENDITURE, HAEMOGLOBIN ESTIMATION, FITNESS ASSESSMENT AND MORBIDITY INJURY PROFILE

All the sports associations located in Vadodara involved with cricket were visited. Elite cricketers from these associations were identified. The operational definition of elite male cricketers is those who train for a minimum of 5 hours for at least five days a week. The operational definition of elite female cricketers is those who train for a minimum of 4 hours for at least five days a week. The following inclusion criteria were used to enrol the participants in the study.

- Elite Male Cricketers 19 to 30 years of age.
- Elite Female Cricketers 14 to 30 years of age.
- Willing to participate.
- Cricketers who were not differently-abled or who did not suffer from any disease.
- Non-pregnant and non-lactating females.
- Those who were not under any drug treatment.

➢ Those with normal Creatine Kinase levels at the baseline.

In this phase, Assessment of nutritional status (by anthropometry + body composition+ dietary intake), Energy Expenditure, Haemoglobin Estimation, Fitness level and Morbidity Injury Profile were carried out on the participants.

The results of this phase are discussed under the following heads:

- Background information of the participants
- Nutritional status assessment based on anthropometric profile
- Body composition
- Energy expenditure
- Nutrient intake assessment
- Iron status
- Morbidity and injury profile
- Fitness assessment

BACKGROUND INFORMATION OF THE PARTICIPANTS

The participants (N=96) belonged to four squads, 2 boys' squads and 2 women's squads. Table 4.1 describes the background information of the participants.

Table 4.1: Background information of the participants across all the squads (N= 96)

Variables	Ranji boys	Under-23 boys	P value between Ranji and U-23 boys	Senior Women	Under-19 women	P value between Senior and U-19 women
No of participants	29	38	-	14	15	-
Gender	Male	Male	-	Female	Female	-
Mean age	24.7± 2.5	20.2± 1.2	**0.000***	22.2 ± 2.2	15.8± 1.0	**0.000***
Age range (yrs)	23-29	19-22	-	19-27	14-18	-
Mean experience of playing the sport (yrs)	9.5 ± 2.6	8.6 ± 2.1	0.136	6.9 ± 2.4	4.2 ±2.1	**0.003***

If the variable fell under the normal distribution curve, an independent sample t test was used, otherwise, the non-parametric test i.e. Mann Whitney U test was applied.

As can be seen from Table 4.1, there was a significant difference in the mean age of Ranji boys and the U-23 boys' squad. The criterion for selection in the Ranji boys was purely based on performance.

Even the players less than 23 years of age who cleared the selection process were included in the Ranji squad. Similarly, a significant difference was also noted in the mean age of Senior women and Under 19 women squads. Senior women had significantly higher mean experience of playing the sport as compared to the Under 19 women.

Table 4.2 narrates the background information of the participants in terms of Marital status, Education and Per Capita Income.

Table 4.2: Background information of the participants across all the squads (%)

Background information	**Ranji boys (n=28)**	**Under-23 boys (n=38)**	**Senior women (n=14)**	**Under-19 women (n=15)**	**Total (N=95)**
Marital Status					
Unmarried	93	100	100	100	97.9
Married	7	0	0	0	2.1
Education level					
Illiterate	0	0	0	0	0
Primary	0	5.3	0	13.3	4.2
SSC	17.9	2.6	14.3	46.7	15.8
HSC	21.4	23.7	35.7	40	27.4
Graduate	42.9	68.4	28.6	0	44.2
Postgraduate	17.9	0	21.4	0	8.4
Others	0	0	0	0	0
Occupation					
Service	25	0	0	0	25
Non – working	75	100	100	100	75
Type of family					
Nuclear	60.7	55.3	64.3	60	58.9
Joint	21.4	21.1	21.4	40	24.2
Extended	17.9	23.7	14.3	0	16.8
Per Capita Income					
< 1122	0	0	0	0	0
1123–2245	3.6	5.3	50	0	10
2246–3742	7.1	13.2	7.1	6.7	9
3743–7486	21.4	26.3	14.3	20	21
≥7487	68.0	55.3	28.6	73.3	55

Based on the modified B.G. Prasad scale (Dalvi, Khairnar & Kalghatgi, 2020) which takes into account the Per Capita Income (PCI) of the participants, the participants were classified into five categories namely upper class, Upper middle class, Middle class, Lower middle class and Lower class. The data revealed that almost the majority of the participants across all the squads belonged to the upper class; Under-19 women squad (73%), Ranji boys (72%), Under-23 boys (56%) and Senior women (29%). The criterion for the Upper class given by this scale is PCI of ≥ 7487 INR.As can be seen from table 4.2, the minimum education level across all the squads was primary. Postgraduates were from two squads; Senior women (21%) and Ranji boys (19%). Twenty-five percent of participants from the Ranji squad were gainfully employed.

Table 4.3 provides information about the education and occupation of the parents of the participants across all the squads.

Table 4.3: Background information of the participants' parents across all the squads (%)

Background information	**Ranji boys (n=27)**	**Under-23 boys (n=38)**	**Senior women (n=14)**	**Under-19 women (n=15)**	**Total (N=94)**
Education of Father					
Illiterate	3.7	5.3	7.1	0	4.3
Primary	0	5.3	14.3	6.7	5.3
SSC	22.2	15.8	21.4	6.7	17.0
HSC	14.8	7.9	28.6	40	18.1
Graduate	48.1	50	21.4	33.3	42.6
Postgraduate	11.1	10.5	7.1	13.3	10.6
MBBS	0	5.3	0	0	2.1
MD/MS/PhD	0	0	0	0	0
Education of Mother					
Illiterate	3.7	5.3	7.1	13.3	6.4
Primary	3.7	15.8	42.9	0	13.8
SSC	18.5	26.3	21.4	6.7	20.2
HSC	18.5	10.5	7.1	40	17.0
Graduate	37.0	28.9	21.4	26.7	29.8
Postgraduate	14.8	10.5	0	13.3	10.6
MBBS	0	2.6	0	0	1.1
MD/MS/PhD	3.7	0	0	0	1.1
Occupation of father					
Expired	3.7	0	0	6.7	2.1
Not working	7.4	2.6	21.4	0	6.4
Retired	14.8	5.3	7.1	0	7.4
Service	33.3	42.1	35.7	40	38.3
Business	29.6	18.4	7.1	33.3	22.3
Self-employed	11.1	31.6	28.6	20	23.4
Occupation of mother					
Expired	0	0	0	0	0
Not working	81.5	86.8	50	80	78.7
Retired	0	0	7.1	0	1.1
Service	18.5	5.3	21.4	20	13.8
Business	0	0	0	0	0
Self-employed	0	7.9	21.4	0	6.4

The majority of the parents were graduates (fathers-42.6%, mothers-29.8%) and the percentage of postgraduates was 10.6 % in both fathers and mothers (Table 4.3). The majority of the fathers were employed and serving (39.6%) while the majority of the mothers were housewives (78.7%).

Table 4.4 provides data on the habits of the participants in terms of addictive substance use.

Table 4.4: Habits of participants across all the squads with respect to addictive substances (%)

Addictive substance	Ranji boys (n=29)	Under-23 boys (n=38)	Senior women (n=14)	Under-19 women (n=15)	Total (n=96)
Tobacco	0	0	0	0	0
Alcohol- regularly	0	0	0	0	0
Alcohol- occasionally	24.1	2.6	0	6.7	9.4
Alcohol– rarely	10.3	5.3	0	0	5.2

As can be seen from table 4.4, Tobacco consumption was not seen in any of the participants. None of the participants consumed alcohol regularly. Participants consuming alcohol occasionally and rarely were from the two boys' squads and Under-19 women's squad, while in the senior women's squad, alcohol consumption was totally absent. The prevalence of alcohol consumption was less in the women's squad as compared to the boys' squad. Alcohol consumption can adversely affect nutritional status by contributing excess energy due to the presence of empty calories. However, there is no published literature available on addictive substance use by cricketers.

A survey of elite rugby league players (n= 404-preseason; 278-in-season) found very high consumption of alcohol. During the preseason, 68.6% of players and in-season 62.8% of them had hazardous levels of alcohol use (as indicated by the Alcohol Use Disorders Identification Test Consumption; 3-item scale questionnaire) (Du Preez et al., 2017)

NUTRITIONAL STATUS ASSESSMENT BASED ON ANTHROPOMETRIC PROFILE

The test of normality applied to various anthropometric variables can be seen in Table 4.5. The Shapiro Wilk test is applied to test normality as the sample size is less than 200. P value more than 0.05 indicates normal distribution. The figures marked with an asterisk and in bold are more than 0.05 and therefore the variables follow a normal distribution.

Table 4.5 Test of Normality

Variables	Shapiro-Wilk		
	Statistic	Df	P value
Ht (cm)	0.991	93	**0.781***
Wt(kg)	0.987	93	**0.521***
BMI	0.962	93	0.009

Variables	Statistic	Df	P value
WC (cm)	0.984	93	**0.302***
WHtR	0.915	93	0.000
HC (cm)	0.973	93	**0.053***
WHR	0.986	93	**0.438***

As can be seen from Table 4.5, variables- Height, Weight, Waist circumference, Hip circumference and Waist height ratio follow a normal distribution.

Table 4.6 reveals the anthropometric profile of the participants.

Table 4.6: Anthropometric profile of the participants across all the squads (Mean±SD)

Variable	Ranji boys (n=28)	Under-23 boys (n=38)	p value between Ranji and U-23 boys	Senior women (n=15)	Under-19 Women (n=14)	p value between Senior and U-19 women
Weight (kg)	67.6±7.8	68.8 ±8.3	0.563	54.4 ±10.6	55.5 ± 5.4	0.718
Height (cm)	172.5±6.4	173.0 ± 8.1	0.777	155.6 ±5.1	161.6 ±4.8	**0.003***
BMI	22.7 ±2.1	23.0 ±2.0	0.606	19.9 ±9.1	21.3 ± 2.2	0.348
WC (cm)	82 ± 5.8	83 ±6.0	0.865	81 ±8.6	80 ±6.3	0.598
HC (cm)	96 ± 4.8	98 ±5.4	0.213	98 ±7.4	98 ±5.1	0.969
WHR	0.86±0.04	0.85 ±0.03	0.163	0.83 ±0.05	0.82 ±0.04	0.350
WHtR	0.48 ± 0.03	0.48 ± 0.03	0.993	0.52 ±0.06	0.49±0.04	0.135

If the variable fell under the normal distribution curve, an independent sample t test was used, otherwise, the non-parametric test i.e.Mann Whitney U test was applied.

As is depicted in table 4.6, the mean height of the U-19 women was spotted to be significantly higher than the senior women squad (p=0.003). However, there was no such difference between the mean height of the two boys' squads. The mean BMI in the Ranji boys’, Senior women and Under-19 women squads was within the normal range of 18.50-22.9 by Asia Pacific Cut-offs (Gallagher, 2004), while that of Under-23 boys was slightly higher (23±2.0). The mean waist circumference of the participants from Ranji boys (82 ± 5.8), Under 23 boys (83 ±6.0) and Under 19 women (80 ±6.3cm) squad was within the normal range the cut-off being ≤90cm and ≤80cm respectively. The mean waist circumference of the participants from the Senior women (81 ± 8.6cm) squad was slightly higher than the cut-off of ≤80 cm. The mean WHR of the participants across all the squads (Ranji boys- 0.86±0.04, Under-23 boys-0.85 ±0.03, Senior women- 0.83 ±0.05 and Under-19 women- 0.82 ± 0.04) was within the normal range, the cut-off being 0.9 for men and 0.85 for women (WHO, 2005). The mean WHtR of the participants from Ranji boys (0.48 ± 0.03), Under-23 boys (0.48 ± 0.03) and Under-19 women (0.49±0.04) was normal according to the cut-off of<0.5. However, the mean WHtR of the participants from the Senior women squad (0.52 ±0.06) was higher than normal. Thus gender appropriate cut-offs (wherever applicable) revealed that the Ranji boys and the U-19 women squad had normal nutritional status as assessed by BMI and absence of abdominal obesity as measured by WC, WHR and WHtR. Though the U-23 boys' squad had a slightly higher mean BMI, the participants showed an absence of central obesity. The senior women squad had normal nutritional status based on BMI but showed high mean waist circumference which indicates abdominal obesity and high mean WHtR which signals short fat phenotype along with central obesity. However, WHR in this squad was in the normal range which could be due to both high hip and waist circumference which normalises the WHR.

A study was conducted on 98 Indian inter-university male cricketers aged 16-25 years (mean age 21.03 years, ± 1.72). The mean height of the participants was 171 ± 7.1 cm, mean weight was 61.8 ± 9.6 kg and BMI was 21.1 ± 2.7. (Koley, 2011) In the present research, participants from both the Ranji (24.7± 2.5yrs) and U-23(20.2± 1.2 yrs) squads weighed more (Ranji-67.6±7.8, U-23 boys-68.8 ±8.3) compared to the participants in the study by Koley, 2011 while the height was almost similar (Ranji-172.5±6.4, U-23 boys-173.0 ± 8.1) and BMI slightly higher. In a study conducted on a younger age group consisting of 60 district-level male cricketers (mean age-17.58±2.09 years) of West Bengal, the mean height of the players was 164.52±7.09cm, weight 54.56 ±9.87 kg and BMI 20.07±2.91. (Biswas & Ghosh, 2020)

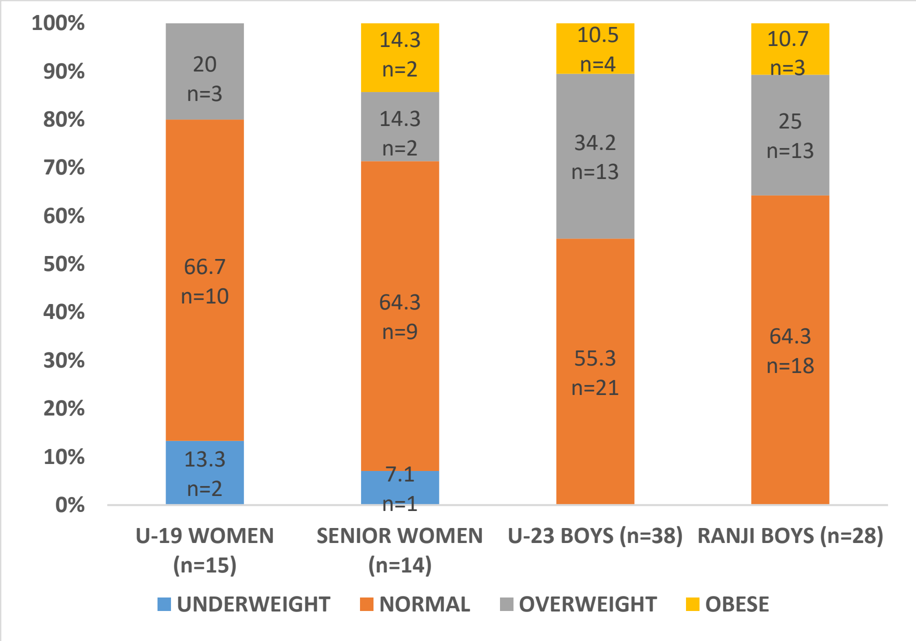
A study was carried out on 79 female state cricketers (39- Maharashtra players and 40- Punjab players) aged 18–25 years. The study revealed that the players were similar w.r.t mean height (156.3± 4.8 for Maharashtra, 157.3±6.5 for Punjab participants), mean weight (53.1 ± 8.4 kg for Maharashtra participants, 53.1 ± 8.5 kg for Punjab participants) and mean BMI (21.6 ±3.2 for Maharashtra, 21.7 ±2.5 for Punjab participants). (Koley, 2011)The participants from the senior women squad in the present study demonstrated similar height (155.6 ±5.1), weight (54.4 ±10.6) and BMI (19.9 ±9.1).

A study conducted on 28 male cricketers (n=14 Iranians and 14 Pakistanis) revealed that the waist circumference of Iranian players was 80.42±6.55 which is almost similar to that of Ranji boys (82 ± 5.8) and U-23 boys (83 ± 6.0) in the present study. The waist circumference of Pakistani players was 89.22±6.29 which is higher than that reported for the Ranji boys and U-23 boys' squads but within the normal range. (Ghalea and Peeri, 2015)

Nutritional status based on Body Mass Index (BMI)

The nutritional status of the participants according to BMI classification is depicted in figure 4.1.

Figure 4.1: Nutritional status based on BMI of participants from Ranji boys, U-23 boys, Senior women and U-19 women squads

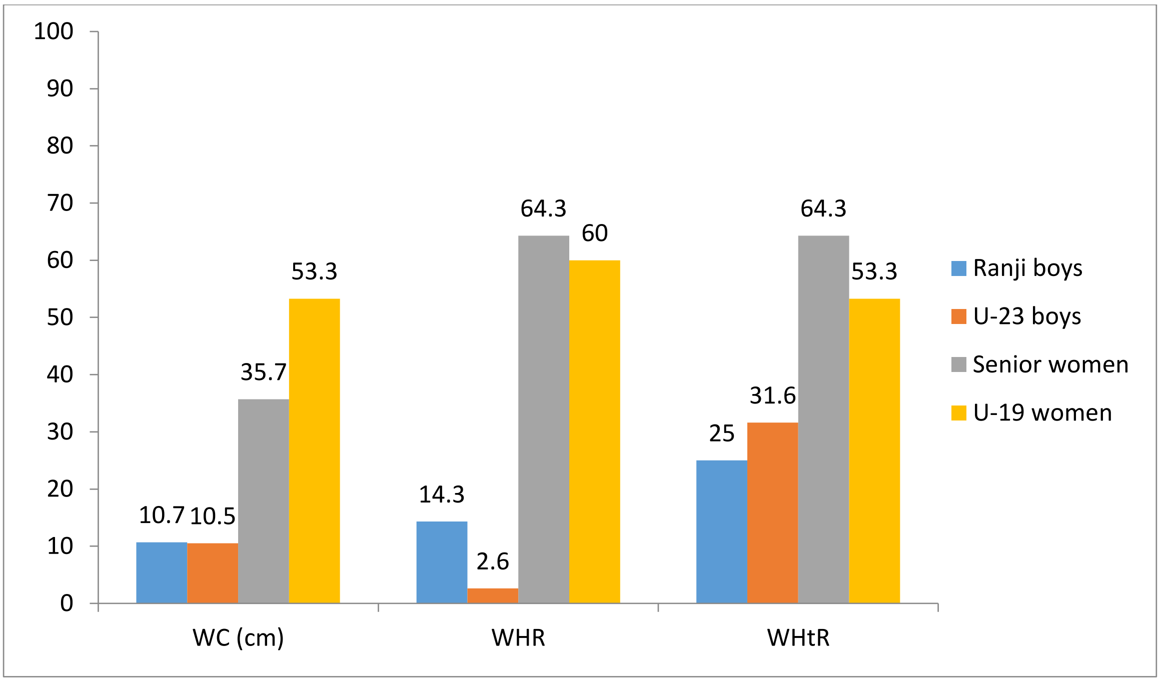


As can be seen in figure 4.1, the prevalence of overweight and obesity combined was highest in U-23 boys (44.7%), followed by Ranji boys (35.7%), Senior women (28.6%) and least in U-19 women (20%). Underweight participants were seen in only women squads; Senior women (7.1%) and U-19 Women (13.3%). Most studies have provided the mean BMI of the players and have not given further categorization of the participants by BMI therefore comparisons cannot be made.

Nutritional status based on Waist circumference (WC), Waist hip ratio (WHR), Waist height ratio (WHtR)

Three indicators namely WC, WHR and WHtR were utilised to assess the prevalence of abdominal obesity in the participants which is depicted in figure 4.2.

Figure 4.2: Prevalence of abdominal obesity based on Waist Circumference, Waist Hip Ratio, and Waist Height Ratio in participants from Ranji boys, U-23 boys, Senior women and U-19 women squads



As is depicted in figure 4.2, central obesity was found to be highest in Senior women (WHtR- 64.3%, WHR-64.3%, WC-35.7%). WHtR was found to capture the highest number of abdominally obese participants (Senior women-64.3%, Under-19 women- 53.3%, Under-23 boys' -31.6% and Ranji boys' -25%); while WC captured the least (Under-19 women-53.3%, Senior women-35.7%, Ranji boys'-10.7% and Under-23 boys'-10.5%). The participants being abdominally obese based on WHtR indicate the presence of short fat phenotype. Based on WHR, there were 64.3% abdominally obese participants in the Senior women, 60.0 % in the Under-19 women, 14.3% in Ranji boys' and 2.6% in the Under-23 boys' squad. Thus, looking at all the 3 indicators, the prevalence of abdominal obesity was found to be highest in Senior women followed by Under-19 women, Under-23 boys and least in Ranji boys. Amongst all these squads, the Ranji squad is the most elite level due to the rigorous selection criteria. WHtR identified maximum number of participants as centrally obese followed by WHR and WC. However, there is a dearth of published data assessing abdominal obesity in cricketers based on WC, WHR and WHtR.

BODY COMPOSITION

Body composition analysis in the participants was carried out by the Bio-electrical impedance method. The BIA instrument provides readings based on Gender, age, height, weight and activity level. The equation fed in it is for the general population and not specifically for athletes. The normality test performed on the variables is given in table 4.7. Shapiro Wilk test was applied to test normality as the sample size was less than 200. P value more than 0.05 indicates normal distribution. The figures marked with an asterisk and in bold are more than 0.05 which suggests that the variables follow a normal distribution.

Table 4.7: Test of Normality

	Shapiro-Wilk		
	Statistic	**df**	**P value**
BMR	0.984	93	**0.305***
Body fat (kg)	0.885	93	0.000
% body fat	0.940	93	0.000
Body lean (kg)	0.977	93	0.106
% LBM	0.932	93	0.000
TBW (lt)	0.962	93	0.009
BFMI	0.855	93	0.000
FFMI	0.972	93	0.043

As can be seen from Table 4.7, only the variable BMR follows a normal distribution.

The body composition data of the participants are depicted in Table 4.8. BFMI is body fat mass index (Body Fat/Ht^2 in metrics) and FFMI is fat free mass index (Lean mass/Ht^2 in metrics).

Table 4.8: Body composition of the participants from the Ranji boys', U-23 boys', Senior women and U-19 women squads (Mean±SD)

Component	**Ranji boys (n=27)**	**Under-23 boys (n=37)**	**P value between Ranji and U-23 boys**	**Senior women (n=14)**	**Under-19 women (n=15)**	**Pvalue between Senior and U-19 women**
BMR	1727.6± 186.0	1789±198.7	0.215	1331.6±128.3	1411.1±78.7	0.053*
Body Fat (%)	17.8 ± 2.9	15.9± 3.7	**0.026***	29.7 ± 5.3	24.0 ±5.2	**0.007***
Lean body mass (%)	82.2 ± 2.9	84.0± 3.7	**0.047***	69.8 ± 4.6	74.0 ± 5.5	**0.036***
Water (lt)	38.2 ± 3.8	39.3 ± 4.3	0.319	27.2 ± 3.0	28.2 ±1.7	0.279
BFMI	4.1 ± 0.9	3.7 ± 1.1	0.160	6.9 ± 2.6	5.15 ± 1.2	**0.036***
FFMI	18.7±1.6	19.2 ± 1.3	0.120	15.5 ±1.8	15.7 ± 1.2	0.734

If the variable fell under the normal distribution curve, an independent sample t test was used, otherwise, the non-parametric test i.e. Mann Whitney U test was applied.

Mean percent body fat (p=0.007) and BFMI (p=0.036) were significantly higher in Senior Women compared to U-19 Women. Whereas the mean percent lean body mass was significantly lower in Senior Women compared to U-19 Women (p=0.036). Mean percent body fat was found to be significantly higher in the Ranji boys compared to the Under 23 boys' squad (p=0.026) and the mean percent lean mass was significantly lower in the Ranji boys compared to the Under 23 boys (p=0.047). BFMI is a more reliable indicator as compared to percent body fat as it takes into account height as well. Thus, in both the boys' and women squads, the older group had higher percent body fat. Research has demonstrated that percent body fat increases every decade starting from 20 years to 50 years in men and 60 years in women. (Marwaha et al., 2014)

American Council on Exercise (ACE), 2009 recommends percent body fat for athletes to be ranging between 6 and 13% for men and 14 and 20% for women. According to these cut-offs, the mean percent body fat of the cricketers belonging to all the squads was higher. Another published ideal range for body fat in athletes is 5-10% for males and 8-15% for females. (Bhide and Madalika, 2018 ; Jeukendrup, 2010)These values are on the lower side as compared to the normal range given by ACE. Research conducted on healthy, non-athletic Asian populations revealed that the participants had a higher body fat percent at a lower BMI compared to Caucasians.(Deurenberg, Deurenberg-Yap, & Guricci, 2002) Studies show that athletes have higher lean body mass and lower body fat mass compared to their non-athletic counterparts. (Sukanta, 2014)However, the same is not seen in the present study where the participants had higher body fat mass than the cut-offs for athletes. The available ideal percent body fat ranges are not specific to the Indian population. Therefore, more research needs to be conducted on Elite Indian and Asian athletes to arrive at the ethno specific ideal percent body fat.

In a study conducted on 60 district-level male cricketers of West Bengal with a mean age of 17.58±2.09 years, the percent body fat of the players was 13.13±4.52 which is less than that of U-23 boys in the present study. However, the percentage of fat was calculated using Durnin andWomersley prediction equation in this study (Biswas & Ghosh, 2020), while in the present study it was assessed using the bioelectrical impedance method. Since the results of BIA and Durnin and Womersley equation compare well (Campa et al., 2022), it can be inferred that participants from the present study had higher percent body fat compared to the study by Biswas and Ghosh. In a study carried out on 30 male cricketers (15-25 years), from the district sports academy in Madhya Pradesh, percent body fat of the players was 16.81±3.88 which is similar to that of Ranji boys and U-23 boys in the present study. The percentage of body fat was determined by Harpenden calliper using the standard method in this study.(Rukadikar, Mundewadi& Kadam, 2020)

There are studies, though limited which have explored effects of higher body fat percent on the performance of cricketers. Higher than normal body fat percent in sports involving movement is linked negatively with performance as fat is not a contractile tissue and it also represents the extra weight that an athlete needs to carry while performing a movement. A study carried out on 82 male cricketers reported an inverse relationship between body fat percent and performance of athletes in fitness tests namely; vertical jump, 10-metre speed, 40-metre speed and agility test involving two 180° turns over a longer distance. An increased muscle mass percent was related to improved vertical jump scores in the participants. (https://cricket.co.za/wp-content/uploads/2021/05/Effect-of-Body-Composition.pdf) However, a study on 35 male cricketers from Amritsar reported findings. No significant effect of high body fat percent or lean body mass was seen on the throwing skills (assessed by the AAHPERD Basketball skill test) of the cricketers. Moreover, in this study association was not observed between any anthropometric and body composition parameters and throwing skill. (Sandeep Singh, 2017)

The mean percent lean body mass of Indian male cricketers playing at university, state or national level (aged 15 to 25 years) was 83.19 as assessed by skin fold measurement. These values are similar to those of Ranji boys and Under-23 boys' in the present study. (Rukadikar et al., 2020)

In a study conducted on district-level male cricketers (n=60) of West Bengal, the BMR of the players was 1516.51±154.85 which is lower than both Ranji boys and U-23 boys in the present study. BMR was predicted from the equation; 66+ (13.7 x body mass, kg) + (5.0 x stature, cm)-(6.8 x age, y) (Biswas & Ghosh, 2020) while in the present study it was assessed using bio-electrical impedance.

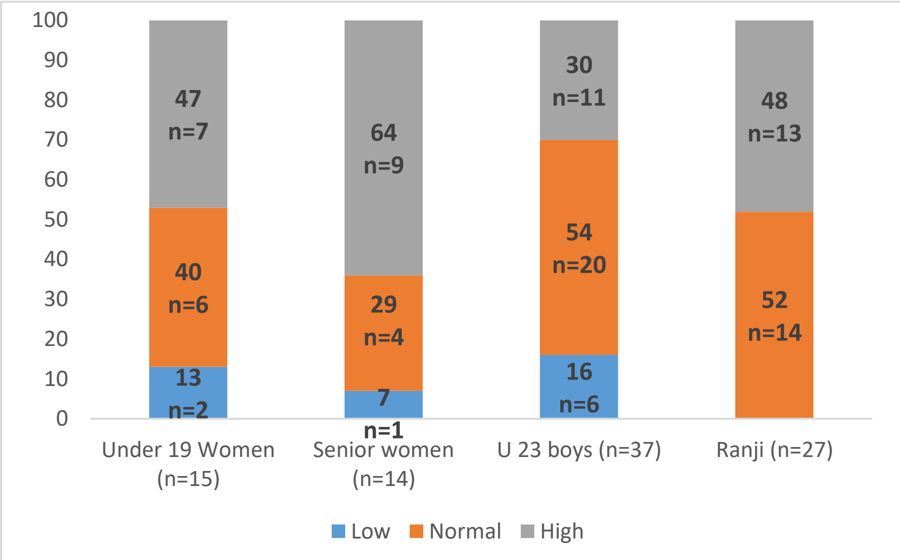
Table 4.9: Association between BMR and Body composition indicators across all the squads (n=93)

		FFMI	% LBM	% body fat	BFMI	TBW (lts)
BMR (kcal/day)	r value	0.864**	0.685**	-0.616**	-0.417**	0.976**
	p value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

As is depicted in table 4.9, percent lean body mass, FFMI and total body water are positively correlated with BMR while percent body fat and BFMI are negatively associated with BMR.

Figures 4.3, 4.4 and 4.5 categorise the body composition components of the participants into low, normal or high. The cut-offs used to classify body composition components into low, normal and high were those generated by the body composition analyser individually for each participant.

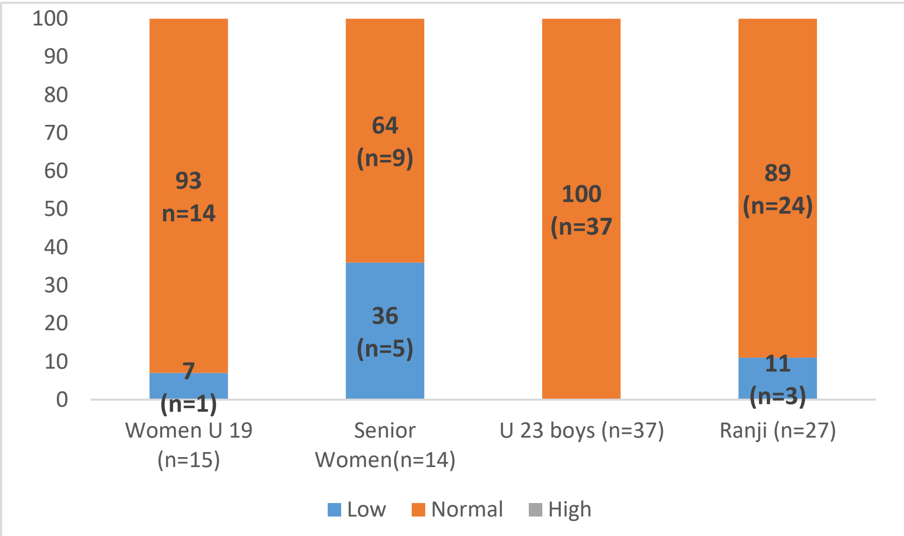
Figure 4.3: Categorization of cricketers across all the squads based on fat levels



As is presented in figure 4.3, only 29-54 % of the participants had normal percent body fat. Sixty-four percent of participants from the Senior women squad, 48% from Ranji boys, 47% from Under-19 women and 30% from Under-23 boys squad had higher than normal percent body fat. A negative correlation has been observed between body fat and athletic performance in movements requiring translocation of body mass either vertically as in jumping or horizontally as in running. (Bhide and Madalika, 2018) As cricketers require both jumping and running as an integral part of their sport, high body fat has the potential to adversely affect their performance. Lower than normal fat was seen in 16% of the Under 23 boys, 13% of the Under-19 women and 7% of the Senior women. Low body fat is also not desirable as it can adversely affect basic physiological functions (like absorption of fat-soluble vitamins) of the body as well as athletic performance. Percent body fat lower than 12% can be detrimental especially in females as it affects the reproductive system and is also linked to amenorrhoea. (Torstveit and Borgen, 2012)There is no literature available which categorises the body composition components of the participants.

The under-23 boys' squad was the only group where 100% of participants had normal percent lean body mass. (Figure 4.4) None of the cricketers across all the squads had higher than normal percent lean body mass. Percent lean body mass was low in 36% of Senior women, followed by 11% of Ranji boys and 7% of the Under-19 women squad. Lean body mass is vital in producing required movement, and energy during sports activities and for strength. Individuals with a greater amount of lean mass have more number of sarcomeres (i.e., biological units where muscle tension occurs) which increases the strength production through muscle contraction. (Almeida-Neto et al., 2020)

Figure 4.4: Categorization of cricketers across all the squads based on Percent Lean body mass levels



ENERGY EXPENDITURE

It was assessed using a Fitness tracker which the participants had to wear on their wrists. The mean energy expenditure in the Women's squad during a one-day (50 over) match was tracked. Average energy expended by the batsman (n=7) per hour was 83 kcal, fielder (113 kcal, n=2), Spinner (82 kcal, n=3), Pacer (107 kcal, n=3) and Wicketkeeper (61 kcal, n=1). As the energy expenditure data were available for only limited participants, further analysis could not be done and the inference was not drawn.

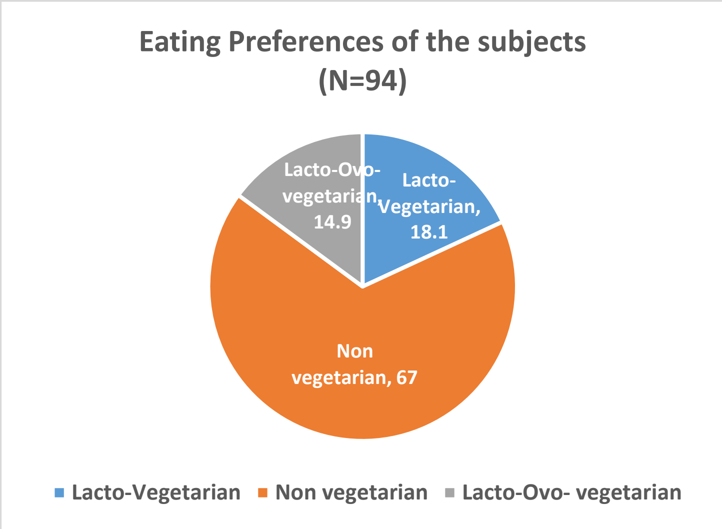
Similar data could not be captured in the boys' squad as due to the stringent Board of Cricket Control in India (BCCI) rules, they do not allow outsiders to be present on the ground during matches.

A study was conducted on Competitive male cricket players (>16y) from the Auckland Cricket Association during competitive 'one-day format' cricket matches. Match data were collected from 27 cases over six games from 18 participants. The average match EE per hour in the participants was 242 ±63.6 kcal/hour. (Mcdonald, 2018)

Eating Preference

Figure 4.5 depicts the eating preferences of the participants. The majority of the participants were non-vegetarians, followed by lacto-vegetarians and lacto-ovo-vegetarians (those who consumed eggs in addition to the vegetarian food).

Figure 4.5: Eating Preference of the cricketers



NUTRIENT INTAKE ASSESSMENT

Twenty-four-hour diet recall was recorded for 3 days to assess the nutrient intake of the participants. The test of Normality for the various nutrients can be seen in table 4.10 and the nutrient intake across various squads is depicted in table 4.10. The Shapiro Wilk test is applied to test normality as the sample size is less than 200.

Table 4.10: Test of Normality

	Shapiro-Wilk		
	Statistic	**Df**	**P value**
Energy (Kcal)	0.974	93	**0.063***
Carbohydrate (g)	0.979	93	**0.132***
Protein (g)	0.951	93	0.002
Total Fat (g)	0.979	93	**0.147***
Calcium (mg)	0.969	93	0.028
Iron (mg)	0.959	93	0.005
Total Ascorbic Acid (mg)	0.758	93	0.000

P value more than 0.05 indicates normal distribution. The figures marked with an asterisk and in bold are more than 0.05 which suggests that the variables follow a normal distribution. The variables Energy, Carbohydrates and total fat follow a normal distribution.

The Estimated average requirement (EAR) provided by ICMR, 2020 for a moderate worker was used to compare the Energy intake of the cricketers. The rationale behind this was that cricket is not a very physically demanding sport and the RDA given by ISSN, IOC and ACSM are not specific to the Indian population and are very much on the higher side. The RDA by ISSN/ACSM/IOC mentioned in tables 4.11, 4.12, 4.13 and 4.14 are presented only for comparison.

Table 4.11 Comparison of Energy and Macronutrient Intake in the cricketers from the Ranji squad with the standards

Nutrient	Mean Intake	Recommendations/ Guidelines	Remarks	Other guidelines
Energy (kcal)	2553±684	2710 kcal/day (ICMR EAR)	94% of the EAR	ISSN- 67.6*50= 3380 kcal 67.6*80= 5408 kcal
Carbohydrate (g)	300.39±82.02	55-60% of total calories	47% of total calories	ISSN- 67.6*6= 405.6 g 67.6*10=676g
Protein (g)	83.5 ± 27.14	15-20% of total calories	13% of total calories	ISSN- 67.6*1=67.6 g 67.6*1.5=101.4g IOC-1.3-1.8 g/kg BW/day 67.6*1.3=87.9 g 67.6*1.8=121.7 g ACSM-1.2-1.7g/kg bw 67.6*1.2=81.1 g 67.6*1.7=114.9g
Fat (g)	101.67 ± 29.5	20-25% of total calories	36% of total calories	ACSM 20-35% - 20%- 56.7g 35%- 99.3g ISSN- 30%- 85.1g IOC- 15 to 20%- 15%- 42.5g 20%- 56.7 g

As is depicted in table 4.11, the mean Energy intake of the Ranji boys' squad was only 94% of the EAR. The desirable ratio of Carbohydrate: Protein: Fat of 55-60%:15-20%:20-25% was used to compare the energy coming from macronutrients in the diet of the players. When the energy contributed by macronutrients was assessed in this squad the distribution was found to be Carbohydrate 47%: Protein-13%: Fat 36%. Thus in the Ranji squad, the participants were consuming more fats and less of carbohydrates and proteins.

As is presented in table 4.12, the mean Energy intake of the Under-23 boys' squad was only 97% of the EAR. Energy intake of inter-university level male cricketers (n=20) from Kashmir was 4840±511 kcal/day which is much higher than that of the participants from Ranji boys (2553 ± 684 kcal/day) and Under-23 boys' (2618±846 kcal/day) squads.(Singh, 2016)

The energy derived from macronutrients in this squad followed a nearly similar pattern to the Ranji boys' squad; the distribution being, Carbohydrate- 48%: Protein-14%: Fat 37% instead of the desirable ratio of Carbohydrate- 55-60%: Protein-15-20%: Fat 20-25%. Thus in the Under-23 boys' squad, calories coming from fat were higher and those from carbohydrates and proteins were less than desirable.

Table 4.12: Comparison of Energy and Macronutrient Intake in the cricketers from the Under-23 boys' squad with the standards

Nutrient	U-23 boys	Recommendations/ Guidelines	Remarks	Other guidelines
Energy (kcal)	2618±846	2710kcal/day (EAR)	97% of the EAR	ISSN- 68.8 *50= 3430 kcal 68.8 *80= 5504 kcal
Carbohydrate (g)	311.82±108.58	55-60% of total calories	48% of total calories	ISSN- 68.8 *10=688g 68.8 *6= 412.8g
Protein (g)	90.87±31.12	15-20% of total calories	14% of total calories	ISSN- 68.8 *1.5=103.2g -68.8 *1=68.8 g IOC-1.3-1.8 g/kg BW/day 68.8 *1.3=89.4 g 68.8 *1.8=123.8 g ACSM-1.2-1.7g/kg bw 68.8 *1.2=82.6 g 68.8 *1.7=117.0g
Fat (g)	107.61±36.31	20-25% of total calories	37% of total calories	ACSM 20-35% - 20%- 58.2 g 35%- 101.8g ISSN- 30%- 87.3 g IOC- 15 to 20%- 15%- 43.6 g 20%- 58.2 g

Table 4.13: Comparison of Energy and Macronutrient Intake in the cricketers from the Senior women's squad with the standards

Nutrient	Senior women	Recommendations/ Guidelines	Remarks	Other guidelines
Energy (kcal)	1740±383	2130kcal/day (EAR)	82% of the EAR	ISSN- 54.4*50= 2720 kcal 54.4*80= 4352 kcal
Carbohydrate (g)	215.11±52.01	55-60% of total calories	49% of total calories	ISSN- 54.4*10=544g 54.4*6= 326.4g
Protein (g)	53.20±16.57	15-20% of total calories	12% of total calories	ISSN- 54.4*1.5=81.6g 54.4*1=54.4 g IOC-1.3-1.8 g/kg BW/day 54.4*1.3=70.7 g 54.4*1.8=97.9 g ACSM-1.2-1.7g/kg bw 54.4*1.2=65.3g 54.4*1.7=92.5g
Fat (g)	71.77±16.25	20-25% of total calories	37% of total calories	ACSM 20-35% - 20%- 38.6 g 35%- 67.6g ISSN- 30%- 58 g IOC- 15 to 20%- 15%- 29 g 20%- 38.6 g

As is presented in table 4.13, the mean Energy intake of the Senior women squad was only 82% of the EAR. The Carbohydrates contributed 49% of the total calories, protein 12% and fats 37% instead of the desirable ratio of Carbohydrate- 55-60%: Protein-15-20%: Fat-20-25%. Thus, in the Senior women squad as well the mean macronutrient intake consisted of excess fats and was deficient in carbohydrates and proteins.

Table 4.14: Comparison of Energy and Macronutrient Intake in the cricketers from the Under-19 women squad with the standards

Nutrient	U-19 women	Recommendations/ Guidelines	Remarks	Other guidelines
Energy (kcal)	1809±504	2130 kcal/day (EAR)	85% of the EAR	ISSN- 55.5 *50= 2775 kcal 55.5 *80= 4440 kcal
Carbohydrate (g)	226.10±64.14	55-60% of the total calories	50% of the total calories	ISSN- 54.4*10=544g 54.4*6= 326.4g
Protein (g)	53.87±15.24	15-20% of the total calories	12% of the total calories	ISSN- 54.4*1.5=81.6g -54.4*1=54.4g IOC-1.3-1.8 g/kg BW/day 54.4*1.3= 70.7g 54.4*1.8=97.9g ACSM-1.2-1.7g/kg bw 54.4*1.2=65.3g 54.4*1.7=92.5g
Fat (g)	74.04±23.40	20-25% of the total calories	37% of the total calories	ACSM 20-35% - 20%- 40.2 g 35%- 70.4g ISSN- 30%- 60.3 g IOC- 15 to 20%- 15%- 30.1 g 20%- 40.2 g

As is presented in table 4.14, the mean Energy intake of the Under-19 women squad was only 85% of the EAR. Half of the calories in this squad were derived from Carbohydrate, 12% from protein and 37% from fats. Thus the mean macronutrient intake of the athletes from this squad was deficient in Carbohydrates and proteins and had excess fats.

All the squads demonstrated lower than normal mean EAR. The energy derived from macronutrients followed nearly similar trends in all the squads. The mean macronutrient intake of participants consisted of more fats and less of carbohydrates and proteins compared to the ideal percent distribution. Low carbohydrate intake is linked with compromised protein sparing action. It can also lead to compromised training and match performance due to the insufficiency of the fuel supply required for physical activity. Carbohydrates also have a crucial role in recovery post strenuous exercise. Moreover, chronic low carbohydrate intake adversely affects the immune and central nervous systems. (Bhide and Mandalika, 2018, Burke et al., 2017) Low energy availability leads to

Relative Energy Deficiency in sports (RED-S) in athletes. RED-S refers to 'impaired physiological functioning caused by a relative energy deficiency and includes, but is not limited to, impairments of metabolic rate, menstrual function, bone health, immunity, protein synthesis and cardiovascular health'.(Mountjoy et al., 2018) A diet deficient in carbohydrates rather than energy is linked with a greater negative impact on an athlete's health. Thus, it is not only important to meet the calories but to ensure that adequate energy comes from carbohydrates failing which athlete becomes more susceptible to RED-S. (Burke et al., 2017)

Insufficient protein intake leads to tissue protein breakdown. Low protein intake can result in compromised protein synthesis and slower recovery post intense workout. Lack of protein is also associated with difficulty in training adaptation. (Bhide and Mandalika, 2018) Excessive fat intake can result in obesity due to the high energy density of fats which can adversely affect health and athletic career.

Table 4.15: Micronutrient intake and percent RDA met for micronutrients in the participants from the Ranji boys, U-23 boys, Senior women and U-19 women squads

Squads	Calcium intake (mg/day)	% RDA met for Calcium	Iron intake (mg/day)	% RDA met for Iron	Ascorbic acid intake (mg/day)	% RDA met for Ascorbic acid
Ranji boys	913.92±321.62	-8.7	15.65±5.50	-17.6%	137.08±99.71	+71.3%
U-23 boys	1104.96±519.06	+10.5	14.30±4.54	-24.7%	118.77±48.06	+48.5%
P value	0.223		0.613		0.678	
Senior women	525.38±212.81	-47.5	9.94±2.28	-65.7%	74.05±36.04	+13.9%
U-19 women	626.48±272.29	-37.3	10.62±3.16	-63.2%	100.23±39.49	+54.2%
P value	0.903		0.977		0.707	

For Calcium, Iron and Ascorbic acid the RDA by ICMR-NIN, 2020 were compared as there are no RDA by ISSN, ACSM and IOC for micronutrients (Table 4.15). The mean Calcium intake of only the Under-23 squad exceeded the RDA of 1000 mg/day for both men and women. Both the Ranji boys and U-23 boys' squads had lesser Iron intake than the RDA of 19mg/day for men. Both the Senior women and Under-19 women also had lesser Iron intake than the RDA of 29 mg/day for women. For ascorbic acid, both the Ranji boys and Under-23 boys exceeded the RDA of 80mg/day for men. Both the Senior women and Under-19 women squad also exceeded the ascorbic acid RDA of 65mg/day for women.

Significant differences were not observed in the means of Calcium, Iron and Ascorbic acid intake in Ranji boys and U-23 boys nor Senior women and U-19 women squads. All the squads had deficient mean Iron intake; while all the squads met the RDA for ascorbic acid. For Calcium, the mean intake of all the squads except the Under-23 boys' squad was deficient compared to the RDA (Table 4.15).

Table 4.16 depicts the mean food group-wise intake and the number of exchanges consumed of each food group across all the squads. The recommended food group-wise exchanges by ICMR for a moderate worker (Dietary Guidelines for Indians, 2011) were used to compare the intake of the participants. The recommendations for a moderate worker were considered as the activity level of the participants matches closest to that of a moderate worker.

Table 4.16: Mean food group-wise intake of participants from Ranji boys, U-23 boys, Senior women and U-19 women squads

Food group	Ranji boys	U-23 boys	Recommended exchanges for men	Senior women	U-19 women	Recommended exchanges for women
Cereals and	213±75 (7.1)	214 ± 80	15	152.8±42.4 (5.1)	166.8±57.4 (5.56)	11
Pulses	56 ± 43 (1.9)	35 ± 22(1.2)	3	42.1±23.4 (1.4)	31.8±23.2 (1.1)	2.5
Other vegetables	167 ± 79	136± 59	2	87.8±56.8 (0.9)	120.4±65.3 (1.2)	2
Roots and tubers	145 ± 76	158 ± 69	2	77.2±46.2 (0.8)	108.1±50.4 (1.1)	2
Green leafy	54 ± 39 (0.54)	43 ± 25	1	38.7±30.4 (0.4)	29.9±28.9 (0.29)	1
Fruits	282 ± 249	207 ± 123	1	121.6±119.2 (1.2)	206.7±105.3(2.1)	1
Milk and milk	541 ± 295	701 ± 383	3	357.4±142.7 (3.6)	453.8±209.0 (4.5)	3
Fats and Oils	43 ± 15 (8.6)	40 ± 12	6	36.5±12.9 (7.2)	31.9±10.8 (6.4)	5
Sugar	39± 39 (7.8)	32 ± 19	6	19.3±9.6 (3.9)	20.0±12.5 (4.0)	6
Egg and egg	65 ± 43 (1.3)	118 ± 97	NA	50.4±43.3 (1.0)	43.5±18.7 (0.9)	NA
Nuts and oilseeds	23 ± 21	13 ± 6	NA	9.3±4.9	29.4±15.9	NA

The figures in parenthesis indicate exchanges

As is evident from table 4.16, the intake of cereals and millets was low than the recommended across all the squads. In all groups, consumption of pulses, other vegetables, roots and tubers, and green leafy vegetables was lower than recommended. The consumption of milk and milk products, as well as fats and oils, exceeded the recommended levels in all groups. Sugar intake was higher than the recommended in both the boys’ squads while it was lower than the suggested in both the women's squads. Low cereal and millet consumption can be linked to the participants' low carbohydrate intake.

Egg, milk, and milk products, as well as fats and oils, contributed to the high fat consumption of all squads.

Frequency of consumption of Iron and Calcium-rich foods in the participants

The participants were interviewed about the frequency of their consumption of Iron and Calcium-rich foods. Table 4.17 depicts the top 10 most frequently i.e. daily, thrice a week, twice a week and weekly consumed Iron-rich foods by the cricketers across all the squads.

Table 4.17: Top ten most frequently consumed (Daily, thrice week, twice a week and weekly) Iron-rich foods in the Ranji boys, U-23 boys, Senior women and U-19 women squad (n,%)

Food item	Ranji boys (n=27)	Under-23 boys (n=37)	Senior women (n=13)	Under-19 women (n=15)	Total
Wheat flour, whole	25(92.6)	37(100)	13 (100)	15 (100)	90 (98.1)
Green gram dal	23 (85.1)	28 (75.6)	11 (84.6)	7 (46.8)	69 (73)
Black gram dal	21 (77.7)	23 (62.1)	6 (46.2)	11 (73.3)	61 (64.8)
Bengal gram(whole)	24 (88.8)	23(67.5)	7 (53.9)	7 (46.8)	61 (64.8)
Bengal gram, dal	20 (40.7)	28(75.6)	10 (76.9)	8 (53.3)	66 (61.6)
Green gram(whole)	22 (48.1)	23(62.1)	10 (77)	10 (46.8)	65 (58.5)
Bengal gram, roasted	13 (48.1)	10(27)	4 (30.8)	4 (95.8)	31(50.4)
Lentil	12 (44.4)	14(37.8)	5 (38.5)	7 (46.6)	38(41.8)
Cowpea	13 (48.1)	12 (32.4)	4 (30.8)	6 (40)	35(37.8)
Coconut, dry	8(29.6)	12 (32.4)	6 (46.1)	7 (40.1)	33(37.0)

Figures in parenthesis represent the percentages

Table 4.18 depicts the top 10 most frequently i.e. daily, thrice a week, twice a week and weekly consumed Calcium-rich foods by the cricketers across all the squads.

Table 4.18: Top ten most frequently consumed (Daily, thrice week, twice a week and weekly) Calcium-rich foods in the Ranji boys, U-23 boys, Senior women and U-19 women squad (n,%)

Food item	Ranji boys (n=27)	Under-23 boys (n=37)	Senior women (n=13)	Under-19 women (n=15)	Total
Curd	22 (81.4)	32 (86.4)	13 (100)	15 (100)	82 (91.9)
Green gram (whole)	22 (81.4)	23 (62.1)	10 (77)	9 (60.1)	64 (70.1)
Black gram dal	24 (77.7)	23 (62.1)	6 (46.2)	11 (73.3)	64 (70.1)
Bengal gram (whole)	24 (88.8)	25 (67.5)	7 (53.9)	7 (46.8)	63 (64.2)
Spinach	18 (66.6)	20 (54)	7 (53.9)	11 (73.3)	57 (61.9)
Milk (buffalo)	20 (74.1)	22 (59.5)	7 (53.8)	9 (60)	55 (61.8)
Dates(dried)	17 (62.9)	25 (67.5)	5 (38.5)	8 (53.3)	55 (55.5)
Paneer	17 (62.9)	25 (67.5)	2 (15.4)	6 (33.4)	50 (44.8)
Fenugreek leaves	12 (44.4)	19 (51.3)	6 (46.2)	8 (53.3)	45 (48.8)
Coconut dry	8 (29.6)	12 (32.4)	6 (46.2)	6 (40.1)	32(37.0)

Figures in parenthesis represent the percentages

As is presented in table 4.18, the top 10 most frequently foods consumed by the players include Milk, curd and paneer. Milk and milk products despite having less Calcium than some other sources, on account of low inhibitors and favourable pH are better sources of Calcium.

IRON STATUS

Iron is one of the most critical minerals with implications for sports performance. Haemoglobin levels were obtained to assess the Iron status of the participants. If haemoglobin levels are low, then less oxygen is delivered to muscle cells, greatly reducing exercise capacity and endurance. Haemoglobin is an important determinant of maximal aerobic power (VO_2max). As aerobic energy systems are largely essential for any exercise lasting longer than 15-30 sec, haemoglobin is vital for success in numerous team and individual sports. (Goodrich et al., 2020)Table 4.19depicts the test of normality for Haemoglobin. The Shapiro Wilk test is applied to test normality as the sample size is less than 200.

Table 4.19: Test of normality

Shapiro-Wilk			
	Statistic	**Df**	**P value**
Hb (gm%)	0.958	64	0.030

P value more than 0.05 indicates normal distribution. As can be inferred from table 4.19, Haemoglobin levels are not normally distributed.

The mean haemoglobin levels of the participants are presented in Table 4.20.

Table 4.20: Haemoglobin status of the participants across all the squads (Mean ±SD)

Parameter	**Ranji boys (n=21)**	**Under-23 boys (n=15)**	**P value between Ranji and U-23 boys**	**Senior women (n=13)**	**Under-19 women (n=15)**	**P value between Senior and U-19 women**
Haemoglobin (g/dl)	15.0± 0.90	14.3 ± 1.15	**0.036***	12.3 ± 0.87	12.3 ± 1.21	0.904

As the variables did not follow a normal distribution non-parametric test i.e. Mann Whitney U test was run

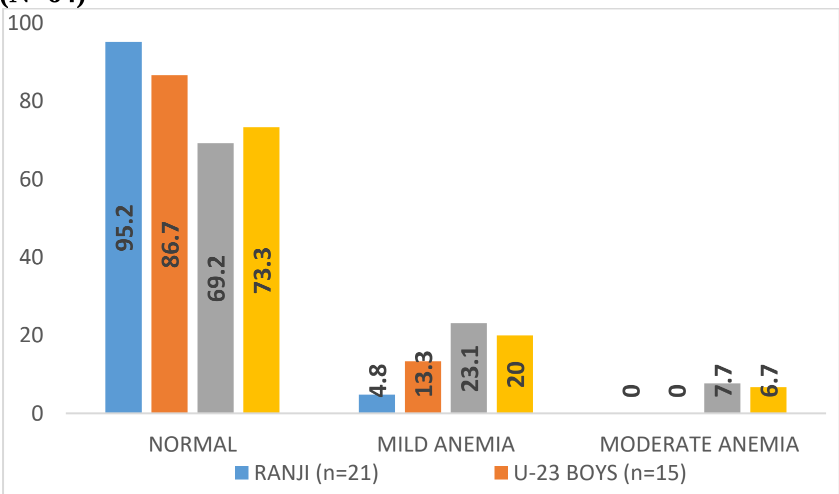
As can be seen from Table 4.20, the mean haemoglobin levels of the participants across all the squads were in the normal range. (Men- >13g/dl and females->12g/dl, WHO)Though the mean Iron intake across all the squads was deficient the mean haemoglobin levels were in the normal range. There was no significant difference in the mean Haemoglobin levels of the 2 women's squads. However, the mean haemoglobin levels of the Ranji boys' squad were statistically higher than that of the Under-23 boys. Normal haemoglobin levels are essential for cardio respiratory fitness and are crucial for activities like running, sprinting, jumping etc and thus influence the components of fitness like agility and speed. The major sources of Iron in the diets of the participants as revealed by the FFQ were whole wheat flour, green gram dal, Black gram dal, whole Bengal gram and Bengal gram dal.

A study was carried out on 12 soccer players at Kwame Nkrumah University of Science and Technology, Ghana. The baseline mean haemoglobin of the participants was 14.66 ± 0.64 which was in the normal range. (Opoku-Okrah et al, 2016)A research was carried out on 97 college athletes who participated in various sports; and the mean Haemoglobin levels were sprinting (Males- 15.7 ± 0.8, females- 13.6 ± 0.2), throwing (Males- 16.1 ± 0.4) , females- 13.9 ± 0.9), jumping (Males- 15.4 ± 1.0, females- 15.3± 1.0), middle and long-distance running (Males- 14.8 ± 0.7, females- 13.0 ± 0.6), judo (Males- 15.6 ± 0.9, females- 13.5 ± 0.7) and gymnastics (Males- 15.0 ± 1.0, females- 13.9 ± 0.9) The hemoglobin levels were within the normal range in all athletes; thus none of the athletes were anemic. (Fujii et al, 2015) Another study conducted on Rugby players (forwards- n=18, backs-n=16 and sedentary controls-n=26), revealed the mean haemoglobin levels in Forwards (15.4±0.8), backs (15.8±0.6) and controls (16.0±0.9). This study also concluded that none of the players had anemia. (Imamura et al., 2013)

However, there are no studies exploring the haemoglobin levels in cricketers.

Figure 4.6 depicts the Categorization of the participants into normal, mild anemia and moderate anemia based on the haemoglobin levels.

Figure 4.6: Categorization of the participants from Ranji boys, U-23 boys, Senior women and U-19 women into normal, mild anemia and moderate anemia based on the haemoglobin levels (N=64)



Similar to the vast available literature, Anemia was more prevalent in women (32.14%) than in men (8.33%). Mild anemia was present in 23% of the Senior women squad, 20% of the Under-19 women, 13% in the Under-23 boys' squad and 5% in the Ranji boys squad. Moderate anemia was found only in Women, Senior Women (7.7%) and Under-19 women squad (6.7%). None of the cricketers had severe anemia.

As these are elite cricketers, the presence of anaemia is surprising and a matter of concern. They should undergo regular monitoring and immediate intervention whenever required. However, the cricketers were not undergoing regular monitoring of iron status. As lack of Haemoglobin has an impact on endurance, it can lead to compromised athletic performance. Therefore an attempt is required to maintain the haemoglobin levels in the players by regular monitoring and providing needed intervention. The cricketers who were deficient were suggested to consume foods rich in iron and vitamin C (to enhance absorption) and a list (Annexure 15) of such foods was provided to them. It was explained to them to consume these foods frequently to improve and maintain their haemoglobin levels.

Table 4.21 depicts the correlation between Iron and Ascorbic acid intake and Haemoglobin.

Table 4.21: Correlation between Hemoglobin and nutrients in the Ranji boys, U-23 boys, Senior women and U-19 women squads (n=63)

Nutrients		**Hb (gm%)**
Protein (mg)	r value	0.511
	p value	**0.000***
Iron (mg)	r value	0.410
	p value	**0.001***
Total Ascorbic Acid (mg)	r value	0.296
	p value	**0.018***

**. Correlation is significant at the 0.05 level (2-tailed).*

As is evident from table 4.21, protein, iron and ascorbic acid intake showed a significant positive correlation with haemoglobin levels. However, when studied gender-wise and squad wise no such correlation was observed.

As can be seen from Table 4.22, the mean protein intake of non-vegetarians (81.64±32.55) was higher than vegetarians (68.42±21.78) and lacto-ovo-vegetarians (68.34±26.27). However, this difference was not statistically significant. The consumption of Haem (non-vegetarian source) or non-haem (vegetarian source) iron did not make a significant difference in the mean Iron intake or haemoglobin levels of the participants. Lacto Ovo-vegetarians had higher mean haemoglobin and mean iron intake compared to vegetarians and non-vegetarians. Fat intake was higher in non-vegetarians compared to vegetarians and lacto-ovo-vegetarians but it was not statistically significant. The high fat intake in the non-vegetarians is due to the high fat (invisible) content of the foods and the cooking methods involving large amounts of fats.

Table 4.22 depicts the differences in the mean protein, fat and iron intake and haemoglobin levels of participants according to their eating preferences.

Table 4.22: Mean protein intake, haemoglobin levels and iron intake based on Eating preferences of the participants from all the squads

Eating preference	**Mean protein intake (g) n=95**	**Mean fat intake**	**Mean Iron intake (mg) (n=95)**	**Mean Hb (g %) (n=63)**
Vegetarian (n=17)	68.42 ±21.78	88.46 ±31.10	13.12±4.21	13.74 ±1.75
Non-vegetarian (n=64)	81.64 ±32.55	99.65 ± 35.32	13.52±5.12	13.52±1.55
Lacto Ovo-vegetarian (n=14)	68.34 ±26.27	83.59 ±22.89	13.71±4.86	14.12±1.63
p value	**0.138**	**0.173**	**0.94**	**0.521**

Kruskal Wallis test was applied

FITNESS ASSESSMENT OF CRICKETERS

Various fitness tests relevant to cricketers were conducted and the data recorded. These tests were conducted in the women squads by the Researcher. In the boys' squads due to the absence of permission, the readings were collected from the annual tests conducted by the support staff of the respective squads of the Baroda Cricket Association (BCA). Run-a-three test assesses the Agility, 20-metre Sprint and 40-metre sprint tests are for Speed, Vertical jump for Power and Prone hold for muscle endurance. Yo-Yo, CVE and repeated sprintability test evaluate the cardio respiratory fitness. The test of normality for fitness variables is given in table 4.23. The Shapiro Wilk test is applied to test normality as the sample size is less than 200. P value more than 0.05 indicates normal distribution. The figures marked with an asterisk and in bold are more than 0.05 which suggests that the variables follow a normal distribution.

Table 4.23: Test of Normality

	Shapiro-Wilk		
	Statistic	**Df**	**P value**
20 m Speed	0.523	96	0.000
Run-a-3	0.831	96	0.000
Vertical jump	0.984	67	**0.554 ***
Yo-Yo	0.915	29	0.023

CVE test	0.940	38	0.043
Prone hold	0.301	26	0.000
40 m Speed	0.961	29	**0.347***
Repeated Sprintability	0.916	29	0.024

As can be inferred from Table 4.23, scores for only the Vertical jump and 40 m speed test follow a normal distribution.

The mean scores of various fitness tests conducted are depicted in table 4.24. The type of tests conducted in each squad varied to some extent depending on the choice of support staff. As is presented in table 4.22, the battery of tests conducted in the Ranji squad were 20m speed, Run a three, Vertical jump and Yo-yo test. In the U-23 boys' squad the tests carried out were 20m speed, Run a three, Vertical jump, Cardio vascular endurance (CVE) test, Prone hold and Repeated sprintability test. The same battery of tests were conducted in the senior women and U-19 women squad which were, 20 m speed, Run a three, Prone hold, 40 m speed and Repeated sprintability tests.

As is presented in table 4.24, the mean scores for the 20m Sprint test for the Ranji boys squad was 2.966±.12 while it was 3.05±.14 for the Under-23 squad. Mean scores of Ranji boys squad was within the cut-off of <3 seconds, while that of Under-23 boys slightly exceeded the limit. For 20 m Sprint, 27% of the Ranji boys' squad did not achieve the BCA benchmark of <3 seconds while in the Under-23 boys' squad 70% did not achieve the same. The minimum standard for this test by ICCHPP (International Cricket Council High Performance Programme) is 3.03 seconds (Weldon et al, 2021)which is similar to the BCA cut-off. A study conducted on international male cricketers (n=19), reported the mean scores of the participants for the 20 m sprint test to be 3.13 ± 0. (Weldon et al., 2021)Another study on male cricket players at the University of the Western Cape reported the time taken to complete the 20 m sprint to be 5.48 sec in batsmen, 5.49 sec in fast bowlers and 5.57 sec in spin bowlers. (Dana, Keeran and Travill, 2014) A study was carried out on 100 odd Junior and Senior cricketers of Goa who were actively participating in state and national tournaments. The time taken to complete the 20 m sprint was 3.12 ± 0.12 sec in U-19 (n=50) and 3.11 ± 0.12 sec in U-25 (n=50). (Mandrekar, 2017) Compared to the participants in all the above 3 studies, the athletes from Ranji boys and Under-23 boys fared well for the 20 m sprint test which demonstrates a better speed component of fitness of cricketers in the present study.

Table 4.24: Fitness tests scores of the participants across all the squads (Mean ±SD)

Fitness tests	Component assessed by the test	Ranji boys (n=29)	U-23 boys (n=38)	p value between Ranji and U-23 boys	Senior Women (n=14)	U-19 Women (n=15)	p value between Senior and U-19 women
20 m Speed -an average of 3 (sec)	Speed	3.22 ± 1.03	3.34±0.74	0.229	3.83±0.29	3.86±0.19	0.686
Run a 3 - average of 2(sec)	Agility	9.70 ± 1.21	10.21±1.34	0.104	11.81±0.60	11.72±0.71	0.715
Vertical jump (cm)	Power	54.04 ± 6.66	55.80±6.69	0.013	NA	NA	NA
Yo-Yo (m)	Cardio vascular endurance	1217.93 ± 242.45	NA	NA	NA	NA	NA
CVE test (sec)	Cardio vascular endurance	NA	9.04±1.01	NA	NA	NA	NA
Prone hold (minutes)	Muscle Endurance	NA	1.19±0.03	NA	1.19±0.04	1.23±0.00	**0.035***
40 m Speed (average of 3)	Speed	NA	NA	NA	7.23±0.39	6.99±0.46	0.142
Repeated Sprintability	Speed	NA	11.52±1.48	NA	12.13±1.07	10.96±1.62	**0.030***

Independent sample t test/Mann Whitney U test was used; p<0.05 is significant.

Mean scores for Run-a-three for Ranji boys' squad was 9.309±0.28 seconds while that for Under-23 boys' squad was 9.878±0.41 seconds. For Run a three, 27% of the Ranji boys squad did not achieve the BCA benchmark of <9.5 seconds while in the Under-23 squad 80% did not achieve the same. In the study carried out on 100 odd Junior and Senior cricketers of Goa who were actively participating in state and national tournaments, the time taken to complete Run a three was 9.67 ± 0.38 sec in U-19 (n=50) and 9.65 ± 0.40 sec in U-25 (n=50) (Mandrekar, 2017) These scores were lower than the scores of Under-23 boys and higher than that of Ranji players. This suggests that in terms of agility, Ranji boys were the best followed by Goa cricketers and the Under-23 boys' squad.

The mean scores for the Vertical jump for the Ranji boys squad was 57.63±6.39 while it was 52.91±6.82 for the Under 23 boys' squad. For the Vertical jump, 27% of the Ranji boys' squad did not achieve the BCA benchmark of ≥55cm while in the Under-23 boys' squad 70% did not achieve the same. The mean vertical jump score of Junior and Senior cricketers of Goa(n=100) was 55.02 ± 6.01 cm in U-19 (n=50) and 55.19 ± 6.06 cm in U-25 (n=50) players (Mandrekar, 2017). These scores were higher than the scores of U-23 boys; while lower than that of Ranji boys. This indicates that in terms of power component of fitness Ranji boys squad was the best, followed by the Goa players and Under 23 boys.

The mean scores for the Yo-Yo test for the Ranji boys' squad was 1217.9±242.5. Only fifty percent of the cricketers met the BCA benchmark of ≥1240m for this test.

There is a dearth of data on other fitness tests conducted on cricketers to make a comparison. For the women's squad, there are no benchmarks set by BCA to make comparisons with. Benchmarks are also unavailable for the CVE test conducted in U-23 boys. In the participants from the Ranji boys squad fared well in Speed, agility and power however, did not score as well for cardio respiratory endurance. The Under-23 boys' squad demonstrated poor scores for Speed, agility and power.

Tukey's post hoc test was further applied to assess the between squads difference. There was no statistically significant difference found between Ranji boys and U-23 boys. A statistically significant difference was noticed in the two women's squad for the Prone hold and Repeated Sprintability test. In both these tests, U-19 women demonstrated better scores compared to Senior women. In the prone hold test, holding for a longer time equals to better performance and in repeated sprintability, the lesser the time taken to finish the test, the better the performance.

A statistically significant negative correlation was observed between the haemoglobin levels of the cricketers and scores of the 20-metre speed test. (Table 4.25) For any speed test, the lower the scores better the performance. As the haemoglobin levels increased the time taken to finish the 20-metre test dropped. This indicates the positive impact of haemoglobin on the speed component of the participants' fitness.

The haemoglobin levels of the participants were negatively correlated with the scores of the Run-a-three test. (Table 4.25) Run-a-three test determines the agility of the players and the lower the scores better the performance. As the haemoglobin levels increased the time taken to complete the Run-a-three test decreased. This indicates the positive impact of haemoglobin on the agility component of the participants' fitness.

A positive association was noted between % body fat and 20-metre speed test, 40-metre speed test, Run-a-three test and repeated sprintability test scores. (Table 4.25) In all these tests mentioned above i.e. 20m, 40m, Run-a-three and repeated sprintability, the lesser the time taken the better. An increase in body fat was correlated with an increase in time taken to finish these tests; thus lower body fat is correlated to better performance in these tests. A negative correlation was observed between % lean mass and 20 metres and Run-a-three test scores.

Table 4.25 depicts the correlation between anthropometric and body composition variables and scores of fitness tests.

Table 4.25: Correlation of anthropometric parameters, body composition variables and haemoglobin with fitness test scores in the Ranji boys, U-23 boys, Senior women and U-19 women squads

Fitness test		BMI	WC (cm)	WHtR	WHR	% body fat	% LBM	BFMI	FFMI	Hb (gm%)
20 m Speed (sec) average of 3	R value	-0.101	0.075	0.437**	-0.136	0.569**	-0.613**	0.488**	-0.501**	-0.372**
	P value	0.329	0.473	**0.000**	0.188	**0.000**	**0.000**	**0.000**	**0.000**	**0.003**
	N	95	95	95	95	93	93	93	93	63
Run a 3 (sec) average of 2	R value	-0.085	-0.014	0.376**	-0.248*	0.543**	-0.595**	0.457**	-0.500**	-0.521
	P value	0.412	0.893	**0.000**	**0.015**	**0.000**	**0.000**	**0.000**	**0.000**	0.000**
	N	95	95	95	95	93	93	93	93	63
Vertical jump (cm)	R value	0.005	-0.259*	-0.127	0.050	0.029	-0.072	0.003	-0.083	0.218
	P value	0.966	**0.036**	0.309	0.691	0.821	0.574	0.980	0.513	0.209
	N	66	66	66	66	64	64	64	64	35
Yo-Yo (m)	R value	-0.023	-0.288	-0.356	-0.392*	-0.325	0.319	-0.280	0.060	0.271
	P value	0.909	0.137	0.063	**0.039**	0.098	0.105	0.157	0.765	0.247
	N	28	28	28	28	27	27	27	27	20
CVE test (sec)	R value	0.459**	0.354*	0.455**	0.313	0.211	-0.122	0.362**	0.532**	-0.24
	P value	**0.004**	**0.029**	**0.004**	0.056	0.211	0.471	**0.028**	**0.001**	0.934

Fitness test		BMI	WC (cm)	WHtR	WHR	% body fat	% LBM	BFMI	FFMI	Hb (gm%)
Prone hold (minutes)	R value	0.093	0.152	0.060	0.229	-0.101	0.112	-0.056	0.157	-0.266
	P value	0.632	0.431	0.756	0.231	0.602	0.563	0.772	0.417	0.199
	N	29	29	29	29	29	29	29	29	25
40 m Speed (sec) Average of 3	R value	0.326	**0.469****	**0.494****	0.249	**0.449***	**-0.613****	0.348	0.033	-0.266
	P value	0.084	**0.010**	**0.006**	0.193	**0.015**	**0.000**	0.064	0.866	0.589
	N	29	29	29	29	29	29	29	29	28
Repeated Sprintability (sec)	R value	0.282	0.285	**0.388***	0.189	**0.584****	**-0.500****	**0.469***	0.128	-0.009
	P value	0.139	0.135	**0.038**	0.325	**0.001**	**0.006**	**0.010**	0.507	0.964
	N	29	29	29	29	29	29	29	29	28

**Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*
For variables which fell under normal distribution, Pearson's correlation was applied; otherwise, Spearman's correlation was used.

A statistically significant positive correlation was observed between BMI and CVE test and BMI and 40-metre speed test. With an increase in BMI, the time taken to complete the CVE test and 40-metre speed test also raised. (Table 4.25) In both these tests, the lower the time taken to complete better the performance.

A positive correlation was found between WHtR and 20m speed, Run-a-three, 40 m speed, CVE and repeated sprintability. In all these tests, lower the time taken to complete better the performance. Thus, the short fat phenotype was associated with compromised agility, speed and cardio vascular endurance.

Waist circumference and vertical jump test scores were negatively correlated. In the vertical jump test, the higher the scores better the performance. So with an increase in the waist circumference, a drop in the vertical jump was observed. Whereas, a positive correlation was found between waist circumference and CVE test and 40 m speed test. In CVE and 40 m speed test, the lower the time taken better the performance. Thus reduction in BMI was correlated with better performance in these tests. A statistically significant negative correlation was found between WHR and run-a-three and Yo-Yo test scores. (Table 4.25)

Thus, in a nutshell, anthropometric parameters, body composition and haemoglobin levels were associated with better performance of the participants in various fitness tests. Therefore, it is imperative for athletes to have normal anthropometry, body composition and haemoglobin values as it directly translates to their physical fitness which is vital for athletic performance.

MORBIDITY AND INJURY PROFILE

The morbidities and Injuries experienced by the participants were recorded as reported and are discussed below.

Morbidities experienced by the Cricketers

Table 4.26 depicts morbidities experienced by the participants. The cricketers (N=91) were asked to report the morbidities that they experienced in the last 15 days.

Table 4.26: Morbidity profile of cricketers in the Ranji boys, U-23 boys, Senior women and U-19 women squads (%)

Morbidity	Ranji boys	Under-23 boys	Senior women	Under-19	Total
No morbidity	59.3	56.8	8.3	26.7	46.2
Cough and cold	14.8	24.3	50	40	27.5
Headache	14.8	10.8	25.0	53.3	20.9
Loss of appetite	14.8	10.8	41.7	6.7	15.4
Fever	11.1	8.1	16.7	6.7	9.9
Stomach ache	7.4	2.7	16.7	6.7	6.6
Vomiting	0	2.7	25.0	6.7	5.5
Diarrhoea	7.4	0	8.3	0	3.3
Toothache	3.7	2.7	8.3	0	3.3
Dengue	0	2.7	0	6.7	2.2
Constipation	3.7	0	0	0	1.1

High-intensity physical activity makes individuals more susceptible to the suppressed immune system. As the cricketers under study were into high-intensity physical activity on regular basis, their morbidity profile was studied. Around 46% of the participants did not experience any morbidity in the last 15 days from the date of the interview. Maximum morbidities were reported in Senior women (91.7%), followed by Under-19 women (73.3%), Under-23 boys (43.2%) and least in Ranji boys (40.7%).The top 5 morbidities reported by the cricketers across all the squads were; cough and cold (27.5%) followed by headache (20.9%), loss of appetite (15.4%), fever (9.9%) and stomach ache

(6.6%). As is depicted in table 4.25, the top 5 morbidities prevalent in the Ranji boys were; cough and cold, headache and loss of appetite (14.8%), fever (11%), stomach ache and diarrhoea (7.4%). In the Under 23 boys, the top 5 morbidities reported were cough and cold (24.3%) followed by headache and loss of appetite (10.4%), fever (8.1%), stomach ache, toothache, dengue and vomiting (2.7%). The top 5 morbidities in Senior women were cough and cold (50%), loss of appetite (41.7%), vomiting and headache (25%), fever and stomach ache (16.7%). In the Under 19 women, the top 5 morbidities reported were; headache (53.3%), followed by cough and cold (40%), loss of appetite, fever, dengue, stomach ache and vomiting (6.7%). None of the participants across all the squads experienced malaria, chicken guinea of any other such illness. There is no scientific literature available on the morbidities commonly experienced by cricketers.

Injuries sustained by the cricketers

Cricket is a non-contact sport still injuries can result in a number of ways. (Finch, Elliott, & McGrath, 1999) Match seasons have become longer in cricket over the years which has made the cricketers prone to more injuries. (Pote & Christie, 2018) Injuries sustained by the cricketers in the last 2 years were recorded and are depicted in Table 4.27.

Table 4.27: Injury profile of participants from the Ranji boys, U-23 boys, Senior women and U-19 women squads during the last 2 years from the baseline (%)

Injury	**Ranji boys (n=27)**	**U-23 boys (n=37)**	**Senior women (n=12)**	**U-19 women (n=15)**	**Total (N=91)**
Absence of any injury	40.7	35.1	41.7	33.3	37.4
Ankle twist	7.4	10.8	16.7	13.3	11.0
Finger/thumb injury (hit by the ball)	0	13.5	8.3	13.3	8.8
Finger fracture (hit by the ball)	3.7	8.1	8.3	6.7	6.6
Shoulder pain	3.7	2.7	25.0	0	5.5
Groin injury	3.7	8.1	0	0	4.4
Knee pain	7.4	2.7	0	0	3.3
Knee injury	3.7	2.7	0	6.7	3.3
Back injury	0	5.4	0	6.7	3.3
Muscle spasm and sprain	3.7	8.1	0	6.7	3.3
Side strain	11.1	0	0	0	3.3
Hamstring pull	0	2.7	8.3	0	2.2
Hand fracture	3.7	0	0	6.7	2.2
Knee ligament tear, surgery	3.7	8.1	0	0	2.2
Shoulder muscle tear while throwing	0	0	0	13.4	2.2
Shoulder spasm and stiffness	0	8.1	0	0	1.1
Wrist ligament damage	0	2.7	0	0	1.1
Wrist pain	0	2.7	0	0	1.1
Leg fracture	0	8.1	0	0	1.1
Thigh muscle pull	0	8.1	0	0	1.1
Calf muscle pain	0	8.1	0	0	1.1

Glute stiffness	3.7	0	0	0	1.1
Eye injury (hit by the ball)	3.7	0	0	0	1.1
Ankle pain	3.7	0	0	0	1.1

As can be seen from table 4.27, Thirty-seven percent of the cricketers (N=91) experienced no injuries in the last 2 years. Maximum Injuries were reported in Under-19 women (66.7%), followed by Under-23 boys (64.7%), Ranji boys(59.3%) and Senior women (58.3%).Thus in both the boys' and women's squads, the older squads having more cricket experience sustained fewer injuries.

The top 5 injuries reported consisted of Ankle twist (11%) followed by finger/thumb injury (8.8%), finger fracture (6.6%), shoulder pain (5.5%) and groin injury and back pain (4.4%). The top 5 injuries experienced by the Ranji squad were side strain (11.1%), ankle twist, knee pain (7.4%), finger fracture, shoulder pain, groin injury, knee injury, muscle spasm and sprain, hand fracture, knee ligament tear, glute stiffness, eye injury, ankle pain (3.7%). The top 5 injuries sustained by the Under-23 boys included finger/thumb injury (13.5%), ankle twist (10.8%), finger fracture, groin injury, muscle spasm and strain, knee ligament tear, Shoulder spasm and stiffness, leg fracture, thigh muscle pull and calf muscle pain (8.1%). In the Senior women, the top 5 injuries recorded were shoulder pain (25.0%), ankle twist (16.7%), finger/thumb injury, finger fracture, hamstring (8.3%). The top 5 injuries sustained by the Under-19 women consisted of ankle twist, finger/thumb injury, shoulder muscle tear while throwing (13.7%), finger fracture, knee injury, back pain, muscle spasm and sprain and hand fracture (6.7%).

Though there is a paucity of literature studying injuries sustained by the cricketers, a study conducted in 2019 shows similarity to some extent in terms of the type of injuries reported as that in the present study. Of the 100 injured cricketers who trained in Bangladesh Krira Shikkha Protishtan (BKSP) &Bangladesh Cricket Board (BCB),40% had shoulder injuries or pain, 30% had groin pain, 20% had hand and finger injuries and knee and leg pain.(Rahman et al, 2019)The present study revealed similar types of injury occurrence but the incidence was lower. Another study from New Zealand recorded injuries only during match days and reported that cricketers playing at both domestic and international level sustained lower limb injuries the most. In this study total of 268 elite male New Zealand cricket players from seasons, 2009–2010 to 2014–2015 were analysed from the New Zealand Cricket injury surveillance system. In the domestic tournaments the hamstring was the most frequently injured body site (8.2% injuries of total), followed by the lumbar spine (7.7%), knee and groin, (7.2%) shoulder, finger, and side (6.7%) and ankle (6.5%). At the international level, the most frequently injured body site was the groin (13.5% of total injuries), followed by the lumbar spine (10.3%) and hamstring (7.9%). (Dovbysh, Reid, & Shackel, 2021)Literature shows lower limb to be the most injured region and a majority of the injuries are reported during matches as against during training sessions. (Pote & Christie, 2018)

Pacers are the most injured discipline in cricket, followed by batsmen and fielders/wicketkeepers. In elite level cricket, overuse injuries are common and related to the physical demands of the sport. (Pote& Christie, 2018; Pote, King, & Christie, 2020) The bowling action involves repetitive twisting, extension and rotation of the trunk. These movements, if performed incorrectly or too frequently, can lead to overuse injuries of the back. Most common injuries include stress fractures of the lumbar spine (fast bowlers), muscle strains of the lower limbs (batsmen) and impact injuries to the upper limbs (fielders/wicketkeepers). (Pote et al., 2020)Moreover, spinal overuse injuries occur more frequently to cricketers adopting a mixed bowling action than to those who go for a front or side-on bowling technique. Strategies to ensure that players do not adopt the mixed action or bowl too fast for extended periods can prevent these back injuries. Injuries resulting from impacts, generally from the cricket ball, can also occur and are more common during low-level competition.(Finch et al., 1999)

Due to the potential severity of various injuries, a range of protective gears ranging from body padding to gloves and helmets are commonly used by cricketers. Also, good stretching programmes before and after play, along with conditioning before and during the match season, are imperative injury prevention actions. (Finch et al., 1999)

PHASE 2

A- SURVEY ON COMPOSITION OF COMMERCIALLY AVAILABLE PROTEIN SUPPLEMENTS AND SPORTS DRINKS

B- DEVELOPMENT, SUPPLEMENTATION AND IMPACT EVALUATION OF A COCOA FLAVANOL RICH DRINK ON MUSCLE RECOVERY

A- SURVEY ON COMPOSITION OF COMMERCIALLY AVAILABLE PROTEIN SUPPLEMENTS AND SPORTS DRINKS

Protein supplements and sports drinks are commonly consumed by cricketers in general. Due to this reason, a market survey of commercially available protein supplements and sports drinks was conducted.

The results of this phase are discussed under the following heads:

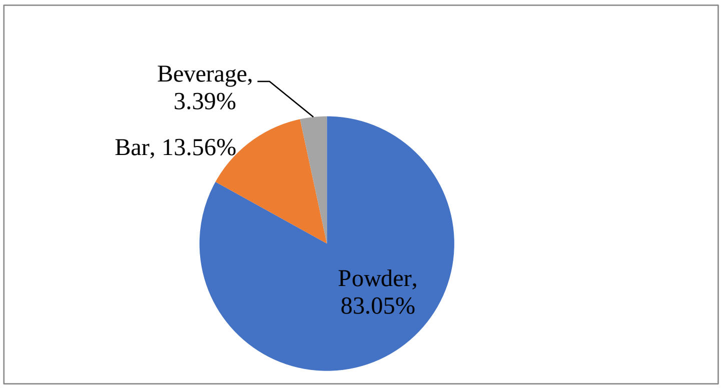
- Various forms of Protein supplements
- Mean Energy and Protein content of the Products
- The protein content of the Supplements
- Sources of Protein in the Supplements
- Cost per gram of protein of the Products
- Sugar/Sweetener in the Supplements

Protein is one of the most popular dietary supplements marketed to athletes and is widely used by athletes including cricketers. Protein supplements are consumed to increase muscle mass, prevent protein catabolism and enhance glycogen resynthesis. In this survey on protein supplements, 60 products were surveyed for their protein content, the source of protein utilized, and the cost of these products by studying the front of pack and back of pack labels. These products belonged to 15 different brands. As all the products are not available on shelves in stores, all the products available on the websites of these stores were surveyed.

Various forms of Protein supplements

The products were in the form of Powder, Bar, and Beverage. The supplements available in powder form have to be reconstituted into a beverage by adding to milk or water. Most of them recommend one serving to be added to 250-350ml of water or milk (if the individual has additional calorie requirements). These products are available in various flavors and pack sizes. The bars are supposed to be consumed one at a time. These are recommended to be taken as snacks in between major meals. Bars are ready to eat and easy to carry on the go. Those supplements which are in beverage form are ready-to-drink formulas. Like the powder forms, beverages are also available in various flavors and pack sizes. Figure 4.10 shows the percent distribution of various forms of products.

Figure 4.10: Percent distribution of various forms of Protein supplements



As can be seen from figure 4.10, powder form protein supplements were as high as 83%. Powder form supplements are low bulk and have higher shelf life compared to bars and beverages. Moreover, appetite is low post-workout and it is easier to consume a liquid compared to solid food. Also, liquid consumption can quench the thirst post-workout. Amino acids also get absorbed better in liquid form. However, the bars and beverages are ready to use and therefore have an added advantage over powders.

Mean Energy and Protein content of the Products

The mean energy and protein content of the protein supplements per 100g of the product and per serving are presented in table 4.28.

Table 4.28: Mean Energy and Protein content of protein supplements across all the forms of products

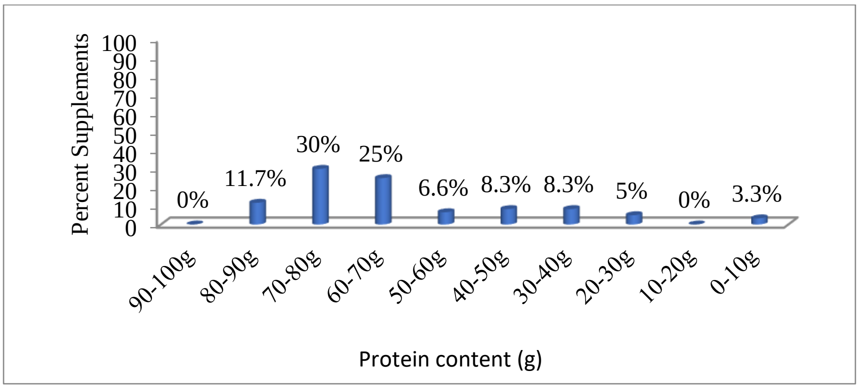
Variable	Powder (n=50)	Bar (n=8)	Beverages (n=2)
Mean Energy content (kcal) per 100g of the product	383± 22	387± 77	44±7 (per 100 ml)
Mean Energy content (kcal)per serving	144 ±42	253±81	185±35 (per serving size of 400 ml)
Mean Protein content (g) per 100g of the product	69.1±12.6	30.6±5.9	8.3±1.5 (per 100 ml)
Mean Protein content (g) per serving	25±7	19±2	35±7 (per serving size of 400 ml)

As is depicted in table 4.28, the mean protein content per serving of the products in powder and beverage form is 25±7g and 35±7g respectively which is in the normal range according to the IOC consensus statement. (Maughan et al, 2018) the mean protein content of products in the bar form is marginally low (19±2g) than the desired quantity of 20-50 g protein per serving.

The protein content of the Supplements

Amongst the protein supplements surveyed, the protein content per 100g of supplement varied largely as demonstrated in Figure 4.11. Maximum i.e. 30% products contained protein in the range of 70-80g. The products in the range of 80-90g protein (11.7%) were all of animal origin. The products in powder form contained protein ranging from 39 g to 90g per 100g of the product. The highest protein content was 90g in a powder form product.

Figure 4.11: Protein content per 100g of Protein Supplements



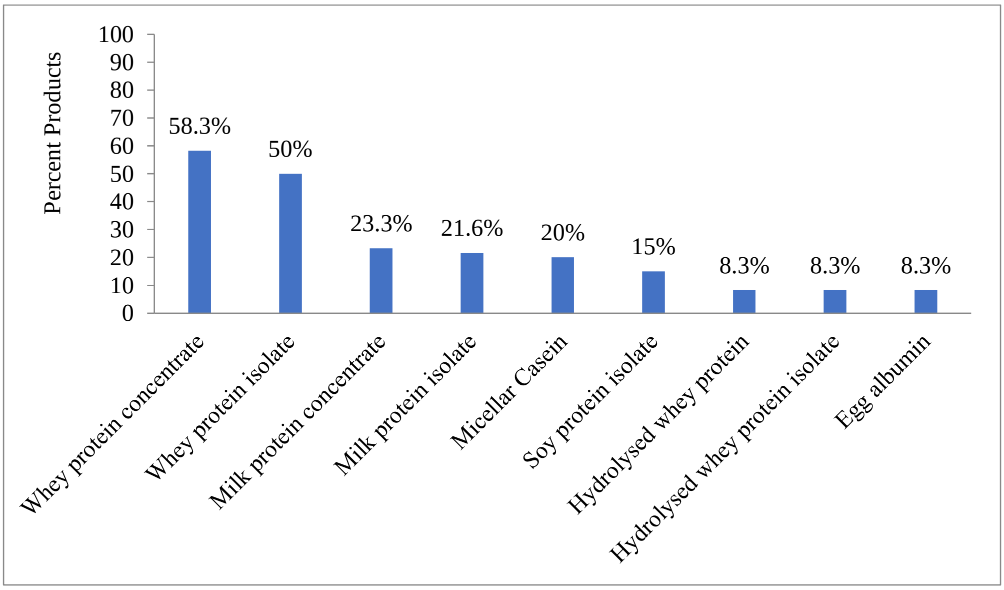
According to the IOC consensus statement, one serving of protein supplement should have 20 to 50g of protein. (Maughan et al, 2018) Only one (2%) product from the powder form contained less than 20g of protein per serving. Two products (25%) in the bar form had <20g protein per serving whereas both (100%) the products in the beverage form met this requirement. Only one product(2%) had a protein content of >50 g per serving and it belonged to the powder form.

Source of Protein in the Supplements under Study

As depicted in figure 4.12, amongst the top nine sources of protein found in the surveyed products, only one (11.1%) was of vegetarian origin (soy protein isolate), seven (77.8%) protein sources were of milk origin and one (11.1%) was egg-based. Milk protein concentrates contain both casein and whey proteins and are available in protein concentrations ranging from 42% to 85%.(Jana, 2022) They are produced by ultra-filtration method or by precipitating the proteins out of milk or by dry blending the milk proteins with other milk components. (Jana, 2022; Agarwal et al, 2015) Compared to skim milk powder or whole milk powder, milk protein concentrates are higher in protein and lower in lactose. (Hoffman and Falvo, 2004) Milk protein isolate is the substance obtained by the partial removal of sufficient non-protein constituents (lactose and minerals) from skim milk so that the finished dry product contains 90% or more protein by weight. (https://www.idahomilkproducts.com/the-ultimate-guide-to-milk-protein-concentrate-isolate/)

The top sources of protein in the supplements under study are depicted in Figure 4.12.

Figure 4.12: Source of Protein in the Supplements under Study



Whey protein has a high amount of essential amino acids, branched-chain amino acids, particularly leucine, and has rapid digestibility. (Devries and Phillips, 2015) Whey is the translucent liquid part of milk that remains following the coagulation and curd removal process of cheese manufacturing. Whey is one of the two major protein groups of milk, accounting for 20% of the milk protein while casein accounts for the remainder. Casein exists in milk in the form of a micelle, which is a large colloidal particle. All of the constituents of whey provide high levels of essential and branched-chain amino acids and rapidly elevate plasma amino acids, thus providing a foundation for the preservation of muscle mass. (Hayes and Cribb, 2008) From whey, whey proteins are separated and purified using various techniques yielding different concentrations of whey proteins. (Shankar and Bansal, 2013) There are three main forms of whey protein; whey protein concentrate, whey protein isolate and hydrolysed whey protein. Whey concentrate typically contains more biologically active components and proteins. (Hoffman and Falvo, 2004) Whey protein isolates contain protein concentrations of 90% or higher. Processing of whey protein concentrate into whey protein isolate leads to significant removal of fat and lactose. As a result, individuals who are lactose intolerant can often safely consume it. Hydrolyzed whey protein is pre-digested whey and it typically releases amino acids at a faster rate. The increased bioavailability of hydrolyzed whey further enhances muscle protein synthesis. Whey is readily available as a by-product of the dairy industry.

Of the three categories in which soybean is utilised, namely flour, concentrates, and isolates; soy flour is the least refined form. While retaining most of the bean's protein, concentrates do not contain as many soluble carbohydrates as flour, making them more palatable. Soy isolates are the most refined soy protein containing the highest protein content but unlike flour and concentrates, contain no fibre and are easily digestible. Soy protein isolate contains maximum i.e. 90% protein, followed by soy protein concentrate (70%) and soy protein flour 50%. (Hoffman and Falvo, 2004)

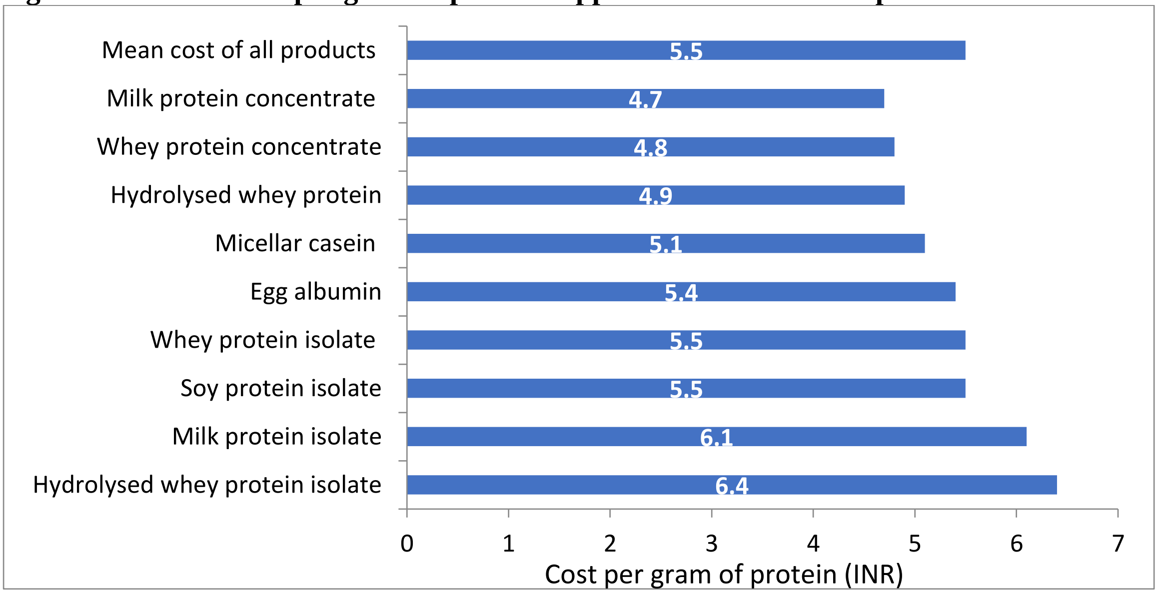
Products containing egg albumin as a protein source are low on fat and carbohydrates. Egg protein is of high biological value and it is digested even slower than casein resulting in a longer release of amino acids in the blood. (Hida et al., 2012)

Bioavailability of whey is highest i.e. 100, followed by the egg which is 88-100, casein- 80, and soy-74. (Millward et al, 2008)

Cost of the protein supplements based on various sources of protein

As the serving sizes, protein content, and cost per serving vary across the products, the cost per gram of protein was calculated rather than the cost per serving of the product. The cost per gram of product also depicted a diverse picture based on the protein source added to the product. A study by Maughan also remarked on similar lines saying that the costs of protein products are highly variable, as are the costs of protein-containing foods. (Maughan, 2013) the figure 4.13 depicts the mean cost per gram of protein supplements having different protein sources.

Figure 4.13: Mean cost per gram of protein supplements based on the protein source

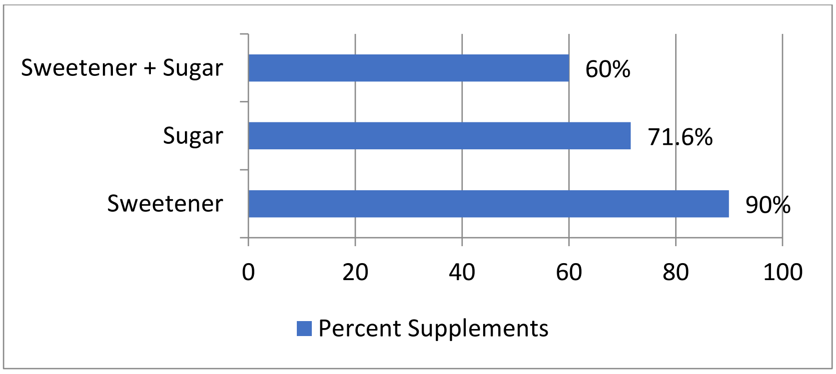


As is evident from the figure 4.13, the mean cost per gram of protein of all the protein supplements was INR 5.5±2.6 however the range was as wide as INR 1.7 to 13.9. Therefore, the cost was studied based on the protein sources used in the supplements to explore whether there was an association between the two. The 4 protein sources which constituted the most expensive products were all isolates; hydrolysed whey protein isolate followed by milk protein isolate, soy protein isolate and whey protein isolate. Hydrolysed whey protein isolate containing protein supplements were the most expensive with INR 6.4±3.6 per gram of protein. Hydrolysed whey protein isolate is expensive as it undergoes the hydrolysation (pre-digestion) process. Concentrates are processed to obtain isolates, making isolates more expensive. After the isolates, egg albumin was the next most expensive source, with a mean price of INR 5.4±1.3 per gram of protein. This was likely due to the cost of eggs and the additional processing required to create albumins. Micellar casein was the second-most expensive item on the list. Following this was hydrolyzed whey protein (INR 4.9±0.8), whey protein concentrate (INR 4.8±2.1), and milk protein concentrate (INR 4.7±2.0).

Sugar/Sweetener in the Supplements

Figure 4.14 illustrates the presence of sweetening agents added to the products. Sweeteners are added in order to reduce the calorie content of the product.

Figure 4.14: Presence of Sugar/Sweetener in Protein Supplements



Some products had sweeteners as the main sweetening agent plus sugar in very minute quantities. Amongst those products that contained sweeteners, 87% had Sucralose, 43% had Acesulfame Potassium and 15% had Stevia. Sucralose is the only noncaloric sweetener made from sugar and is about 600 times sweeter than sugar. It is minimally absorbed by the body. It is approved by both the Food and Drug Administration and the Prevention of Food Adulteration Act. Stevia is a sweetener used as a sugar substitute extracted from the leaves of the plant species Stevia Rebaudiana and is about 150 times sweeter than sugar. Acesulfame Potassium is a non-calorie sweetener with a clean, quickly perceptible sweet taste. It has good solubility and is 200 times sweeter than sugar. In 2003, it was approved by the United States Food and Drug Administration. (Tandel, 2011)Recommended upper limit of sweeteners is 400 ppm or 400mg/kg. However, the quantity of added sweetener could not be verified as it was not mentioned on the pack.

Directions for use indicate the way in which the product has to be consumed. The products in powder form were recommended to be added to either water or milk and turned into a shake. Bars and ready-to-drink beverages carried the recommended use to be consumed which was one serving at a time. Directions for use were not indicated on 20% of the products. This may be considered a drawback of the product as the consumers would be forced to consume the supplement in their own different ways.

PHASE 2 (A) SURVEY ON THE COMPOSITION OF COMMERCIALLY AVAILABLE SPORTS DRINKS

The results of this phase are discussed under the following heads:

- Various forms of Sports drinks
- Carbohydrate content of Sports drinks
- Sources of Carbohydrates in the Sports drinks
- Sodium content in the Sports drinks

Sports drinks are used widely by athletes involved in high-intensity physical activities. (Armstrong et al, 2007) They are designed to deliver a balanced amount of carbohydrate and fluid to allow an athlete to simultaneously rehydrate, refuel and replace sodium losses during physical activity. (Begum et al, 2015) In all, fifty products from 26 brands were surveyed mainly for their composition in terms of carbohydrate content, source of carbohydrate, and sodium content.

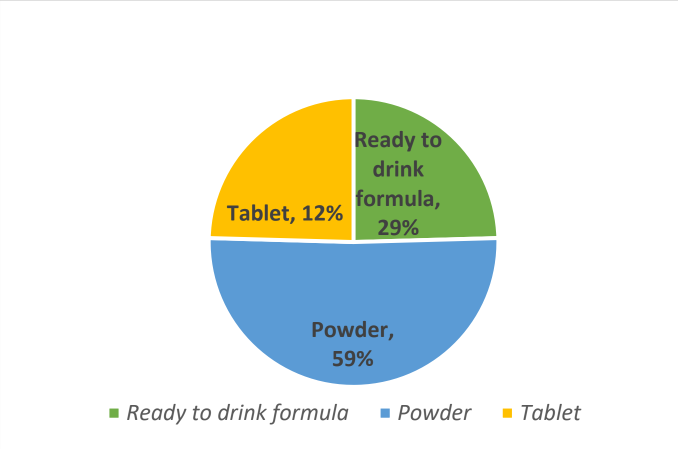
Various forms of Sports drinks

The products were in the form of Powder, Ready to drink formula, and tablets. The supplements available in powder and tablet form have to be reconstituted into a beverage by adding to water.

The serving sizes of the sports drinks varied from 10g to 79g for powders (to be reconstituted by adding water up to 200ml -1 litre), 4.7-50g for tablet (to be reconstituted by adding water up to 100ml -750ml), 118-567ml for ready to drink formula. While drinking sports drinks in powdered or tablet form it is important to follow the manufacturer's instructions regarding reconstitution to ensure that the carbohydrate and electrolyte balance is optimal for gut absorption, fluid balance, and fuel delivery. Incorrect preparation may lead to gastrointestinal discomfort and a negative impact on performance.

Figure 4.15 shows the percent distribution of various forms of products.

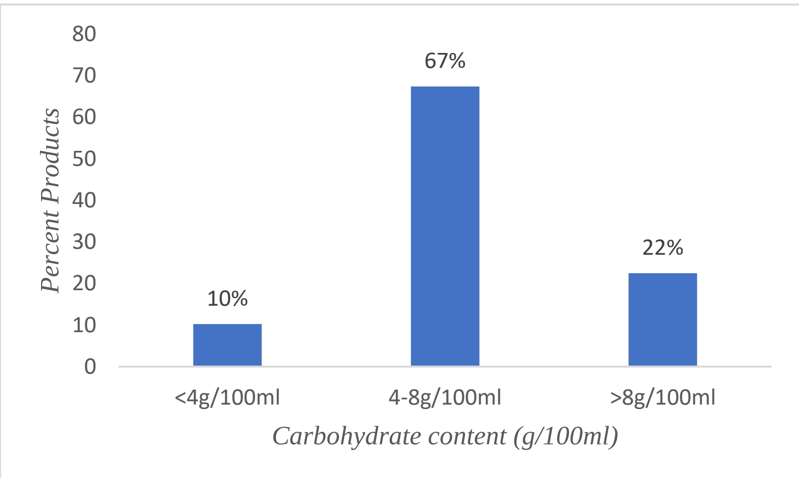
Figure 4.15: Percent distribution of various forms of Sports drinks



Carbohydrate content of Sports drinks

The recommended range of carbohydrates in Sports drinks is 4-8g/100ml. (American College of Sports Medicine et al. 2007; American Dietetic Association et al. 2009). (Sawka et al., 2007; Rodriguez et al, 2009) As is presented in figure 4.16, the majority of the products i.e. 67% fell in this range. Around 10% of products had a carbohydrate content of less than 4g/100 ml. Products containing carbohydrates less than the recommended range may not be sufficient to assist refuellingand thereby not be of much use. Around 22% had a carbohydrate content of more than 8 g/100 ml. Products having carbohydrates in greater quantity than required may cause abdominal discomfort, and gut intolerance and delay gastric emptying. (Singh, 2003)

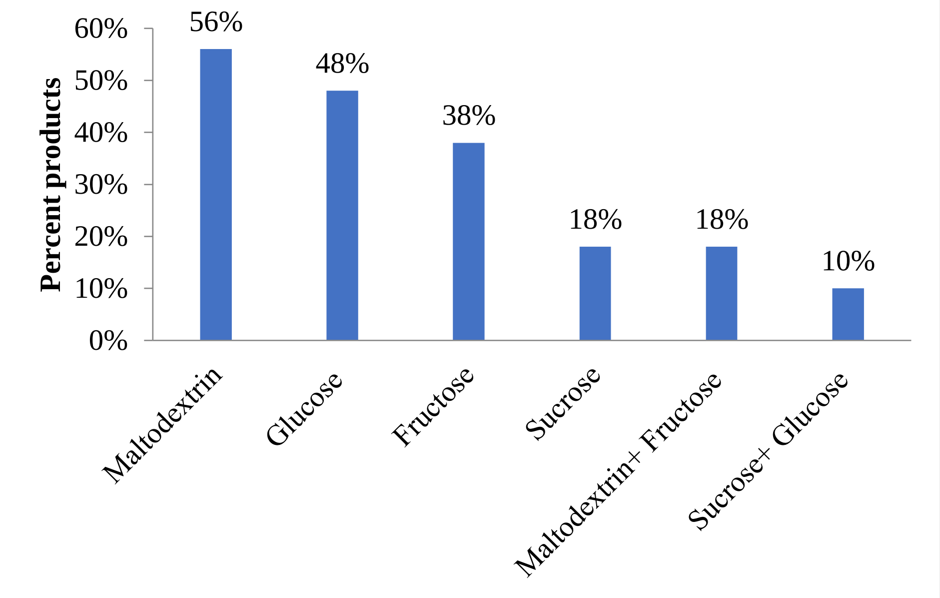
Figure 4.16: Carbohydrate content per 100ml of Sports drinks



Sources of Carbohydrates in the Sports drinks

The top sources of carbohydrates in sports drinks under study are depicted in Figure 4.17.

Figure 4.17: Most commonly added sources of Carbohydrates in the Sports drinks under Study



The most commonly added carbohydrates to the sports drinks were Maltodextrin (56%), Glucose (48%), Fructose (38%), and Sucrose (18%). Fifty-two percent of the products had 2 sources, 12% had 3 sources and 6% had 4 sources of carbohydrates.

Maltodextrin plus Fructose (in 18% of products) was the most common combination, followed by Sucrose plus glucose (10%). All other combinations constituted a negligible proportion of ≤6%. Studies have demonstrated that ingestion of multiple transportable carbohydrates reduced fatigue and improved exercise performance compared to single carbohydrate. (Jeukendrup, 2013) When >60g/hour carbohydrate ingestion is required during exercise or match, absorption rate becomes a limiting factor. The highest oxidation rate of a single carbohydrate is 1g/min which is for glucose but when two sources are combined greater oxidation rate is observed. Glucose and maltodextrin are absorbed into the blood via the sodium-dependent glucose co-transporter (SGLT1) and glucose transporter (GLUT2), whereas fructose is transported through a separate glucose transporter (GLUT5) via facilitated diffusion and GLUT2. Sixty grams of glucose can be absorbed hourly, but as the transporter proteins that aid in glucose absorption are different than for fructose, the former can still be absorbed at the rate of 30g/hour even when glucose transporter proteins are saturated, thus providing carbohydrates at the rate of 90g/hour. (Fuchs, Gonzalez, & van Loon, 2019; Sutehall et al, 2018) Literature suggests that amongst various carbohydrate combinations, maltodextrin and fructose in the ratio of 2:1 are more suitable. The oxidation rate of the maltodextrin and fructose combination is 1.5g/min while that of glucose and fructose is 1.75g/min. (Jeukendrup, 2013) However, maltodextrin is preferable compared to glucose due to the lower osmolality for a given energy density that does not reduce gastric emptying to the same extent as glucose. (Sutehall et al, 2018) Moreover, the combination of maltodextrin and fructose has a desirable level of sweetness and therefore is more palatable as well. (Jeukendrup, 2013)

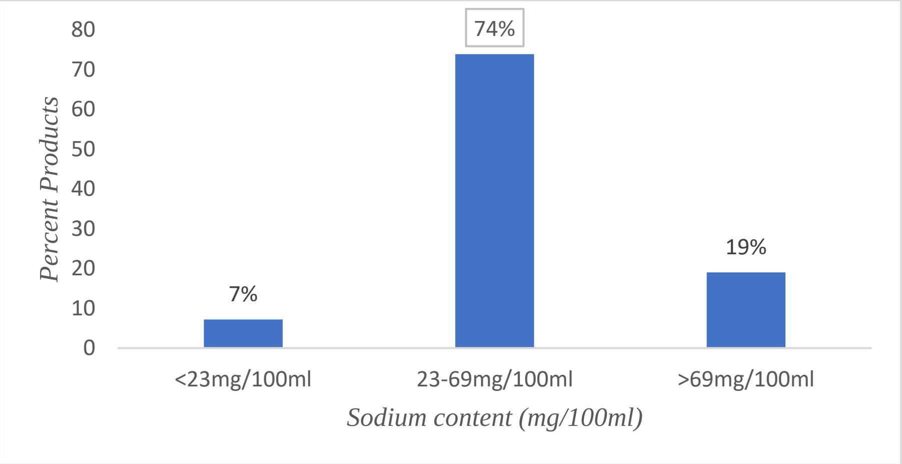
The sweetener in the Sports drinks

Twenty-six percent of the products had the presence of sweeteners. Sweeteners are used to create low-calorie products while still maintaining the taste that consumers like. Sucralose (54%) was the most commonly used sweetener. Sucralose is a low-calorie sweetener and is 385 to 650 times sweeter than sugar. ("Sports Drinks," 2009) The quantity of sweeteners added to the products was not mentioned therefore could not be ensured whether they are within the recommended upper limits of 400 ppm.

Sodium content in the Supplements

The recommended range for sodium content in sports drinks is 23-69 mg/100ml. (Sawka et al., 2007; American College of Sports Medicine et al. 2007; American Dietetic Association et al. 2009).

Figure 4.18: Sodium content per 100ml of Supplements



Almost 74% of products fell in that range as can be seen from Figure 4.18. Around 7% products contained sodium below 23mg/100ml. As these products contain sodium below the recommended range, excessive consumption of these drinks can result in low plasma sodium concentration. This can cause headache, lethargy, fatigue, decreased concentration, muscle cramps, etc. which can adversely affect the performance of an athlete. Nineteen percent of products contained sodium above the recommended upper range which can cause hypernatremia or high plasma sodium concentration. This condition is also not desirable as it can cause dizziness, diarrhoea, and vomiting.

Only forty percent of products met both the Carbohydrate and Sodium content guidelines. Seventy-four percent of products met the guideline for only Sodium content and 67% met the guideline for only carbohydrate content.

In 12% of the products, sodium content was not mentioned on the label despite salt being present. This can be considered a non-compliance with respect to labelling of products. Nutritional information was presented 'Per Serving' on the labels making it easy for the consumers to assess their intakes. Front of pack labelling which is essential for easy identification of products was missing on these products. Only a few products mentioned statutory note regarding the reconstitution instructions of the products which are in powder or tablet form. The absence of such instructions can result in incorrect preparation which may lead to gastrointestinal discomfort and may impair performance.

The average cost of sports drinks per serving was INR 66.5 (n=41). The range of cost per serving of these products varied widely from INR 9.3 to 186.

Ten percent of the products had caffeine. Caffeine is added to certain sports drinks in small to moderate doses (75 to 200 mg), to help sustain exercise performance, reduce the perception of effort, and is unlikely to alter hydration status during exercise. Moreover, caffeine is no longer banned by The World Anti-Doping Agency. ("Sports Drinks," 2009) Nevertheless, excess caffeine intake can result in side effects like anxiety, jitteriness, rapid heartbeat, gastrointestinal distress, and insomnia and could be ergolytic for novice users. Therefore drinks containing caffeine should be avoided unless dire need. (Rodriguez et al, 2009)

PHASE 2 (B) DEVELOPMENT, SUPPLEMENTATION AND IMPACT EVALUATION OF A COCOA FLAVANOL RICH DRINK ON MUSCLE RECOVERY

The survey of Protein supplements and Sports drinks revealed that there was no Muscle Recovery drink available in the market. A muscle recovery drink was developed, standardized, and supplemented to study the impact to address this gap.

The results of this phase are discussed under the following heads:

a. Standardization of Muscle Recovery drink
b. Supplementation with the drink
c. Impact Evaluation of Supplementation on Muscle recovery (CreatineKinase)

In cricket as in any other sport, exercise-induced muscle damage (EIMD) is very common in response to training or workout or intense physical activity. EIMD further results in delayed onset muscle soreness (DOMS). Speedier muscle recovery from DOMS is crucial for the next athletic performance. Studies have been conducted on assessing the impact of foods on muscle recovery. Few studies have explored the effect of Cocoa flavanols on muscle recovery from EIMD. Reviewed literature shows that acute administration of 350 mg of cocoa flavanol (equivalent to about 10 g cocoa powder) is ineffective in the recovery of muscles post-EIMD. It is also suggested that the cumulative effect of cocoa flavanol needs to be assessed. (Corr et al, 2020) Therefore, the Cocoa flavanol-rich drink was developed to assess its cumulative effect on muscle recovery after supplementation for 21 days.

a. Standardization of Muscle Recovery drink

Hershey’s unsweetened cocoa powder was selected due to the following reasons

- It is un-alkalized and therefore has higher flavanol content.
- Hershey’s was the only brand that provided information on the flavanol content of their product.
- Ten grams of cocoa powder provided 350 mg flavanol (based on communication with Hershey’s) which could be administered conveniently in one serving of the drink.
- Hershey's cocoa powder does not contain any added colours or flavors. As the drink had to receive clearance from the Anti-doping Agency of the Board of Cricket Control in India (BCCI), it needed not to contain any added substances.

The quantity of cocoa powder was fixed i.e. 10g which is the suggested quantity based on literature to see a positive impact on muscle recovery. The quantity of sugar to be incorporated in both the drinks was arrived at using sensorial methods (9 point hedonic scale). The placebo drink with 15 g sugar and experimental drink with 20g sugar were found to be most acceptable.

Based on the Sensory evaluation, the experimental and placebo drink composition per serving of 250 ml was as follows.

Table 4.29: Composition of the drinks per serving

Ingredient (ml/g)	Placebo	Experimental
Milk	250	250
Cocoa	0	10
Sugar	15	20
Milk Powder	5.6	0

Natural Chocolate colour and flavour within safe limits were added to the Placebo drink to simulate the taste and appearance of the experimental drink and avoid any bias. Sugar had to be incorporated at a higher level in the experimental drink than its placebo counterpart to balance the bitter flavour of the cocoa powder.

As the placebo did not have any cocoa powder, the calculated flavanol content was nil in it whereas the experimental drink had about 350 mg of cocoa flavanols. The Energy and Protein content of both the drinks was maintained almost similar. The Energy content in the Experimental drink was 215 Kcal and Placebo was 194 Kcal while the Protein content in the Experimental drink was 9.73g and in Placebo was 9.72g respectively. The nutrient content of both the drinks can be seen in table 4.30

Table 4.30: Nutrient content of the drinks per serving

Drink (250ml)	Energy (kcal)	Protein (g)	CHO (g)	Fat (g)	Sugar (g)	Calcium (mg)
Placebo	194	9.72	30.2	3.86	15.0	339
Experimental drink	215	9.73	38.2	4.85	20.2	272

b. Supplementation with the drink

This phase was carried out during fitness training camp as that is the only time of the year when the training schedule could be controlled as per the requirement of the study design. During the rest of the year, the training schedule varies with individual goals and targets and the emphasis is on skill training.

Creatine kinase (CK) is studied as a biomarker of muscle recovery in athletes. It assesses the extent of Exercise-Induced Muscle Damage (EIMD) in athletes, Delayed Onset Muscle Soreness(DOMS) due to EIMD, and recovery from the same. CK levels increase in blood in response to muscle damage and the fall in these levels post-workout-induced-rise indicates muscle recovery. CK levels increase up to as high as over 10,000 U/L following EIMD. (Koch, Pereira, & Machado, 2014) Inter-individual variability in CK levels is observed and the contributors to this include gender, age, ethnicity, training status, type of exercise, and genetic factors. Obesity based on BMI and higher body fat percent is also linked with higher CK levels. (Kim & Lee, 2015) The three tissue-specific isoenzymes of CK are CK-MB (cardiac muscle), CK-MM (skeletal muscle), and CK-BB (brain).

Baseline CK total levels in the participants were assessed to rule out any muscle injury. Participants having 10 times higher CK total levels compared to the upper normal limit need to be excluded from the study, but there were none and therefore all the participants were included. CK-MB levels were assessed to rule out any cardiac abnormality and CK-MM levels were calculated from CK-MB (formula in methods). As only those participants having normal CK-MB were included in the trials, the rise in the CK total levels was considered to be due to CK MM therefore, only CK total levels were assessed subsequently.

After collecting the blood samples for the baseline CK levels, the participants performed a specially designed workout consisting of eccentric exercises planned with the help of their Physiotherapists and Strength and Conditioning Coaches. This workout schedule was made separately for the Ranji boys' and the Women's squad. (Appendix 8 and 9) Twenty-four hours post-performance of this workout the pre-intervention post-workout CK levels were assessed. The participants received the respective drinks from the next day for 21 days. According to the research protocol, the participants had to consume the drink daily within 30 minutes post-training. For this period of supplementation, the training schedule was maintained the same for all the participants of a particular squad. On the 22nd day, the participants again performed the same workout containing eccentric exercises and 24 hours later the CK levels (post-intervention post-workout) were assessed.

The number of participants who participated in this phase can be seen in table 4.31

Table 4.31: Participants from different squads who participated in the Supplementation phase

	Ranji boys'	**Women squad**
Placebo group	7	12
Experimental group	7	12

In the Women's squad (n=24), the supplementation could be successfully carried out for 21 days. From the Ranji boys' squad (n=20) there were three dropouts each in the experimental and placebo group so the final data could be obtained on seven participants in each group. In this squad, the supplementation could be carried out only for 10 days due to the unexpected announcement of their match schedule during the intervention period. Supplementation could not be carried out in the Under-23 boys' squad due to their prolonged match season and invitation matches even during the off-season.

Less control was possible over the Ranji boys' squad mainly in terms of monitoring. Immediately after the training, the players took an ice bath. As this was also the time (30 minutes post-training) when they were supposed to consume the drink, they would pick up their respective drinks and proceed for the ice bath. So monitoring the drink consumption was not possible the majority of the time.

c. Impact Evaluation of Supplementation on Muscle recovery (CK)

The test of normality conducted on various variables is given in table 4.32. Shapiro Wilk test was applied to test normality as the sample size is less than 200. P-value more than 0.05 indicates normal distribution.

Table 4.32: Test of Normality

Variables	**Shapiro-Wilk**		
	Statistic	**Df**	**p-value**
Baseline CK total (U/L)	0.616	38	0.000
Baseline CK MB (U/L)	0.711	38	0.000
Baseline CK MM (U/L)	0.618	38	0.000
Pre-intervention Post-workout CK (CK 1)	0.823	38	0.000
Post-intervention Post-workout CK (CK 2)	0.251	38	0.000

As none of the variables has a p-value>0.05, none of the variables followed a normal distribution. (Table 4.32)

Table 4.33 depicts the CK levels (CK total, CK- MB, CK-MM) of the participants from Ranji boys' and Women's squads. CK MM levels are calculated using the formula mentioned in Methods and Materials. The U-23 squad wasn't available for intervention and therefore table 4.33 presents the mean CK levels of the Ranji boys' and Women's squads only. Table 4.33 also presents median CK levels of Ranji and Women squad as, for skewed data; the median better represents the middle of the data than the mean. (Mahmutyazicioglu et al, 2018) In the Ranji boys' squad, data is presented for 6 participants in the experimental group in all the subsequent discussions, as data of one outlier is excluded for statistical analysis.

As can be observed from table 4.33, at the baseline, the CK total levels in the placebo {P} and the experimental {E} groups were similar for both Ranji Boys' squad and Women's squad (243.3±132.9 U/L {P}; 296 ±126.0 U/L {E} and 130.7±72.2 U/L {P}; 117.3± 52.5 U/L {E} respectively).

Table 4.33: Creatine Kinase levels at Baseline of the participants from Experimental and Placebo group from Ranji boys' squad and Women squad

Variables (U/L)	**Ranji boys' squad**		**Women squad**	
	Placebo (n=7)	**Experimental (n=6)**	**Placebo (n=12)**	**Experimental (n=12)**
Baseline CK- total Range Mean	 95-467 243.3±132.9	 156-497 296 ±126.0	 35-249 130.7±72.2	 47-230 117.3± 52.5
Median	186	301	122	105.5
p- value	**0.236**		**0.608**	
Baseline CK-MB Range Mean	 9-13 11.7±3.9	 6-14 10.5± 2.6	 6-31 9.4 ±5.0	 5-19 9.6 ±5.2
Median	11	11	8.5	8.0
Baseline CK-MM Range Mean	 78.5-453.5 340.7±279.0	 139.5-476 280.3 ± 124.9	 23-237 113.0±63.6	 35-213.5 111.5 ± 62.3
Median	169.5	292	96.25	93.75

As the variables do not follow the normal distribution, Mann Whitney U test was applied.

Gender has an influence on CK levels. The CK levels were found to be higher in the participants from Boys' Squad at baseline, pre-intervention post-workout and post-intervention post-workout 243.3±132.9 U/L {P}; 296±126.0 U/L {E}, 326.7±195.4 U/L {P}; 329.17±182.74 U/L {E} and 211.0±96.0 U/L {P}; 376.8±281.7 U/L {E} respectively as compared to the participants from the Women's Squad 130.7±72.2 U/L {P}; 117.3± 52.5 U/L {E}, 203.2±121.7 U/L {P}, 147.9 ±96 U/L {E} and 133.6±75.0 U/L {P}, 128.9± 68.9 U/L {E} respectively. CK levels are reported to rise with an increase in muscle mass which explains the higher CK levels observed in the participants from Boys' Squad. (Yen et al., 2017; Mougios, 2007; Hortobagyi & Denahan, 1989) Moreover, these differences can also be attributed to the higher CK content of men's muscle than that of women's muscle. (Mougios, 2007)

The reference limit range of CK levels is quite wide as can also be seen from the data in table 4.33. The reference limit for CK levelsfor boys is 82-1083 U/L and for women, it is 47-513 U/L. (Mougios, 2007) As per these cut-offs, the mean baseline CK total value was within the reference limits for participants from both Ranji boys' and women's squads. However, there is a need to formulate sports-specific reference limits for CK levels as harsh playing conditions like heat also impact CK levels and thus can result in inter-sport CK variability. (Mougios, 2007; Hortobagyi & Denahan, 1989)

A study conducted on 30 female basketball players, reported mean baseline CK levels of the participants as123.30±1.76 U/L which is similar to that obtained in the present study for the women's squad. (Khajehlandi & Janbozorgi, 2018) A study conducted on 8 male athletes, reported the mean baseline CK levels of the participants as 252.97±160.44 U/L which is similar to that obtained in the present study for the Ranji boys' squad. (Peschek et al, 2014)

Normal reference values for serum CK–MB range from 3 to 5% (percentage of total CK) or 5 to 25 IU/L for all; women and boys. (Tsung & Savory, 1986) The mean CK-MB values were within the normal range for all the squads. CK-MB levels rise in the event of cardiac abnormalities therefore, the CK MB levels were assessed to rule out the possibility of cardiac ailments in the participants.

Table 4.34 depicts the baseline CK levels and Pre-intervention post-workout CK levels of the participants of the Ranji boys' squad and Women's squad. In the Ranji boys' squad, data is presented for 6 participants in the experimental group, as data for one outlier is excluded for statistical analysis.

Table 4.34: Baseline CK and Pre-intervention post-workout CK (CK1) levels in the participants from Experimental and Placebo group from Ranji boys' squad and Women's squad

Variables (U/L)	Ranji boys' squad		Women squad	
	Placebo (n=7)	**Experimental (n=6)**	**Placebo (n=12)**	**Experimental (n=12)**
Baseline CK- total Mean	243.3±132.9	296 ±126.0	130.7±72.2	117.3± 52.5
Pre-intervention post-workout CK total (CK 1) Mean	326.7±195.4	329.1±182.74	203.2±121.7	147.9 ±96
p- value	0.221	0.474	0.125	0.341

As the variables do not follow the normal distribution, the Related Samples Wilcoxon Signed Rank Test was applied.

As can be seen from Table 4.34, there was an increase in the CK levels pre-intervention post-workout from 243.3±132.9 U/L to 326.7±195.4 U/L in the placebo group and from 296 ±126.0 U/L to 329.1±182.74 U/L in the experimental group of Ranji boys' squad. However, this rise was not statistically significant. Similar findings have been reported from a study conducted on 8 male athletes, wherein a non-significant rise in the CK levels from 252.97 ±160.44 to 266.78±254.38 U/Lwas observed post eccentric workout. (Peschek et al, 2014)

The data from the Women's squad shows an increase in the CK levels pre-intervention post-workout from 130.7±72.2 to 203.2±121.7 U/L in the placebo group and from 117.3± 52.5 to 147.9 ±96 U/Lin the experimental group of women squad. This elevation was again statistically non-significant. A study conducted on 30 female basketball players, reported the post-workout CK levels of the participants as 132.25±8.27 U/L, these levels are similar to the mean pre-intervention post-workout

CK levels (CK 1) observed in the women squad in the present study. (Khajehlandi & Janbozorgi, 2018)

The non-significant elevation observed in the CK levels pre-intervention post-workout could be due to the conditioning of the muscles seen in athletes. (Hortobagyi & Denahan, 1989) The participants from the present study were elite athletes with a mean training/cricketing experience of 7.9 years.

Table 4.35 depicts the pre-intervention post-workout CK levels (CK 1) and post-intervention post-workout CK levels (CK 2) of the participants from the Experimental and Placebo group from the Ranji boys' squad and Women's squad

Table 4.35: Pre-intervention post-workout CK levels and Post-intervention post-workout CK levels of the participants from Experimental and Placebo groups from Ranji boys' squad and Women squad

Variables (U/L)	Ranji boys' squad		Women squad	
	Placebo (n=7)	**Experimental (n=6)**	**Placebo (n=12)**	**Experimental (n=12)**
Pre-intervention post-workout CK total (CK1)	326.71 ± 195.37	329.17 ± 182.74	203.17 ± 121.72	147.92 ±96.06
	P value- 0.562		**P value- 0.230**	
Median	270.0	319.0	151.0	110.0
Post-intervention post-workout CK total (CK2)	211.00 ± 96.028	376.83 ±281.73	133.58 ± 74.99	128.92 ± 68.92
	P value- 0.27		**P value- 0.830**	
Median	160	347	111.5	98

As the variables do not follow the normal distribution, Mann Whitney U test was applied.

As can be observed from table 4.35, the mean CK levels recorded for the Ranji Boys' squad were 326.7±195.4 U/L (Pre-intervention post-workout) and 211.0±96.0 U/L (Post-intervention post-workout) in the placebo group and 329.2±182.7 U/L (Pre-intervention post-workout)and 376.8±281.7 U/L (Post-intervention post-workout) in the experimental group. The pre and post-intervention post-workout mean CK levels observed in the Women's squad were 203.2±121.7 U/L and 133.6±75.0 U/L respectively in the placebo group and 147.9 ±96 U/L and 128.9± 68.9 U/L respectively in the experimental group. The CK1 and CK2 levels were similar in the placebo and experimental groups of both the Ranji boys' and women's squad as can be seen in table 4.35. The elevation in the CK levels at pre-intervention post-workout and post-intervention post-workout observed in the participants from both the squads in the present study were within the upper reference limits reported by other studies. CK elevations of 10,000 IU/L to >20,000 IU/L post eccentric workout have been reported by various investigators. Even with the CK elevation of >20,000 IU/L renal compromise has not been reported. (Koch et al., 2014)

Table 4.36 depicts the impact of intervention with cocoa flavanol rich milk-based beverage based on the change in the pre-intervention post-workout CK levels (CK 1) and post-intervention post-workout CK levels (CK 2) of the participants from both the squads.

Table 4.36: Impact of intervention with Cocoa Flavanol rich drink on CK levels of the participants from Experimental and Placebo group from Ranji boys' squad and Women squad

Variables (U/L)	Ranji boys' squad		Women squad	
	Placebo (n=7)	Experimental (n=6)	Placebo (n=12)	Experimental (n=12)
Pre-intervention post-workout CK total (CK1)	326.71 ± 195.37	329.17 ±182.74	203.17±121.72	147.92 ±96.06
Post-intervention post-workout CK total (CK2)	211.00 ±96.028	376.83±281.73	133.58 ± 74.99	128.92 ±68.92
P-value	**0.080**	**0.44**	**0.108**	**0.605**

As the variables do not follow the normal distribution, the Related Samples Wilcoxon Signed Rank test was applied.

The pre-intervention and post-intervention CK values were compared to assess the impact of the intervention with cocoa flavanol rich drink on the muscle recovery of the participants (Table 4.36). At the baseline, the placebo and experimental groups were similar in terms of CK levels for both the squads. Reduction in the CK levels was observed in the Ranji boys' squad placebo group from 326.71 ± 195.37 U/L (Pre-intervention) to 211.00 ± 96.028 U/L (Post-intervention); the reduction being non-significant (p=0.08). The rise was observed in the CK levels of the Ranji boys' squad experimental group from 329.17 ±182.74 U/L (Pre-intervention) to 376.83±281.73U/L (Post-intervention); the rise being non-significant (p=0.44). The rise in CK 2 levels in the Ranji squad instead of the reduction cannot be explained due to two limitations in the supplementation in this squad. The first limitation was the reduction in the supplementation period from21 days10 days due to the unexpected announcement of their match schedule during the intervention period. Secondly, the participants used to pick up the drink andproceed for the ice bath as per their protocol therefore, monitoring of the drink consumption was not possible in the Ranji boys' squad. (Monitoring was possible in the women's squad as they don't have the protocol of ice bath)

In the women squad placebo group, a reduction in the CK levels was observed from 203.17 ± 121.72 U/L (Pre-intervention) to 133.58 ± 74.99 U/L (Post-intervention); but the reduction was statistically non-significant (p=0.108). In the women's squad experimental group, a reduction in the CK levels was observed from 147.92 ±96.06 U/L (Pre-intervention) to 128.92 ± 68.92 U/L (Post-intervention); the same being statistically non-significant(p=0.605).

The CK levels post-intervention post-workout (CK2) in the placebo groups of both the squads were expected to show no change over baseline values but the results from the present study show a non-significant fall in the CK levels (CK2). It can be attributed to the 'repeated bout effect' or 'rapid adaptation', where the muscles get adapted to stimuli of similar workout performed and the CK levels don't rise as much after the second workout as after the first stimuli. The non-significant fall post-intervention post-workout in the experimental group can also be attributed to the 'repeated bout effect' or 'rapid adaptation'. (Hortobagyi & Denahan, 1989; Mougios, 2007)

Reviewed literature shows that supplementation with cocoa flavanols ranging from 308 mg to 350 mg for a period of 1 day to 7 days did not show improvement either in the CK levels or in the fitness test performance following the eccentric workout. However, improvement was reported in the perceived muscle soreness by the athletes. (Giolo de Carvalho et al., 2019, Peschek et al., 2014, Mcbrier et al, 2010) No beneficial effects were found either after short-term supplementation for 10 days in the Ranji squad nor after long-term supplementation for 21 days in the Women squad and the reviewed literature shows similar findings.

An important conclusion that can be drawn from the results of the present study is that use of a single biomarker with wide variation in the lower and upper reference limits for assessing muscle recovery can lead to inconclusive results. Therefore, future research should include a recovery marker that has a narrower reference limit as compared to CK levels. The biomarker can further be coupled with indicators like the assessment of self-perceived muscle soreness and fitness test performance scores before and after the intervention.

Association between baseline CK total levels and BMI, anthropometric parameters, body composition and the cricketing experience was studied and the results are presented for each squad in table 4.37.

Table 4.37: Correlation of baseline CK total levels with BMI, anthropometric parameters and body composition across all squads

Baseline CK total levels (U/L)		**BMI**	**WC (cm)**	**WHtR**	**WHR**	**% body fat**	**% LBM**	**BFMI kcal/day**	**FFMI (kcal/day)**
Ranji	r value	0.065	-0.263	-0.181	-0.449	-0.163	0.163	-0.058	-0.025
	p value	0.792	0.276	0.459	0.054	0.505	0.505	0.814	0.919
U-23 boys	r value	0.179	0.120	-0.025	0.014	0.147	-0.147	0.172	-0.048
	p value	0.524	0.670	0.930	0.960	0.615	0.615	0.557	0.864
Senior women	r value	0.429	0.378	0.429	-0.038	0.352	-0.396	0.396	-0.226
	p value	0.144	0.203	0.144	0.901	0.239	0.181	0.180	0.459
U-19 women	r value	-0.414	-0.459	-0.482	-0.500	-0.336	0.282	-0.427	0.383
	p value	0.125	0.085	0.069	0.058	0.221	0.308	0.112	0.159

As the variables did not follow the normal distribution, Spearman's Correlation was used.

No significant correlation was noted between baseline CK levels and BMI, anthropometric parameters and body compositionas can be seen from data presented in table 4.37. However, a study carried out on 4500 participants (males and females) observed that higher CK levels in the participants were positively associated with high BMI, high body fat mass and greater waist circumference. (Yen et al., 2017) The postulation to explain this is based on the theory that high CK levels are associated with a predominance of type II muscle fibres. Type II fibers have lower mitochondrial content, lower expression of insulin-dependent transporter protein GLUT-4, and lower utilization of fatty acid oxidation. Therefore, high circulating CK levels may indicate a greater propensity to excessive fat storage in the body.

Table 4.38 presents the association between Pre-intervention post-workout CK levels (CK1)and BMI, anthropometric parameters, body composition and cricketing experience in the participants from Ranji, Senior women, and U-19 women squads. The intervention could not be carried out in the U-23 boys' squad hence the CK1 levels data are not available for this particular group.

Table 4.38: Correlation of Pre-intervention post-workout CK levels (CK 1) with BMI, anthropometric parameters, body composition and cricketing experience across all squads

Pre-intervention post-workout CK levels (U/L) (CK 1)		BMI	WC (cm)	WHtR	WHR	% body fat	% LBM	BFMI kcal/day	FFMI (kcal/day)	Cricket Experience
Ranji	r value	0.250	0.137	0.069	-0.051	-0.135	0.135	-0.007	0.007	0.297
	p value	0.333	0.601	0.794	0.844	0.606	0.606	0.978	0.977	0.247
Senior women	r value	-0.137	-0.204	-0.210	-0.424	-0.287	0.319	-0.274	-0.337	0.187
	p value	0.689	0.548	0.536	0.194	0.392	0.339	0.415	0.311	0.582
U-19 women	r value	-0.243	-0.152	-0.100	0.173	0.000	0.295	-0.004	0.030	-0.179
	p value	0.383	0.589	0.723	0.537	1.000	0.286	0.990	0.916	0.523

As the variables did not follow the normal distribution, Spearman's correlation was used.

None of the squads showed a correlation between Pre-intervention post-workout CK levels (CK1) with BMI, anthropometric parameters, body compositionand cricketing experience. Greater sports experience can have an inverse association with the increase in creatine kinase (CK) because, as a result of body training, CK levels post-workout do not increase as much as in untrained individuals. There was no link between CK1 and cricket experience in any of the squads.A study conducted on 40 male university students showed a positive correlation between the BMI of the participants and their CK levels post eccentric workout. (Kim & So, 2018) Positive correlation was also reported between high percent body fat and CK levels post eccentric exercise in 30 healthy male undergraduates (mean age: 22.0 ±2 years, height: 176.9±5 cm, weight: 75.8±11.6 kg). The implication of this finding for the sports fraternity is that obese athletes or those having high body fat percent should be given sufficient time for recovery and provided required nutrition care before the next exercise bout. (Yoon & Kim,

2020) Moreover, pre-conditioning with mild intensity eccentric exercise must be incorporated before the training programme consisting of intense eccentric workouts. (Kim & Yoon, 2021)

PHASE-3

ASSESSMENT OF NUTRITION KNOWLEDGE OF CRICKETERS AND IMPACT EVALUATION OF INTERVENTION WITH A NUTRITION EDUCATION TOOL

Basic nutrition knowledge, specific to the particular sport in which an athlete is training to excel, can result in better nutrition-based choices which can result in improved athletic performance. (Trakman et al, 2016) Therefore, the existing knowledge, practices and attitudes of athletes towards Sports Nutrition were assessed using a semi-structured questionnaire. The gaps in knowledge identified formed the basis for the development of the tool (Nutrition Education Module - Appendix 14) for intervention. The tool was administered following the protocol mentioned in the methodology chapter and post-intervention changes in the knowledge were measured using the same questionnaire used at baseline. The data at baseline and post-intervention were collected using the interview method. The results of this phase are discussed under the following heads:

Baseline (Pre-intervention) nutrition knowledge among participants
Intervention with Nutrition Education Module
Post-intervention (Nutrition Education Module) shift in knowledge scores

BASELINE (PRE-INTERVENTION) NUTRITION KNOWLEDGE AMONG PARTICIPANTS

The nutrition knowledge among the participants was assessed using a semi-structured knowledge Attitude Practices (KAP) questionnaire by interview method. Following were some of the components that were assessed under the KAP survey.

a. Knowledge assessment of the participants regarding basic nutrition and sports nutrition-
   Basic understanding of the importance of various nutrients, their sources, carbohydrate loading and ergogenic aid etc.
b. Perception of participants regarding the importance of nutrition and sports nutritionist
c. Knowledge and practices related to dietary intake and hydration- Pre, during and post competitive events-
   Consumption of foods and fluids, before, during and after competitive events/matches, foods avoided in general by the participants and foods avoided especially during the events and reasons for the same.

d. Attitude and Practices of the participants regarding supplement use.
e. Consumption of specific foods for recovery from injury.

a. Knowledge assessment of the participants regarding basic nutrition and sports nutrition

The knowledge assessment questionnaire emphasised questions related to the basic understanding of the importance of various nutrients, their sources, carbohydrate loading and ergogenic aid etc. The questions were asked and the responses recorded by the researcher based on how the participants responded. The questions pertaining to knowledge assessment had options from which the participants could choose. For each correct response, a score of one was assigned. Based on the knowledge scores, the participants were classified into the following categories- poor (<40%), fair (41-50%), average (51-60%), good (61-70%), very good (71-80%) and excellent (81-100%).

Table 4.39 depicts the mean baseline knowledge scores of the participants across all the squads.

Table 4.39: Mean percent baseline nutrition knowledge scores of the participants from Ranji boys, U-23 boys, Senior women and U-19 women squads

Ranji boys (n=26)	**U-23 boys (n=28)**	**Senior Women (n=12)**	**U-19 Women (n=15)**	**P-value**
52.5 ±10.4	45.2±10.5	51.1 ±8.7	55.4±15.2	**0.024***

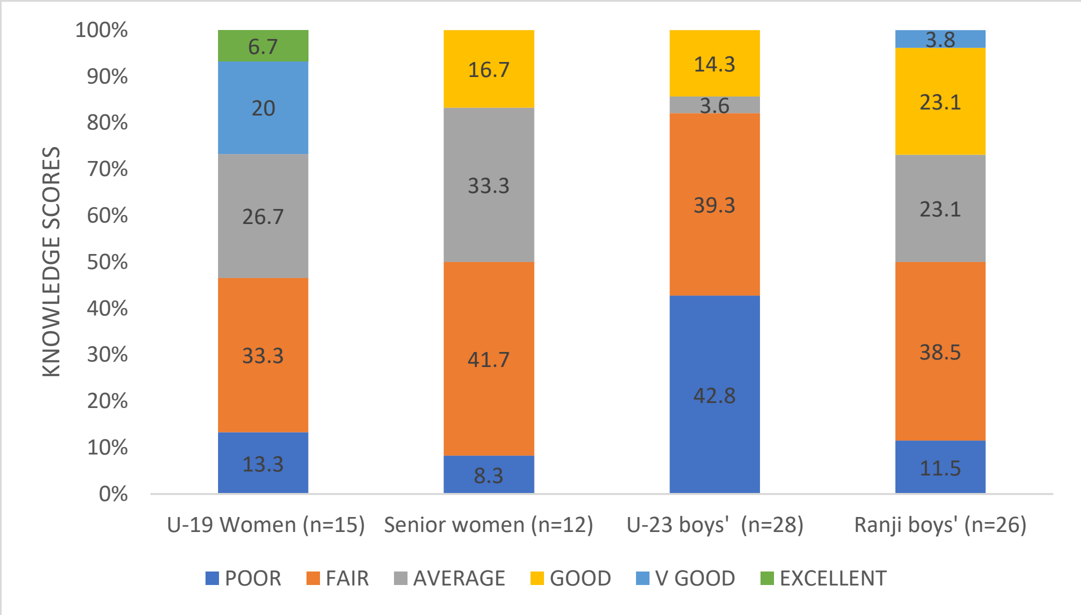
ANOVA was applied

The data from table 4.39 show that the U-19 women's squad had the highest mean percent nutrition knowledge score (55.4±15.2) followed by Ranji boys' (52.5 ±10.4), Senior women (51.1 ±8.7) and U-23 boys' (45.2±10.5). As is evident from the data the mean scores of participants from the Ranji boys', Senior women and U-19 women squads were in the average category and those of U-23 boys fell in the fair category. A study conducted on 328 female Gaelic players found similar results. The mean nutrition knowledge score of the participants was 46.0% ± 11.8% and classified as "poor".(Renard et al, 2020)

As the ANOVA test revealed a significant difference in the means, Tukey's post hoc test was performed to identify the groups with significantly different means. The Tukey's post hoc test revealed that the U-19 women's squad had a significantly higher (p=0.028) mean percent knowledge score (55.4±15.2) than the U-23 boys' squad (45.2±10.5)

Figure 4.19 depicts the categorization of the participants from all squads based on their baseline nutrition knowledge scores.

Figure 4.19: Categorisation of participants from Ranji boys, U-23 boys, Senior women and U-19 women based on baseline nutrition knowledge scores



As can be seen from figure 4.19, the knowledge scores of the players at baseline reveal that majority of the players across all the squads were in the FAIR category i.e., 41-50% score. The players in the Excellent score category were found only in one squad i.e. U-19 Women Squad. The highest percentage of participants in the poor score category was from the U-23 boys' squad. The reviewed literature endorses the findings on nutrition knowledge in athletes from the present study. A study was conducted to assess the sports nutrition knowledge of Gaelic footballers (n=100). The mean knowledge scores of the participants were 47.6±12.3%. (Brien et al, 2021) A study conducted on 3323 Jordanian athletes revealed that as high as 88.3% of the participants had poor nutrition knowledge (<50%) and only 3.2% had excellent nutrition knowledge (>75%). (Elsahoryi et al; 2021) In research conducted on 40 footballers and 50 hockey players, 53.3% of the participants were found to have inadequate nutrition knowledge. (Debnath et al, 2019) Overall nutritional knowledge scores of 10 elite ultramarathon runners (six males and four females), were found to be good (77.50±16.89%), with only one male participant scoring below 50%. (Citarella et al., 2019)A study of 46 elite male Australian footballers found that the participants' average nutrition knowledge score was 60.5 percent. (Devlin &Belski, 2015) The research was conducted on 101 athletes (males = 37, females = 64) to measure their overall nutrition knowledge. In this study, participants received an average score of 58 percent. (Spronk et al, 2015)

In the present study, the mean nutrition knowledge score of Women (32.1±7.6) was marginally higher than boys (29.2±6.6); but it was not statistically significant (p=0.08). Studies have evaluated the impact of gender on nutrition scores but there are mixed findings. In a study conducted on 3323 Jordanian athletes, males scored higher than females (38.17% v/s 35.9%; p-value ≤ 0.001) (Elsahoryi et al., 2021) A study conducted on 128 NCAA (n=70 female; n=58) Division I athletes from eight sports in the United States of America, females scored significantly ($p<0.001$) better than the males (66.5% ±16.4% versus 46.2% ± 14.7%). (Werner et al, 2020)In a study carried out on 101 athletes from Australian state sports institutes, females scored higher than males for nutrition knowledge (Females: 59.9%; Males: 55.6%; $p = 0.017$) (Spronk et al, 2015)

In the present study, the participants obtained the poorest mean knowledge scores at the baseline for components like Basic understanding of ergogenic aids (0), knowledge of nutrients that aid in iron (0.5) and calcium absorption (0.9), the most important source of energy during exercise (0.9) and sources of iron (1.6). The components in which the participants fared well were nutrients important for cricketers (3.3), sources of protein (3.1) and role of protein (2.8). A study conducted on 100 Gaelic footballers revealed that the players scored poorly in categories like micronutrients and supplements while scoring well in others such as alcohol and weight management. (Brien et al, 2021) In a study conducted on 328 female Gaelic players the majority of participants scored well on food-based questions and performed best in subsections related to alcohol and scored poorly on questions referring to micronutrients. (Renard et al, 2020) In a study conducted on 79 endurance athletes from Finland, the participants scored highest in the section of Fluid balance and Hydration (87.2%) and lowest in the category of Dietary supplements (71.4%). (Heikkila et al, 2019) In a study conducted on 10 elite ultramarathon runners (6 males and 4 females) participants scored well on components like "dietary recommendations" and "nutrient sources" knowledge but obtained lower scores on "healthiest meal option" and "diet-disease association" component. (Citarella et al., 2019)

The data on nutrition knowledge scores were segregated by gender to study the correlation between the scores and variables namely age, cricketing experience, anthropometric and body composition indices. The results are presented in Tables 4.40 and 4.41.

Table 4.40: Correlation between baseline knowledge scores and age, anthropometric indices and body composition variables and cricketing experience in the participants from Ranji boys and U-23 boys squad (n=54)

	Age (yrs)	WC (cm)	WHtR	WHR	Cricket Experience	% Body fat	% LBM	BFMI kcal/day	FFMI (kcal/day)
R value	0.210	-0.170	-0.236	-0.167	0.067	-0.136	0.087	-0.154	-0.034
P value	0.128	0.220	0.086	0.228	0.629	0.336	0.541	0.275	0.809

Table 4.41: Correlation between baseline knowledge scores and age, anthropometric indices and body composition variables in the participants from senior women and U-19 women squads (n=27)

	Age (yrs)	WC (cm)	WHtR	WHR	Cricket Experience	% Body fat	% LBM	BFMI kcal/day	FFMI (kcal/day)
R value	0.047	0.287	0.156	0.078	0.102	-0.107	-0.025	-0.069	0.006
P value	0.815	0.147	0.438	0.700	0.612	0.595	0.902	0.731	0.976

Data presented in tables 4.38 and 4.39 show no correlation between the nutrition knowledge scores of male and female cricketers at baseline with the variables studied namely, age, cricketing experience, anthropometric indices and body composition. Studies assessing the association between nutrition knowledge scores and age and duration of playing the sport have reported mixed findings. In a study conducted on 3323 Jordanian athletes, a significant difference was found in the knowledge scores of the participants based on age categories, and duration of playing sport in years. The mean knowledge score was higher amongst participants aged from 26 to 35 years and participants who had played sports for four years or more. (Elsahoryi et al., 2021) In a study conducted on 100 Gaelic footballers, the mean knowledge scores did not differ significantly between different age groups. (Brien et al, 2021) In a study conducted on 260 athletes from Bangladesh, age (p= 0.007) and duration of sports training (p=0.004) of participants were significantly associated with knowledge scores. (Bakhtiar et al, 2021) In a study conducted on 328 female Gaelic players, no significant correlation (p = 0.493) was observed between the age and knowledge scores of the participants. (Renard et al, 2020)In a study carried out on 101 athletes from Australian state sports institutes, no significant association was found between knowledge scores and age. (Spronk et al, 2015) In a Research conducted on 46 elite male Australian football players, no statistically significant associations were noticed between total nutrition knowledge scores and neither age nor years of playing the sport. (Devlin & Belski, 2015)

Table 4.42 depicts the association between baseline knowledge scores of the participants and haemoglobin levels and iron intake. The 2 boys' squads and the 2 women's squads were clubbed for the analysis.

Table 4.42: Correlation between baseline knowledge scores and Haemoglobin and Iron intake in all the participants from boys' squad (Ranji boys' and U-23 boys' squad) and women squad (Senior women and U-19 women squad)

Squad	**Haemoglobin Levels (g/dL)**	**Iron intake (mg/day)**
All boys(n=32) **R value**	0.183	0.369**
P value	0.315	**0.006**
All women (n=27) **R value**	-0.065	0.142

P value	0.747	0.479

As is evident from table 4.42, a significant positive correlation was observed between baseline knowledge scores of the boys' squad and iron intake. However, no correlation was found between knowledge scores and haemoglobin levels. There is a dearth of literature exploring the association between nutrition knowledge of athletes and their dietary intake and/or nutritional status.

The correlation between Education levels and knowledge scores is presented in table 4.43. Data were analysed to examine if educational attainment affects the nutrition knowledge scores of participating athletes.

Table 4.43: Education levels of the participants and baseline knowledge scores

Education Level	**Primary**	**Secondary**	**Higher secondary**	**Graduate**	**Postgraduate**	**p value**
Mean	25.25	30.23	29.52	30.83	32.17	0.58
N	4	13	23	35	6	
SD	3.10	6.38	8.87	6.56	4.35	

ANOVA is applied

As can be observed from the data presented in table 4.43, the education level of the study participants did not have a significant association with nutrition knowledge scores at baseline assessment. However, the scores of participants with only primary level education were least (25.25± 3.10) while for others the scores ranged from 29.52 ± 8.87 to 32.17 ±4.35. Since the sample size was inadequate in the individual education category further statistical analysis was not done. In a study of 3323 Jordanian athletes, significant differences in nutrition knowledge were noted among the participants across educational levels; high school or less (34.37±13.73), diploma or bachelors (36.68±15.20), postgraduate (40.73±16.25). (Elsahoryi et al., 2021) Whereas in a study conducted on 260 athletes in Bangladesh, the educational level of the participants did not show any significant association with their nutritional knowledge. Participants who were studying in schools had a similar level of knowledge score as those who were studying in college (p= 0.619). (Bakhtiar et al, 2021) A study was conducted on 100 elite Gaelic footballers, which demonstrated that there was no association between knowledge scores and the education levels of the participants. (Brien et al, 2021) A study carried out on 101 athletes from 4 Australian Sports Institutes also found no association between knowledge scores and education levels of the participants. (Spronk et al, 2015) Thus, several studies have investigated the association between the education levels of the athletes and their knowledge scores and have demonstrated mixed findings.

b. <u>Perception of participants regarding the importance of nutrition and sports nutritionist</u>

Table 4.44 depicts the perception of participants regarding the importance of nutrition in sports and the merits of having a sports nutritionist in the support staff squad.

Table 4.44: Perception of cricketers regarding the importance of nutrition and sports nutritionist

Practices	Ranji (n=26)	Under-23 boys (n=28)	Senior women (n=12)	Under-19 Women (n=15)
Do you think nutrition support is important in sports?				
Yes	96.2	89.3	100	100
No	3.8	10.7	0	0
If yes, due to what reasons?				
It helps improve performance	72.0	60.0	83.3	86.7
It helps in better recovery post-training	88.0	76.0	75.0	93.3
It improves strength and stamina	96.0	84.0	91.7	93.3
It improves immunity	56.0	32.0	66.7	86.7
If no, then due to what reasons?				
It does not have any benefits	100	0	NA	NA
A good diet is very expensive	100	66.7	NA	NA
Only coaching and training help to improve performance	100	66.7	NA	NA
Do you feel there is a requirement for a sports nutritionist as a part of the sports professionals' team?				
Yes	92.3	92.9	100	86.7
No	7.7	7.1	0	13.3
If yes, due to what reasons?				
To design personalized diet plans for better performance	87.5	80.8	83.3	100.0
Regularly monitor the diet plans of each player	83.3	73.1	83.3	84.6
Conduct workshops on Sports Nutrition	33.3	38.5	66.7	53.8
Dietary Counselling for special conditions (e.g. Anemia, injury)	54.2	42.3	75.0	69.2
If not, due to what reasons?				
Support staff gives us adequate nutrition guidelines	100	100	0	100
We access knowledge about nutrition through media	50	50	0	0
A sports nutritionist may not make a significant difference in our performance	50	0	0	0

The sum of the options of various questions can be more than 100% as the participants could choose multiple responses.

Over 89.3 percent of respondents indicated that nutrition support is critical in their sport. The primary argument given was that it increases strength and stamina. For individuals who stated that nutrition support is not necessary for their sport, the most frequently given reasons were that a healthy diet is too expensive and that only coaching and exercise increase performance.

Over 86.7 percent believed that a nutritionist should be a member of the sports professionals' team. A sports nutritionist's most well-recognised job was that of a person who could construct customised diet plans to help athletes improve their performance. Some respondents claimed that eating a healthy diet is unreasonably expensive; this highlights the need of having a sports nutritionist who can debunk such myths. The association to which the participants were affiliated did not have a sports nutritionist on staff. Occasionally, the association contracted with nutritionists to deliver seminars. However, coaches, strength and conditioning coaches, and to a lesser extent, physiotherapists provided the necessary nutrition recommendations. These support workers lacked the necessary nutrition training to cater to elite athletes, but in the absence of a nutritionist, they provided dietary recommendations.

A study was conducted to examine the impact of having a sports dietitian (SD)v/s strength and conditioning coach (SCC) on nutrition practices of baseball players (n=74, 20.7 ± 1.4 years) from 3 NCAA Division I institutes. The SD group (n=32) found it easier to eat before activity (92% vs. 71%, p = 0.03), did not consume fast food (31% vs. 14%, p = 0.02), caffeinated beverages (57% vs. 46%, p = 0.02), or soda (56% vs. 37%, p = 0.10), prepared their own meals more often (86% vs. 73%, p = 0.07), and took daily multi-vitamins (56% vs. 32%, p = 0.02). The SCC group (n=42) ate more at burger locations (21% vs. 6%, p = 0.02). The SD group ate breakfast before training/lifting sessions (67% vs. 37%, p = 0.02). The study therefore concluded that presence of SD as support staff is a valuable asset to the athletic program. (Hull et al., 2017)

c. <u>Knowledge and practices related to dietary intake and hydration- Pre, during and post competitive events</u>

Pre, during and post-match or workout diet is very crucial for an athlete for sustained energy and hydration which can help achieve optimal athletic performance. Table 4.45, depicts the practices of the participants in terms of consumption of food and fluids before and after a match.

Table 4.45: Practices of the cricketers in terms of consumption of food and fluids before and after a match

Practices	Correct (%)	Incorrect (%)
When do you consume solid foods before a match?		
Ranji (n=26)	65.4	34.6
Under-23 boys (n=28)	60.7	34.3
Senior women (n=12)	75	25
Under -19 Women (n=15)	60.0	40
When do you consume fluids before a match?		
Ranji (n=26)	100	0
Under-23 boys (n=28)	100	0
Senior women (n=12)	100	0
Under -19 Women (n=15)	86.7	13.3
Practices	**Correct (%)**	**Incorrect (%)**
When do you consume solid foods after a match?		
Ranji (n=26)	50.0	50

Under-23 boys (n=28)	21.4	78.6
Senior women (n=12)	33.3	66.7
Under -19 Women (n=15)	33.3	66.7
When do you consume fluids after a match?		
Ranji (n=26)	100	0
Under-23 boys (n=28)	100	0
Senior women (n=12)	100	0
Under -19 Women (n=15)	100	0

As can be seen from Table 4.45, the majority of respondents (over 60%) ate solid food 30 minutes to 1 hour before a match, which is the proper procedure. Over 86.7 percent of the participants said they drank water 30 minutes before a match, which is a good habit. All the respondents stated that they consumed fluids within 30 minutes of the match, which is another acceptable practice. The window of recovery is thirty minutes after a match or other strenuous physical activity, and it is vital to ingest solid foods including carbohydrates and proteins during this time. Over 21% of the participants consumed solid items within the recommended period of 30 minutes after the match. However, most of them (over 46.2%) had solid items within 30 minutes to an hour following the contest. These findings indicate a lack of awareness among the participants regarding the timing of solid foods. Making this tiny adjustment can significantly aid in the recovery process, which is a vital element of every athlete's regimen.

The majority of respondents from both the sexes reported eating within one hour of exercises and/or practises (67.1 percent males vs. 58.9 percent females) in a research of 331 NCAA Division III players from the United States of America (n= 149 males; n= 181 females), which is similar to the findings of the current study.However, the majority of the athletes (49.7% males vs. 59.4% females) consumed meals within one-to-two hours post-workouts instead of within the 30 min window. (Klein et al, 2021)A study conducted on 31 soccer players representing a University in South Africa revealed that none of them consumed any food within the window of recovery i.e. within 30 minutes post-training. Whereas, with respect to pre-match meal, 65% consumed meals 2–3 hours before the training, 35% before 1-2 hours and 5% of them before < 1 hour of training. (Masoga et al, 2022)

During the BCCI matches, the association provided food on match day. The pre-match meals (breakfast) are provided in the hotel and then at the match ground, lunch during the lunch break of the match is followed by the post-match snacks. The pre-match meal usually has some of these items; eggs, poha, upma, paratha, cereal with milk, sandwich, idli-sambhar and fruits. The lunch consists of items like Roti, subji, dal, rice, sweets, salad, chicken, ice cream, fruits etc. The majority of the participants reported that they avoid ice cream during the lunch break. The post-match snacks include some the foods like pasta, sandwich, cutlets, noodles etc. Thus the majority of the food options were carbohydrate-rich. In a study conducted on 331 NCAA division III athletes from the United States of

America, the participants reported consuming mostly carbohydrate and protein-rich foods before and after workouts/practices. (Klein et al, 2021)

The participants were asked about their food preferences and habits in general, throughout the year. The most common foods that the participants avoided in general were fried foods, excessive oily food, fast food and soft drinks and the reason stated behind it was to avoid putting on body fat. The most common foods that the participants avoided before a match were outside food and the reason stated was to avoid any infection, and spicy foods to avoid gastrointestinal discomfort. There have been no studies that specifically look at the food preferences and patterns of athletes. Nonetheless, a study conducted in the United States on 331 athletes from the National Collegiate Athletic Association Division III found that intake of items such as cakes, sweets, and pastries was as low as 3.4 percent for males and 2.8 percent for girls. However, chips, pretzels, and crackers were consumed by 28.9 and 35.4 percent of males and females, respectively. (Klein et al, 2021)

d. <u>Knowledge, Attitude and Practices of the participants with regards to supplement use</u>

Supplement use is very common in sports and varies from sport to sport. The data on supplement usage in the participants is shown in Table 4.46.

Table 4.46: Percent consumption of supplements and Types of supplements consumed by participants from Ranji boys, U-23 boys, Senior women and U-19 women squads (%)

	Ranji boys (n=29)	**Under-23 boys (n=38)**	**Senior women (n=14)**	**Under-19 women (n=15)**	**Total (n=96)**	**p value**
Supplements taken	100	100	100	100	100	-
Sports drinks	89.7	97.4	100	100	95.8	0.235
Protein	72.4	52.6	0	6.7	43.8	**0.000***
BCAA	6.9	2.6	0	0	3.1	0.507

As is depicted in table 4.46, all the participants (100%) across all the four squads were consuming some kind of supplement. A study conducted on 302 Canadian university athletes (30.5% male, 69.5% female; 20.5 ± 1.8-year old) who were competing in intermittent, power and endurance-based sports revealed that 58.3% of the athletes reported having used at least one Dietary Supplement in the past six months.(Roy et al, 2020) A cross-sectional study was undertaken on 359 professional athletes participating in individual (boxing, cycling, and athletics) and team (basketball, rugby, football, netball, and volleyball) sports. The study revealed that 48 athletes (13.4%) used nutritional supplements. (Muwonge et al, 2017) Another study was carried out on 182 athletes of both genders from 20 different sports. Forty-seven percent of athletes reported having consumed at least one type of supplement and 38% mentioned that they take more than 3 different types of supplements concurrently. (Nabuco et al, 2017) Portuguese athletes from 13 sports completed a Nutrition supplement usage questionnaire assessing information over the previous 12 months. Of the 244 athletes, 64% reported consuming supplements. (Sousa et al, 2016) In a study conducted among professional footballers in Saudi Arabia, it was found that of the 105 athletes surveyed, 93.3% were taking supplements. (Aljaloud and Ibrahim, 2013)

As is evident from table 4.46, Sports drinks were the most widely used segment of supplements followed by protein supplements and BCAA. In all the three squads, namely Under-23 boys, Senior women and Under-19 women all the cricketers consumed sports drinks. The usage of sports drinks was equally high in the Ranji squad with 88.5 percent of the individuals doing so. Protein supplement usage was found to be significantly greater in the boys' squad (72.4 percent in the Ranji boys and 52.6 percent in the U-23 boys') than in the women's team (none in senior women and 6.7% in Under-19 Women). Branched-chain amino acid supplement consumption was seen only in the Ranji squad (6.9%) and U-23 boys’ squad (2.6%). In a study conducted on 302 Canadian university athletes, the types of DS most commonly consumed were protein (48.7%), vitamins and minerals (48.0%) and carbohydrate (36.1%) supplements. (Roy et al, 2020) In a study conducted among professional footballers in Saudi Arabia, 88.7% of the participants were taking sports drinks, which is similar to the numbers found in the present study. (Aljaloud and Ibrahim, 2013)

In the present study, Sports drinks were consumed during matches as all the BCCI organised tournaments provide sports drinks to the players. Sports drinks were also consumed during off-season training to compensate for the water and electrolyte loss and to gain some energy. Protein and BCAA supplements were majorly consumed during the offseason as during the match season, they are avoided due to the chances of positive dope tests because of possible contamination with banned substances.

Table 4.47 depicts the Knowledge, Attitudes and Practices of the participants concerning Supplement use.

Table 4.47: Knowledge, Attitude and Practices of the participants from Ranji boys, U-23 boys, Senior women and U-19 women squads with regards to supplement use (%)

Variables	**Ranji (n=26)**	**Under-23 boys (n=28)**	**Senior women (n=12)**	**Under-19 Women (n=15)**
Do you think supplements are useful to you as a cricketer?				
Yes	100	100	83.3	93.3
No	0	0	16.7	6.7
If yes, then due to what reasons?				

To improve performance	57.7	42.9	58.3	40.0
To build strength	76.9	64.3	58.3	73.3
To improve fitness	53.8	50.0	25	26.7
To improve cardiorespiratory endurance	42.3	50.0	41.7	46.7
If no, then due to what reasons?				
They are officially banned	NA	NA	0	0
Do not have any benefit	NA	NA	0	100
Have a negative impact on health	NA	NA	0	0
Have more side effects compared to benefits	NA	NA	100	0
In how many instances do you choose the supplements yourself?				
Never	7.7	14.3	75	86.7
Occasionally	61.5	39.3	25	6.7
Majority of the times	7.7	0	0	0.0
Rarely	23.1	46.4	0	6.7
What is the source from where you procure supplements?				
Sports association	100	100	100	100
Sport supplement stores	0	0	0	0
Online	0	0	0	0
Others	84.6	89.3	16.7	6.7
If you have to take supplements, whose advice would you follow?				
Physiotherapists	46.2	53.6	75	86.7
Strength and conditioning coaches	76.9	67.9	66.7	60.0
Coaches	7.7	0	25	6.7
What is the source of your supplement related knowledge?				
Journals	7.7	0	0	6.7
Internet	42.3	53.6	41.7	40.0
Supplement marketing personnel	7.7	7.1	0	0
Seminars by supplement companies	11.5	14.3	25	40.0
Others	69.2	75.0	58.3	53.3
Which supplements do you trust for their quality?				
Indian	7.7	17.9	33.3	33.3
International	65.4	57.1	25	40.0
Don't know	26.9	25.0	41.7	26.7
Which country has the best sports supplements?				
United States	46.2	42.9	16.7	26.7
Australia	65.4	7.1	25	6.7
United kingdom	15.4	17.9	8.3	13.3
Others	0	0	0	0
Don't know	26.9	32.1	50	53.3

For certain questions, the sum of the percentages can be greater than 100 as the participants could choose multiple responses

As is presented in table 4.47, the majority (83.3%) of the participants across all squads reported that supplements were useful to them in their sport. The most frequently quoted reason for consuming supplements was for building strength which was reported by over 58.3% of the participants. In the Ranji squad, 61.5% reported occasionally choosing supplements themselves instead of advice from a professional. This can be a matter of concern as it can result in incorrect choice, excess or inadequacy of the required nutrient etc. The one common source of procurement of the supplements as reported by all the participants was their Sports association. The supplements received from the Sports association were only Sports drinks and that too only during competitive matches. Any other supplements like protein supplements or Branched-chain amino acids were not provided by the association. The participants procured these supplements from their strength and conditioning coaches of the association and at times from the gym trainers. The cricketers were asked to not consume protein or BCAA’s before or during match season to avoid any chance of doping violation. There have been instances where the supplements contained traces of banned substances due to which the athlete had to face strict adverse consequences after testing dope positive.

When it came to taking advice regarding supplements majority of the participants consulted strength and conditioning coaches and physiotherapists while a very small percentage of participants talked to the coaches. The majority of the participants' supplement-related knowledge came from their support staff, such as Strength and conditioning coaches and physiotherapists (over 53.3%), followed by the internet (over 40%). None of them mentioned having consulted a Sports Nutritionist or a Nutritionist for the supplement advice. In a study conducted on 302 Canadian university athletes, the most common sources of information regarding supplements were health care professionals (59.2%), friends/family (53.4%), internet (48.3%), their own judgment (48.3%), teammates (44.8%) and coaches (39.1%). (Roy et al., 2020) In a survey carried out on 3363 athletes, 61.8% reported social media, followed by a dietitian (38.1%), coaches (30.6%), friends (25.3%) and scientific sources (24.4%) as their source of supplement related information. (Elsahoryi et al., 2021)Of the 331 Australian athletes assessed for nutrition knowledge, 20%, 19%, and 16% of athletes chose 'dietitian', 'internet' and 'nutritionist' as their preferred sources of nutrition information, respectively. (Trakman et al, 2019) In a survey involving 306 athletes, 65% reported social media use for nutrition purposes in the last 12 months. Female athletes were more likely to have used social media for nutrition purposes (OR=2.7, 95% CI: 1.52–4.62, p = 0.001) than males. (Bourke et al, 2019)

In terms of the quality of supplements, more participants chose international products over national brands. When asked about the country having the best Sports Supplement, the United States and Australia came high on their perceived list.

e. Consumption of specific foods for recovery from injury

Injuries are an unavoidable part of Sports and speedy recovery is very important for an athlete's professional career. The participants were asked if they consumed specific foods to recover faster from injuries. The responses received are put forth in the table 4.48

Table 4.48: Foods consumed by the participants from Ranji boys, U-23 boys, Senior women and U-19 women to recover faster from an injury (%)

Foods	Ranji (n=26)	Under-23 boys (n=28)	Senior women (n=12)	Under-19 Women (n=15)
Milk with turmeric	15.4	14.3	8.3	20.0
Chicken/ Chicken soup	3.8	7.1	8.3	6.7
Paya soup	15.4	10.7	-	-
Milk	7.7	-	8.3	-
Fish	-	3.6	-	6.7
Mutton/Mutton soup	-	3.6	-	6.7
Pulse	-	-	8.3	-
Egg	-	-	-	6.7
Electral	-	-	-	6.7
Nimbupani	-	-	-	6.7
Protein shake	3.8	-	-	-
Ghee and butter	3.8	-	-	-
Calcium supplement	3.8	-	-	-
Avoid sour foods	3.8	-	-	-
Fruits	3.8	-	-	-
Paneer	3.8	-	-	-
Boiled meat	3.8	-	-	-
Dryfruits	-	3.6	-	-
None	46.2	67.9	75	53.3

As can be observed from table 4.48, a substantial percentage (over 46.2%) of the participants reported consuming no specific foods for recovery from injuries. Amongst various foods reported by the remaining participants, milk with turmeric topped the list which was reported by participants from all the squads though not very large in numbers. Turmeric milk is an age-old remedy and its effects are attributed to Curcumin which is the active component in turmeric and has anti-inflammatory, antimicrobial and antioxidant properties. The anti-inflammatory property of curcumin is one of the most remarkable properties due to which it plays an important role in healing from injuries. (Agarwal, 2018) The next highly consumed food for recovery was chicken or chicken soup which was again reported by participants across all the squads. Chicken meat and its extracts have long been recognized as a source of bioactive molecules that can potentially improve health status in general. The health benefits of chicken extracts are attributed to its active components; including proteins, free amino acids, taurine, many minerals, trace elements, and vitamins. (Barbaresi et al, 2021) However, there is no literature available which has explored the foods that athletes consume to recover from injuries.

INTERVENTION WITH NUTRITION EDUCATION MODULE

Based on the gaps identified from the knowledge assessment of the participants a Nutrition Education Module was developed to address the gaps. This module was developed in the form of a booklet (Appendix 14) to educate the participants on the basics of Nutrition and Nutrition strategies for cricket specifically.

Components of the Nutrition Education Module

Some key concepts incorporated in the booklet are as follows.

- Nutrients of significance to athletes
- Nutrition before, during and after the event
- Recovery Nutrition
- Hydration
- Electrolyte requirements

Pretesting of the module was conducted to assess the ease of understanding the content and its usefulness. The pretesting was carried out on 20 cricketers from the Under-19 boys Zonal Cricket Association (ZCA) camp. This group consisted of boys under the age of 19 years who were selected for the ZCA camp. They came from various socioeconomic and educational backgrounds. In addition, their support staff (coaches, trainers, and physiotherapists) who had more than thirty years of experience working with elite cricketers were also involved in the content validation of the module. After receiving positive feedback, the final printing of the booklet was done. This module was distributed to all the participants included in the study and their support staff. Permission was not granted for one-to-one interaction so the reinforcement of the key messages was done daily for 15 days through social media (What's app groups).

SHIFT IN KNOWLEDGE SCORESON INTERVENTION WITH NUTRITION EDUCATION MODULE

The impact evaluation was carried out after a washout period of two months. The same questionnaire which was used at the baseline was administered for collecting post Nutrition education module intervention responses. The Post-intervention data revealed that the knowledge scores of the participants had improved.

Table 4.49 depicts the normality test results of knowledge scores of the participants. Shapiro Wilk test is applied to test normality as the sample size is less than 200. P value more than 0.05 indicates normal distribution. The figures marked with an asterisk and in bold are more than 0.05 and therefore the variables follow a normal distribution.

Table 4.49: Normality test of knowledge scores

	Shapiro-Wilk		
	Statistic	**Df**	**p value**
Baseline knowledge scores	0.991	55	**0.080***
Post-intervention knowledge scores	0.887	55	**0.091***

Table 4.50 depicts the comparison between the pre and post-intervention knowledge scores among participants across the squads. Table 4.50 does not include the Ranji squad as the post-intervention data could not be collected in this squad due to their long-term professional commitment.

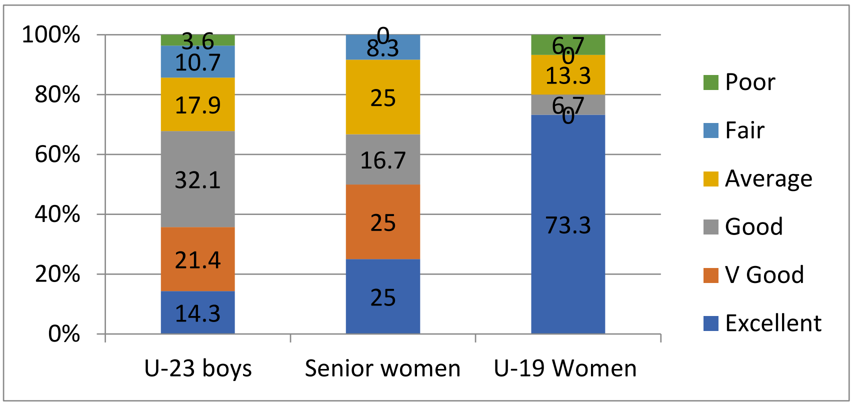
Table 4.50: Impact of the intervention with the Nutrition Education Module on the mean percent knowledge scores of the cricketers from U-23 boys, Senior women and U-19 women squads

Squad	Pre-intervention knowledge scores	Post-intervention knowledge scores	p value
Under-23 boys (N=28)	45.2±10.5	66.7 ±15.3	**0.000 ****
Senior women (N=12)	51.1 ±8.7	71.3±17.4	**0.000 ****
Under-19 Women's (N=15)	55.4±15.2	85.1±21.8	**0.000 ****

As shown in Table 4.50, in all the squads the post-intervention knowledge scores improved over the baseline pre-intervention scores (p=0.000). The mean post-intervention knowledge scores of U-19 women were in the excellent category, followed by senior women (Very good category) and U-23 boys' (Good category). Tukey's post hoc test revealed that there was a significant difference in the mean post-intervention knowledge scores of the U-23 boys' squad (66.7 ±15.3) and U-19 women's squad (85.1±21.8) (p=0.06). Under-19 women showed maximum improvement in the post-intervention knowledge scores compared to the baseline (55.4±15.2 to 85.1±21.8 i.e. 53.6%), followed by U-23 boys (45.2±10.5 to 66.7 ±15.3 i.e. 47.6%) and senior women (51.1 ±8.7 to 71.3±17.4 i.e. 39.5%). ANOVA test revealed that the post-intervention knowledge scores were significantly different (p=0.000).

The post-intervention knowledge scores are depicted in figure 4.20. The post-intervention data are presented only for three groups; data could not be collected for the Ranji boys' squad as they were unavailable due to their long-term professional commitment.

Figure 4.20: Post-intervention knowledge scores among cricketers across all the squads



The number of participants in the excellent category increased from 0% to 14% in the U-23 boys' squad after the intervention, whereas those in the poor category decreased from 43% to 4%. The number of participants in the excellent group increased from 0 to 25% post-intervention in the senior women's squad, whereas those in the poor category decreased from 8% to none. Similarly, in the Under-19 women's squad, the number of participants in the excellent group increased from 7% to 73 percent after the intervention, while those in the poor category decreased from 13% to 7%.

All the components of the knowledge assessment displayed improvement post-intervention. The components in which the participants were poor at the baseline showed improvement post intervention. A basic understanding of ergogenic aids showed 110% improvement, Nutrient that helps in Iron absorption-69%, Nutrient that helps in Calcium absorption- 44%, Sources of Iron – 39%, an important source of energy during exercise- 33%.

Similar to the significant improvement in knowledge scores post-intervention in the present study, the literature also displays the positive impact of nutrition education. A study carried out on 32 Brazilian athletes also showed improvement in nutrition knowledge in the participants after intervention with nutrition counselling. The protocol consisted of four consultations separated by an interval of 45 to 60 days. The knowledge scores were tested for three broad categories namely, basic nutrition, the food pyramid and sports nutrition. All the three major components showed improvement however, maximum improvement was noted in the topics related to the Brazilian Food Guide Pyramid.(Nascimento et al, 2016) In a research conducted in Malaysia, 105 male athletes representing four team sports under the elite sports programme were enrolled for the study. The Experimental group received 7 weeks education intervention programme based on a validated booklet covering basic sports nutrition for team sports. There were significant increments ($p<0.001$) in the Experimental group's post-intervention mean scores for knowledge.(Elias et al, 2018)A randomized, controlled trial was carried out on 79 Finnish endurance athletes (18.0 ±1.4 years). The participants were divided into 2 groups; one group received participatory nutrition education sessions alone (n=37) and the other got additional access to a mobile food application (n=42) via which they received written feedback from the nutritionist to support their learning. Both groups attended three 90-min education sessions fortnightly for 3 months. The questionnaire was divided into the following sections; Nutrition recommendations for endurance athletes, dietary supplements, fluid balance and hydration, energy intake and recovery, and the association between food choices and body image. Significant improvement was seen in all 4 sections except the association between food choices and body image section. Nutrition knowledge improved significantly after only three education sessions ($p<0.001$) in both the groups; however there was no further improvement in group having the mobile application access. (Heikkila et al, 2019) Thus literature strongly proves the positive impact of nutrition education in athletes.