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Original Article

Physiology Section

Gender Difference in Aerobic Capacity and the Contribution by Body Composition and Haemoglobin Concentration: A Study in Young Indian National Hockey Players

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ABSTRACT

Introduction: Although gender difference in aerobic capacity is known, the contributing factors have been researched seldom.

Aim: To investigate this gender gap and the contribution by percentage Body Fat (BF), Body Mass Index (BMI) and haemoglobin concentration (Hb).

Materials and Methods: The study was conducted on 30 (17 males, 13 females) training status matched young hockey players. Healthy players who were playing upto national level competition were the inclusion criteria. BW (Body Weight), BF, BMI, LBM (Lean Body Mass), rHR (restring Heart Rate), HRR (Heart Rate Recovery), (Hb), a/rVO_2max (absolute/relative), a/rPWC (Physical Work Capacity) and RMR (Resting Metabolic Rate) were measured and analysed.

Results: There was significant gender difference in the measured parameters. Difference in a/rVO_2max remained significant even after controlling for BF, BMI and (Hb). Multiple regression and correlation analysis revealed gender difference in VO_2max/LBM was due to: BMI(31.91%)>BF(27.60%)>(Hb)(9.91%). BMI also significantly contributed 3.66% of VO_2max/LBM variance, independent of that by gender. Difference in RMR was mainly related to LBM, BF and BMI.

Conclusion: The study provided an understanding for gender gap in aerobic capacity. Differences in BMI & BF were one of the main reasons.

Keywords: Body fat, Body mass index, Male-female gap, Physical work capacity, Resting metabolic rate, VO_2max

INTRODUCTION

Gender is a major determinant of best athletic performances, due to various morphological and physiological differences, which may include more aerobic capacity and physical work capacity among males [1]. The average gender difference in aerobic capacity as measured by VO_2max (maximal oxygen uptake) has been reported earlier [2,3]. Average female value of VO_2max is about 70-75% of that of male after puberty [4].

Due to the increasing participation of women in hockey and popularity of women-hockey both internationally and nationally, the understanding of gender difference in sports performance and expectations and the underlying physiological and anthropometric basis has been studied increasingly. This is particularly important for aerobic capacity, since field hockey demands high VO_2max from its players due to the involvement of large number of high intensity interval training [5].

Although many studies have evaluated the role and relative contribution of gender related factors for sex difference in aerobic capacity [1,6], there is scanty of information available in Indian scenario, that too in field hockey players. Our study therefore evaluated the gender difference in aerobic capacity (VO_2max) and other related variables like Physical Work Capacity (PWC), resting Heart Rate (rHR) and Heart Rate Recovery (HRR) and haemoglobin concentration (Hb). The difference in Resting Metabolic Rate (RMR) was also studied as RMR, being the major component of the daily energy expenditure, would affect body composition afterward and hence aerobic variables. The anthropometric basis for the gender difference in aerobic capacity, as well as the contribution by (Hb) was investigated in our study.

MATERIALS AND METHODS

The present cross-sectional study was carried out in the Sports Sciences & Fitness Centre, North-East Regional Centre (NERC), Sports Authority of India (SAI), Imphal, Manipur, India within a duration of one month. A total of 13 females and 17 males hockey trainees in NERC, SAI were the volunteers. The sample size was obtained as the number of players satisfying the study criteria, which was unfortunately relatively small due to the limited availability of trained national players at the time of the study in the institute.

The criteria followed were:

- **Inclusion criteria**
  - Those who have participated in any recognized National level competitions, including Inter SAI meets.
  - Those who were selected by the state sports federations for national meets.
  - Those who gave full consent for the tests.
- **Exclusion criteria**
  - Having disease/general health problems during the past 15 days of the study.
  - With acute or acute-on-chronic musculo-skeletal or soft tissue injuries/pathologies.
  - Found unfit for any other reasons in the pre-participation physical evaluation & medical screening conducted by the sports medicine doctor of the institute.
  - Who did not give consent for the tests.

The age of the player was taken from the legal document submitted to NERC, SAI. Both the gender groups were comparable in age, Duration of training (DOT), nutritional aspects (based on supervised diet chart), physical activity habits and training status.

All tests were conducted early morning around the same time (±1.5hours), 2 hours after a light breakfast. The temperature & relative humidity were 25±2°C and 61-65% respectively. No physical exertion before 12 hours and no caffeinated drinks 4 hours before the testing were allowed. The players were instructed to have 8

hours of sound sleep and 12 hours of fasting (for RMR estimation). They were also asked to empty bladder and bowel at least 30 minutes before body composition analysis. A written and informed consent was obtained from all the participants, and the study was approved by the ethical committee of the Institute.

Standing Heights (HT) of the players were measured using a stadiometer (Seca220, UK) to the nearest 0.1 cm. Body Weight (BW in kg), percentage Body Fat (BF) and Lean Body Mass (LBM in kg) were measured using TANITA Body Composition Analyser (TBF310 Model, Japan) based on bioelectrical impedance analysis technique [7]. RMR (KJ/day) was also estimated using the same machine. Body Surface Area (BSA in m^2) was estimated using Du Bois method [8].

Beep test or 20-meter multistage shuttle run test is an accurate estimate of aerobic capacity [9] and was used for predicting VO_2max (in ml/kg of BW/minute) [10]. It was conducted following the standard methodology [10]. PWC as work rate at 170 heart rate was measured using PWC test, a submaximal aerobic test, following standard protocol described earlier [11]. For this, an electronically operated computerized bicycle ergo-meter (Jaeger, LE900, Germany) was used. Absolute (aVO_2max in ml/min, PWC in W) and relative (rVO_2max: VO_2max/BSA in ml/m^2/minute & VO_2max/LBM in ml/kg/min; rPWC: PWC/BSA in W/m^2, PWC/BW in W/kg & PWC/LBM in W/kg) values of both VO_2max and PWC were used for analysis.

HRR was measured using the above bicycle ergo-meter. The players were asked to do an all out cycling at a fixed power with maximum Revolution Per Minute (RPM) possible till exhaustion. This was done after 5 minute warm up with minimum load at 60 RPM. The fixed power used in Watt (W) was calculated as 5 times BW (kg) for females and 6 times BW (kg) for males. HRR3/6 was calculated as difference between maximum heart rate (HR) during the exercise minus HR at 3rd/6th minute post exercise with the players sitting passively, using sports testers (Polar heart rate monitor). HRR is a measure of duration required for heart rate to return to resting level after exercise, and is an indirect index of aerobic fitness [12].

rHR was self measured in the early morning before the player rose from bed after a relaxing night's sleep manually from carotid pulse for one minute. All the players were taught beforehand the required technique. (Hb) in g/dl was measured using cyanmethaemoglobin method, and was done after 12 hours of fasting, and 24 hours of the last exercise bout. They were included in the analysis due to their significant relationship with VO_2max [13,14].

STATISTICAL ANALYSIS

Standard descriptive statistics (mean±standard deviation) were determined for directly measured and derived variables. Unpaired t-test and one-way ANCOVA was used for comparison of studied parameters between the genders, after checking for normality by visual method using histogram and Shapiro-Wilk test. The covariates used separately for ANCOVA were: BF, BMI, obesity component score (OC) and (Hb). These co-variates were all on continuous scale. OC was obtained by principal component analysis with regression method from BF & BMI. It was used instead of using BF & BMI together as covariates due to the high positive correlation found between them. Also, using both would reduce degree of freedom. Whenever the Levene's test of homogeneity of variances came out to be significant, Welch's test was used instead. Levene's test was significant for these parameters: VO_2max/BSA, PWC, PWC/BSA, PWC/BW and PWC/LBM. In case of ANCOVA, first, equalization of sample size was done for the two groups through random selection, then the level of significance was set at p-value(2-tailed)<0.001, in order to decrease α-error. For all other analysis, statistical significance was chosen at p-value(2-tailed)<0.05.

Simple and hierarchical multiple regression analysis were used to generate various regression equations for predicting VO_2max/LBM as the Dependent Variable (DV). The assumption of homoscedasticity was made as indicated by virtual method using scatter-plot between the standardized residual and standardized predicted value, and Breusch-Pagan test and White test. The assessment of the relative contribution of BF, BMI & (Hb) on gender difference in VO_2max/LBM involved calculation of difference between two semi-partial correlation R^2s between gender and VO_2max/LBM. Gender related VO_2max/LBM variance independent of that explained by some combination of selected independent variables or IVs (zero, one or two) which were used in the equation was indicated by the first semi-partial correlation R^2. If a new variable was added subsequently using hierarchical multiple regression analysis, the second semi-partial correlation R^2 indicated VO_2max/LBM variance accounted by gender independent of the combination of the IVs used in the first equation plus the newly added variable. Hence, difference between the two semi-partial correlation R^2s indicated the gender related VO_2max/LBM variance accounted for by the variable added subsequently.

Four such estimates of BF, BMI & (Hb) were calculated (by holding constant zero, one, or two of the other variables), and the mean was taken as the representative value. This was done as the magnitude of semi-partial correlation depends on the order in which the correlated IVs are entered into multiple regression equation. The representative value thus obtained for each IV, were then expressed as percentage of the total gender related VO_2max/LBM variance [6,15]. SPSS (Statistical Package for Social Science) version 20.0 was used for analysing the data.

RESULTS

There was significant difference between the two groups in HT, BF, BMI, LBM, rHR, HRRs, (Hb), aVO_2max, rVO_2max, PWC, rPWC, RMR and RMR/BW [Table/Fig-1]. The differences in VO_2max related parameters were still significant after controlling for BF, BMI or both (OC) (exception: VO_2/BSA) and (Hb). Differences in rPWC and RMR/BW remained significant after controlling for OC and (Hb) (exception: PWC/BSA and PWC/LBM), BMI and OC respectively [Table/Fig-2].

The mean difference (ΔMean) was minimum (12.18%) for VO_2max/LBM among VO_2max and PWC parameters [Table/Fig-1], and was used as DV for multiple regression analysis [Table/Fig-3]. Also, VO_2max/LBM is not affected by extent of body fatness unlike BW, making its interpretation as a measure of aerobic capacity more accurate than for VO_2max (per BW) or VO_2max/BSA [6,16].

From [Table/Fig-3], it becomes clear that equation (c) had the highest aR^2 (adjusted R^2) of 76% with both its IVs having significant ß-weights. Out of BF, BMI & (Hb), only BMI contributed a statistically significant unique variance of 3.66% out of the total variance in VO_2max/LBM, over & beyond that explained by gender. This was followed by (Hb) (2.6%) & BF (1.56%), though statistically insignificant [Table/Fig-3c,d].

Gender, however, contributed a statistically significant variance of 73.96% out of the total variance in VO_2max/LBM [Table/Fig-3]. After controlling for those contributed by the combination of BF, BMI & (Hb), gender related variance in VO_2max/LBM was reduced to 16.03% (21.67%, expressed as percentage of 73.96%), which was statistically significant [Table/Fig-3]. Hence, even after matching for the difference in BF, BMI & (Hb), the males, on an average, would still have significantly higher VO_2max/LBM than those of females by 21.67% or 2.64 of 12.18 ml/kg/min.

Gender related VO_2max/LBM variance accounted for BF or BMI or (Hb) individually was calculated as mean of four differences between two semi-partial correlation R^2s as described in statistical analysis section. The values are given in [Table/Fig-4]. Difference in BMI accounted for the largest percentage of gender difference in VO_2max/LBM (31.91%), followed by BF (27.60%) and (Hb) (9.91%). Hence, on an average, differences in BF, BMI & (Hb) accounted for 69.42% of the gender difference in VO_2max/LBM, that is, 8.45 of 12.18 ml/kg/min.

DISCUSSION

The male players, on an average, had 18.16% & 12.18% higher VO_2max & VO_2max/LBM than the females [Table/Fig-1]. The physiological factors which may cause higher aerobic capacity among male players who are equally trained with same competition and optimal nutritional level as females include post-pubertal hormonal induced higher LBM and (Hb) content/concentration among them [17]; and lesser maximum stroke volume and hence maximum cardiac output among females due to their smaller cardiac size & lesser blood volume, as a result of their smaller body size or LBM. [4].

Parameters	Females (n=13) Mean±SD	Males (n=17) Mean±SD	ΔMean^ (% of Male's)	p-value
Age (years)	16.00±2.16	15.06±1.85	-6.24	0.210
DOT (years)	3.31±1.54	4.12±1.40	19.66	0.143
HT (cm)	155.14±5.32	162.90±6.87	4.76	0.002**
BW (kg)	53.17±5.04	51.32±5.39	-3.60	0.346
BSA (m^2)	1.51±.09	1.54±.10	1.95	0.416
BF (%)	26.02±3.06	17.42±4.30	-49.37	<.001**
BMI (kg/m^2)	22.05±0.96	19.33±1.48	-14.07	<.001**
LBM (kg)	39.33±4.08	42.27±3.73	6.96	0.049*
rHR (bpm)	75.31±3.35	62.88±4.72	-19.77	<.001**
HRR3 (bpm)	91.62±7.40	101.00±8.86	9.29	0.005**
HRR6 (bpm)	97.92±6.41	107.35±11.35	8.78	0.012*
(Hb) (g/dl)	14.49±1.18	15.85±1.41	8.58	0.009**
aVO_2max (ml/min)	2333.95±251.43	2851.84±203.19	18.16	<.001**
VO_2max/BSA (ml/m^2/min)	1547.77±110.41	1856.23±67.90	16.62	<.001**#
VO_2max (ml/kg/min)	43.92±2.76	55.85±3.94	21.36	<.001**
VO_2max/LBM (ml/kg/min)	59.36±2.41	67.59±2.57	12.18	<.001**
PWC (W)	157.43±8.35	216.30±53.46	27.22	<.001**#
PWC/BSA (W/m^2)	104.75±6.55	141.64±37.09	26.04	0.001**#
PWC/BW (W/kg)	2.98±0.24	4.29±1.26	30.54	0.001**#
PWC/LBM (W/kg)	4.03±.29	5.15±1.29	21.75	0.003**#
RMR (KJ/day)	1327.92±129.66	1486.12±160.60	10.65	0.007**
RMR/BSA (KJ/m^2/day)	885.72±110.78	971.43±123.37	8.82	0.059
RMR/BW (KJ/kg/day)	25.21±3.59	29.33±4.76	14.05	0.015*
RMR/LBM (KJ/kg/day)	34.08±4.62	35.37±4.47	3.65	0.444

[Table/Fig-1]: Comparison of the studied parameters between female and male players.
*Significant: p–value<0.05; **Highly Significant: p–value<0.01. Unpaired t-test. #Welch's test p–value; ^Mean difference: -ve means more than male's. SD=standard deviation.

The greater, essential sex specific fat store in female means more O_2 utilization per unit LBM or energy cost by females at submaximal weight bearing exercise work rate, and lower VO_2max expressed per BW [18]. However, gender difference in VO_2max even after adjusting differences in body fat & LBM has been reported earlier [19]. This is in line with our finding [Table/Fig-1,2]. Nevertheless, body fatness in females has been reported as one of the major determinants for gender difference in VO_2max & metabolic response to running [18]. Difference in BF accounted for 74% of the gender difference in 12-minute run performance, a commonly used test for aerobic fitness, in an earlier study [6]. In our study, however, only 27.60% of the gender difference in VO_2max/LBM was due to difference in BF [Table/Fig-4]. The difference in BMI accounted for 31.91% of the gender difference in VO_2max/LBM in our study [Table/Fig-4], although the difference in VO_2max/LBM remained significant after controlling it [Table/Fig-2]. It is to be noted that BMI is not just a surrogate for BF: one with high LBM & low BF may have high BMI [20]. Positive correlation was found between BMI with LBM (significant in female: r=.760, p=.003, not given in Table) and with BF (significant in male: r=.920,p=<.001, not given in Table) in our study. Hence, BMI has both LBM & BF component, and this may partly explain the higher percentage of gender difference in VO_2max/LBM accounted for by its gender difference.

Lower mean (Hb), red cell mass and haematocrit levels among females are other reasons for gender difference in VO_2max [21], which cause lower arterial O_2 concentration (CaO_2) and less O_2 delivery to working muscle per blood volume [1,4]. If lower (Hb) causes proportional decrease in arterio-venous O_2 concentration difference or $C(a\text{-}v)O_2$, VO_2max also decreases proportionately, holding other variables constant, since aVO_2max=COmax X $C(a\text{-}v)O_2$max where COmax is maximum Cardiac Output (CO). However, this may not be the case.

Lower haematocrit & (Hb) in females are associated with reduced blood viscosity, resulting in proportionately increase in blood flow & CO; also CvO_2 does not decrease proportionately leading to more steeper increase in $C(a\text{-}v)O_2$ at submaximal power outputs [1]. The delivery of red cells to the capillary circulation and tissue oxygenation per red cell mass have been argued to be higher in females [21]. Also, (Hb) in females has been reported to have lower affinity for O_2 even though there is no significant changes in red cell 2,3-diphosphoglycerate concentration [22].

Hence, the proportion of the gender difference in VO_2max parameters accounted for by (Hb) difference would be small. In our study, it

Parameters	Covariates (One-way ANCOVA)							
	BF		BMI		Obesity component score^		(Hb)	
	F–value (df=1,27)	p–value	F–value (df=1,27)	p–value	F–value (df=1,27)	p–value	F–value (df=1,27)	p–value
aVO_2max (ml/min)	8.77	0.006**	22.48	<.001**	12.37	.002**	25.60	<.001**
VO_2max/BSA (ml/m^2/min)#	22.38#	<.001*#	35.13#	<.001*#	3.16#	.089#	69.46#	<.001*#
VO_2max (ml/kg/min)	24.62	<.001**	31.28#	<.001*#	28.03#	<.001*#	76.78	<.001**
VO_2max/LBM (ml/kg/min)	24.53	<.001**	23.75	<.001**	19.33	<.001**	54.10	<.001**
PWC (W)	1.12	0.300	<.01	0.987	2.45	0.129	5.66	0.025*
PWC/BSA (W/m^2)	1.67	0.207	0.32	0.575	4.51	0.043*	3.74	0.064
PWC/BW (W/kg)	1.24	0.276	0.44	0.513	4.98	0.034*	4.49	0.043*
PWC/LBM (W/kg)	.99	0.330	1.54	0.225	4.74	0.038*	2.07	0.162
RMR (KJ/day)	2.61	0.118	1.24#	0.277#	5.61#	0.027#	–	
RMR/BW (KJ/kg/day)	2.04	0.164	4.29	0.048*	8.86	0.006**		

[Table/Fig-2]: Comparison of aerobic and RMR parameters between gender after controlling for selected variables.
*Significant (p–value<0.05, except for #F–values, where it is<.001); **Highly significant (p–value<0.01, except for #F–values). #ANCOVA with df(1,23). df=degree of freedom. ^ Obtained by principal component analysis with regression method from BF & BMI.

Sl. No.	regression equations (Durbin-Watson statistics)	R^2(aR^2) %	Semi-Partial correlation R^2(%) for significant predictors	R^2 Change (%)	F-value (df)
(a)	VO_2max/LBM=67.59-8.23(G#). (2.11)	73.96(73.10)	G#(73.96)**	–	79.78** (1,28)
(b)	VO_2max/LBM=70.29-6.9(G#)-.16(BF). (2.10)	75.52(73.7)	G#(22.28)**,BF(1.44)	1.56 {from (a)}	41.53** (2,27)
(c)	VO_2max/LBM=81.7-6.25(G#)-.73(BMI). (2.25)	77.62(76)	G#(19.62)**,BMI(3.66)*	3.66* {from (a)}	46.97** (2,27)
(d)	VO_2max/LBM=58.04-7.41(G#)+.6((Hb)). (2.26)	76.56(74.9)	G#(46.79)**,(Hb)(2.62)	2.6 {from (a)}	44.26** (2,27)
(e)	VO_2max/LBM=74.1-6.56(G#)-.62(BMI)+.05(BF)+.29((Hb)). (2.29)	77.97(74.4)	G#(16.03)**,BMI(1.3), BF(.06),(Hb)(.25)	4.01 {from (a)} 16.03** {from (a)}	22.07** (4,25)
(f)	VO_2max/LBM=109.64-1.48(BMI)-.32(BF)-.56((Hb)). (1.69)	61.94(57.6)	BMI(8.82)*,BF(3.84), (Hb)(1.10)	–	14.14** (3,26)

[Table/Fig-3]: Regression equations for predicting VO_2max per LBM (ml/kg/min).
*Significant: p–value<0.05;**Highly Significant: p–value<0.01. G(Gender)=0 for male & 1 for female. ^aR^2: Adjusted R^2. Hierarchical Multiple Regression Analysis.

Selected Variables	% of gender related variance in VO_2max/LBM explained					
	Absolute					Expressed as % of total gender related VO_2max/LBM variance
	Values				Mean	
BF	51.68	2.81	23.36	3.79	20.41	27.60
BMI	54.34	5.47	27.07	7.51	23.60	31.91
(Hb)	27.17	.09	1.15	.89	7.33	9.91
Residuals due to other gender related factors					22.62	30.58
Total gender related VO_2max/LBM variance					73.96	100

[Table/Fig-4]: Percentage of gender related VO_2max/LBM variance explained by selected variables.

was 9.91% of the gender difference in VO_2max/LBM [Table/Fig-4]. Also, the differences in VO_2max parameters were significant after controlling for (Hb) [Table/Fig-2]. Earlier study also reported small non-significant contribution of (Hb) in gender difference of rVO_2max, but significant in case of aVO_2max [1].

In our study, 30.58% of the gender difference was accounted by some other factors, which were not included in our analysis. Some portion of this may be related with cardiac morphology and function. In fact, the difference in cardiac size or left ventricular mass was reported to account for 68.3% of the gender difference in VO_2max in groups of similarly trained males and females of comparable age [23].

Since PWC parameters are measure of submaximal aerobic fitness, they are expected to be associated positively with VO_2max parameters & follows similar pattern [11]. The significant gender difference in them continued to remain so only after controlling (Hb) & OC with some exceptions [Table/Fig-1,2]. The difference in pattern may partly be due to difference in data type (predicted for VO_2max and direct for PWC), and exercise used for measuring them: weight bearing exercise for VO_2max (Beep test) and non-weight bearing for PWC (bicycle ergo-meter based). Differences in BF & BMI separately had significant contribution in gender difference of PWC parameters [Table/Fig-2]. Earlier study also reported significant difference in PWC (measured as ride time in bicycle ergo-meter) even after adjusting for difference in (Hb) [1].

Higher HRRs and lower rHR among males having higher VO_2max are understandable, since HRR & rHR have been considered as indicators of aerobic fitness [24,25]. Increase in parasympathetic and/or decrease in sympathetic tone associated with higher aerobic fitness may be responsible [25,26]. The significant gender difference in RMR disappeared when it was expressed relative to either BSA or LBM [Table/Fig-1] or controlling for BF or BMI or OC with few exceptions for RMR/BW [Table/Fig-2]. Although LBM & fat mass act as significant contributors to RMR, the gender difference after controlling for body composition may be due to lower Na^+-K^+ATPase activity among females [27], gender difference in skeletal muscle metabolism and in aerobic fitness [28].

CONCLUSION

Males had greater aerobic capacity (VO_2max/LBM) with more rPWC, HRRs & lesser rHR as compared to females with similar training & competition level. The gender difference was mainly due to difference in: BMI(31.91%)>BF(27.60%)>(Hb)(9.91%), out of which BMI also had significant effect on VO_2max/LBM independent of gender: increment of 1.37 kg/m^2 in BMI decreased VO_2max/LBM by 1ml/kg/min. Difference in BMR was mainly related to LBM, BF & BMI. Although our sample size was small, the study provides a better understanding of basis of gender gap in aerobic capacity, and hence the extent to which appropriate interventions may reduce the gap. It also serves a platform for better designed study with larger sample size that includes other gender related factors (cardiac structure & function etc) for better explanation of gender difference.

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