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Sport-specific variations in cardio-functional parameters: A comparative analysis of resting heart rate and cardiac output among athletes and non-athletes

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Abstract
Background: Regular exercise is associated with adaptations in cardiac autonomic regulation and cardiac structure, although responses may vary by training type. Objective: To compare resting heart rate (RHR) and cardiac output (CO) among male participants from different sports disciplines and a non-athlete group. Methods: The source document describes a cross-sectional comparison of 160 males aged 18–25 years: long-distance runners (n=20), volleyball players (n=20), basketball players (n=20), football players (n=20), hockey players (n=20), yoga practitioners (n=30), and non-athletes (n=30). Measurements were reportedly obtained using a Cheetah Cardiac Output Monitor. Results: The source reports significant between-group differences for RHR, $F(6,153)=24.55$, and CO, $F(6,153)=27.01$, both marked significant at $p<.01$. The reported group means suggest the lowest RHR among long-distance runners (55.00 beats/min) and the highest CO among football players (8.75; unit not specified). However, the source contains conflicting RHR values and inconsistencies in pairwise comparisons. Conclusion: The supplied results suggest group differences in resting cardiovascular measures, but the numerical inconsistencies and missing protocol details must be resolved against the raw dataset before the findings can be considered definitive or submitted for publication.

Keywords: Resting heart rate, cardiac output, athletes, non-athletes, sports discipline, cardiovascular adaptation, yoga

Introduction

Resting heart rate (RHR) is a readily measured cardiovascular indicator influenced by autonomic regulation, habitual physical activity, cardiorespiratory fitness, age, medication, and other individual characteristics. Regular exercise is generally associated with a lower resting heart rate, although the magnitude of change depends on the type, dose, and duration of training and on participants' baseline characteristics. In a systematic review and meta-analysis, Reimers *et al*. (2018) [12] found that exercise interventions reduced RHR overall, with endurance exercise and yoga showing particularly consistent effects. These findings support the use of RHR as a useful descriptive marker in comparative exercise physiology, but RHR should not be interpreted as a stand-alone measure of cardiovascular health or athletic performance. Evidence reviews also emphasize that cardiovascular responses depend on exercise frequency, intensity, and duration (Wilson *et al*., 2016; Hellsten & Nyberg, 2016) [6, 14].

Long-term exercise training may also produce structural and functional cardiac adaptations commonly described as the athlete's heart. A meta-analysis by Pluim *et al*. (2000) [11] reported that cardiac structure and function differ according to the type of training, with endurance and strength-oriented sports producing partly different adaptation patterns. Baggish and Wood (2011) [2] emphasized that physiological adaptations in athletes must be interpreted in the context of training history, clinical findings, and the possibility of underlying disease. More broadly, Opondo *et al*. (2015) [9] describe the cardiovascular system's ability to deliver oxygenated blood to active muscle as a key component of exercise performance. These findings suggest that cardiovascular characteristics may vary across sports, rather than following a single athlete-versus-non-athlete pattern. Reviews of competitive athletes similarly describe training-related structural and functional changes while stressing the need to distinguish physiological adaptation from disease (Dores *et al*., 2015; Martinez *et al*., 2021) [4, 8].

Cardiac output (CO) is the volume of blood pumped by the heart per minute and is determined by heart rate multiplied by stroke volume. CO changes with metabolic demand and is affected by factors such as body size, posture, hydration, recent activity, and measurement conditions. Consequently, resting CO should not be treated as a direct proxy for aerobic capacity: a higher value at rest is not automatically superior, and interpretation is stronger when CO is considered alongside stroke volume, heart rate, body size, and standardized measurement conditions (Opondo *et al*., 2015) [9]. The athlete's heart literature also indicates that structural and functional adaptations are influenced by training type and duration (Baggish & Wood, 2011; Pluim *et al*., 2000) [2, 11]. The central role of oxygen transport and maximal cardiac output in endurance performance has also been discussed in exercise physiology literature (Bassett & Howley, 2000; Heinonen, 2025) [3, 15].

Although the physiology of exercise-related cardiac adaptation is well established, comparisons across several distinct sporting disciplines within one sample can help describe the extent of between-group variation in practical sports settings. Endurance running, intermittent team sports, and yoga involve different training demands; however, cross-sectional comparisons cannot determine whether observed differences were caused by the sport itself. Factors such as training history, training volume, body composition, diet, sleep, and selection into sport may also contribute. The present study therefore compares reported RHR and CO

values among long-distance runners, volleyball, basketball, football, and hockey players, yoga practitioners, and non-athletes. The findings are interpreted as group-level associations and are qualified by the need to verify inconsistencies in the supplied source tables.

Materials and Methods

The source describes a cross-sectional comparative study involving 160 male participants aged 18–25 years. The groups were long-distance runners (n=20), volleyball players (n=20), basketball players (n=20), football players (n=20), hockey players (n=20), yoga practitioners (n=30), and non-athletes (n=30). The source states that elite athletes had achieved at least first, second, or third place at inter-university or national-level competitions. The source reports one-way analyses of variance (ANOVAs) for RHR and CO, each comparing seven groups. The reported degrees of freedom were 6 between groups and 153 within groups. Based on the reported F statistics, approximate eta-squared effect sizes were calculated as $\eta^2 = (F \times df_between) / [(F \times df_between) + df_within]$. This yields $\eta^2 \approx 0.490$ for RHR and $\eta^2 \approx 0.514$ for CO. These estimates are provisional because they are derived from the source-reported F statistics and should be recalculated from verified raw data. The source's pairwise t-test tables were not pooled or reanalysed because several entries conflict with the displayed means, standard deviations, or narrative.

Results

The source-reported ANOVA for RHR showed a statistically significant difference among groups, $F(6,153)=24.55$, $p<.01$. The corresponding source sums of squares were 9,459.26 between groups and 9,825.183 within groups, with mean squares of 1,576.543 and 64.217, respectively. The provisional η^2 estimate was approximately 0.490.

The source-reported ANOVA for CO also showed a statistically significant difference among groups, $F(6,153)=27.01$, $p<.01$. The reported sums of squares were 255.602 between groups and 241.285 within groups, with mean squares of approximately 42.6 and 1.577. The provisional η^2 estimate was approximately 0.514.

Table 1: One-way ANOVA for resting heart rate

Source of variation	Sum of squares	Df	Mean square	F-value
Between groups	9459.26	6	1576.543	24.55**
Within groups	9825.183	153	64.217	—

** Significant at the 0.01 level, as marked in the source.

The one-way analysis of variance revealed a statistically significant difference in resting heart rate among the seven groups, $F(6,153)=24.55,\ p<.01$. The between-group sum of squares was 9459.26, with a mean square of 1576.543, whereas the within-group sum of squares was 9825.183, with a mean square of 64.217. These findings indicate that the variation in resting heart rate among the groups was statistically significant at the 0.01 level. Therefore, the null hypothesis of no difference in mean resting heart rate among the groups is rejected. However, ANOVA alone does not identify which specific groups differ significantly; this requires valid post-hoc comparisons.

Table 2: Pairwise comparisons of cardiac output: non-athletes versus other groups (source table)

Sport 1	Sport 2	Mean 1	Mean 2	Mean difference	SD 1	SD 2	Significance	p-value	t-value
Non-athletes	Basketball	5.39	8.55	-3.16	0.86	1.85	Yes	0.00	7.14**
Non-athletes	Football	5.39	8.75	-3.37	0.86	0.92	Yes	0.00	13.02**
Non-athletes	Hockey	5.39	7.59	-2.21	0.86	2.00	Yes	0.00	4.66**
Non-athletes	Volleyball	5.39	8.57	-3.18	0.86	0.98	Yes	0.00	11.80**
Non-athletes	Long-distance runners	5.39	8.27	-2.88	0.86	0.85	Yes	0.00	11.68**
Non-athletes	Yoga	5.39	6.45	-1.06	0.86	1.04	Yes	0.00	4.30**

The source-reported pairwise comparisons indicate that non-athletes had a lower mean cardiac output (5.39) than basketball players (8.55), football players (8.75), hockey players (7.59), volleyball players (8.57), long-distance runners (8.27), and yoga practitioners (6.45). The reported mean differences ranged from −1.06 to −3.37, with all comparisons marked significant at the 0.01 level in the source table.

The largest reported difference was between non-athletes and football players (−3.37), while the smallest was between non-athletes and yoga practitioners (−1.06). These results suggest differences in cardiac output between the non-athlete group and each comparison group. Nevertheless, the significance labels and test statistics should be verified against the original dataset before drawing definitive conclusions.

Table 3: Pairwise comparisons of resting heart rate: non-athletes versus other groups (source table)

Sport 1	Sport 2	Mean 1	Mean 2	Mean difference	SD 1	SD 2	Significance	p-value	t-value
Non-athletes	Basketball	72.57	63.00	9.57	7.71	8.70	Yes	<0.001	3.98**
Non-athletes	Football	72.57	70.45	2.12	7.71	6.50	No	0.29	1.07
Non-athletes	Hockey	72.57	66.05	6.52	7.71	9.27	Yes	0.006	2.61**
Non-athletes	Volleyball	72.57	67.95	4.62	7.71	8.55	No	0.06	1.95
Non-athletes	Long-distance runners	72.57	55.00	17.57	7.71	4.67	Yes	<0.001	10.04**
Non-athletes	Yoga	72.57	70.37	2.20	7.71	7.71	No	0.27	1.11

The source table reports a mean resting heart rate of 72.57 beats/min for non-athletes. Their mean was higher than that of basketball players (63.00), hockey players (66.05), volleyball players (67.95), long-distance runners (55.00), and yoga practitioners (70.37), although the size and statistical significance of these differences varied. Significant differences were reported for basketball players (mean difference = 9.57, \(p<.001\)), hockey players (mean difference = 6.52, \(p=.006\)), and long-distance runners (mean difference = 17.57, \(p<.001\)). Differences with football players, volleyball players, and yoga practitioners were reported as non-significant. The largest reported difference was between non-athletes and long-distance runners. These findings should be interpreted cautiously because the non-athlete mean is reported elsewhere as 80.57 beats/min, and the pairwise statistics require verification.

Table 4: Pairwise comparisons of resting heart rate: football versus other groups (source table)

Sport 1	Sport 2	Mean 1	Mean 2	Mean difference	SD 1	SD 2	Significance	p-value	t-value
Football	Basketball	69.89	63.00	6.89	6.18	8.71	Yes	0.01*	0.85
Football	Hockey	69.89	66.05	3.84	6.18	9.27	No	0.14	1.50
Football	Volleyball	69.89	67.95	1.94	6.18	8.55	No	0.42	0.81
Football	Long-distance runners	69.89	55.00	14.89	6.18	4.68	Yes	0.00**	8.51
Football	Yoga	69.89	73.37	-3.47	6.18	9.13	No	0.12	1.51
Football	Non-athletes	69.89	80.57	-10.67	6.18	7.71	Yes	0.00**	5.25

According to the source table, football players had a mean resting heart rate of 69.89 beats/min. Significant differences were reported between football players and basketball players (mean difference = 6.89, reported \(p=.01\)), long-distance runners (mean difference = 14.89, \(p=.00\)), and non-athletes (mean difference = −10.67, \(p=.00\)). Comparisons with hockey players, volleyball players, and yoga practitioners were reported as non-significant. The largest absolute mean difference was observed between football players and long-distance runners. These findings suggest that resting heart rate may vary across sporting disciplines. However, some reported t-values do not appear consistent with the corresponding means, standard deviations, and p-values; the original calculations should be checked before publication.

Table 5: Pairwise comparisons of cardiac output: football versus other groups (source table)

Sport 1	Sport 2	Mean 1	Mean 2	Mean difference	SD 1	SD 2	Significance	p-value	t-value
Football	Basketball	8.75	8.55	0.20	0.92	1.85	No	0.67	0.43
Football	Hockey	8.75	7.59	1.16	0.92	2.00	Yes	0.03	2.25*
Football	Volleyball	8.75	8.57	0.19	0.92	0.98	No	0.54	0.62
Football	Long-distance runners	8.75	8.27	0.48	0.92	0.85	No	0.10	1.69
Football	Yoga	8.75	6.45	2.30	0.92	1.04	Yes	0.00	3.57**
Football	Non-athletes	8.75	5.39	3.37	0.92	0.86	Yes	0.00	3.56**

The source table reports a mean cardiac output of 8.75 for football players. Significant differences were reported between football players and hockey players (mean difference = 1.16, \(p=.03\)), yoga practitioners (mean difference = 2.30, reported \(p=.00\)), and non-athletes (mean difference = 3.37, reported \(p=.00\)). Differences between football players and basketball players, volleyball players, and long-distance runners were reported as non-significant. The largest reported mean difference was between football players and non-athletes, suggesting a substantial difference in the source-reported cardiac-output values. However, the unit of measurement is not stated, and some test statistics require verification. Accordingly, these comparisons should be treated as provisional.

Table 6: One-way ANOVA for cardiac output (source-reported values)

Source of variation	Sum of squares	Df	Mean square	F-value
Between groups	255.602	6	42.6	27.01**
Within groups	241.285	153	1.577	—

** Significant at the 0.01 level,

The one-way ANOVA showed a statistically significant difference in cardiac output among the seven groups, \(F(6,153)=27.01,\ p<.01\). The between-group sum of squares was 255.602, with a mean square of 42.6, while the within-group sum of squares was 241.285, with a mean square of 1.577. The result indicates that the group means were not all equal at the 0.01 significance level. Therefore, the null hypothesis of no difference in mean cardiac output among the groups is rejected. The ANOVA result establishes an overall group difference but does not, by itself, establish which individual pairs differ. Interpretation also depends on confirmation of the cardiac-output unit and the underlying data.

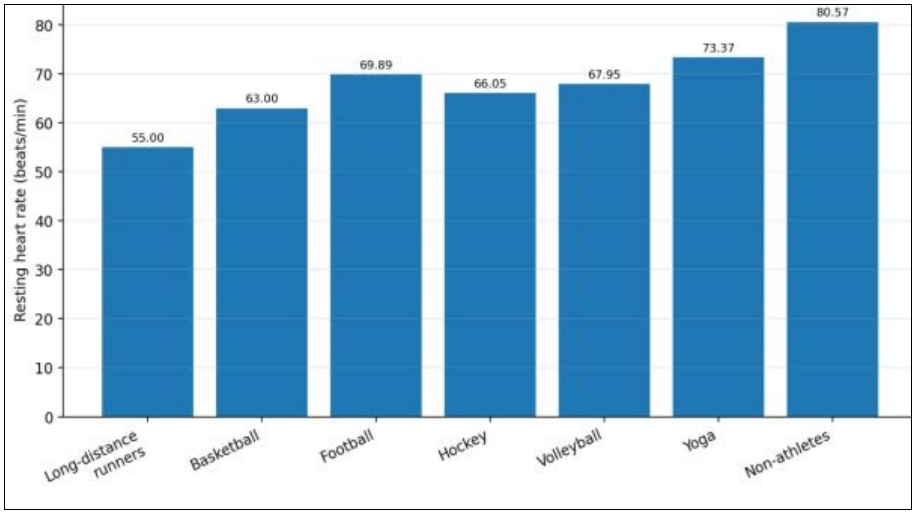


Fig 1: Reported mean RHR by group. Values are transcribed from one source table and require verification because alternate values appear elsewhere in the supplied document.

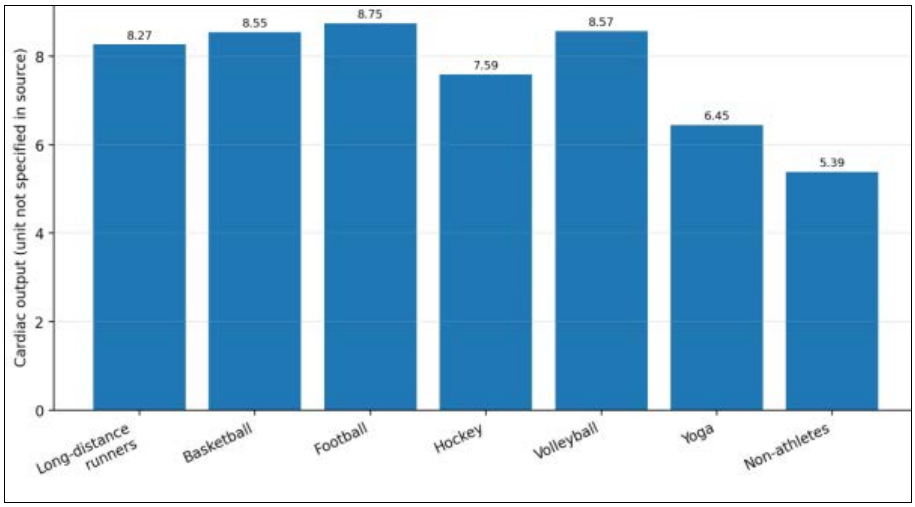


Fig 2: Reported mean CO by group. Values are descriptive source values only; the unit and measurement protocol must be confirmed.

Table 7: Source-reported ANOVA results and provisional effect sizes

Outcome	SS between	SS within	F(6,153)	Source significance	Approx. η^2
RHR	9459.26	9825.183	24.55	$p < .01$	0.490
Cardiac output	255.602	241.285	27.01	$p < .01$	0.514

The source-reported ANOVA results indicate statistically significant group differences in both resting heart rate and cardiac output. Resting heart rate produced $F(6,153)=24.55,\ p<.01$, with a provisional eta-squared value of $\eta^2=.490$. Cardiac output produced $F(6,153)=27.01,\ p<.01$, with a provisional eta-squared value of $\eta^2=.514$. These effect-size estimates suggest that approximately 49.0% of the observed variation in resting heart rate and 51.4% of the observed variation in cardiac output are associated with between-group differences in the respective ANOVA models. These estimates are calculated from the supplied sums of squares and should be confirmed after the source data are reconciled.

Discussion

The supplied ANOVA results indicate statistically significant differences in RHR and CO across the seven groups. If the reported statistics are correct, the provisional η^2 estimates (approximately 0.49 for RHR and 0.51 for CO) suggest substantial between-group variation in this sample. These estimates must remain provisional because the source document contains inconsistent means and potentially inconsistent pairwise statistics. The overall ANOVA findings establish only that at least one group mean differs; they do not, by themselves, establish which groups differ or explain the cause of the differences.

The lowest transcribed RHR was observed among long-distance runners. This pattern is consistent with evidence that regular exercise, especially endurance training, can reduce resting heart rate (Reimers *et al*., 2018) [12]. Proposed contributors include training-related changes in autonomic regulation and cardiovascular function, although the relative contribution of autonomic and intrinsic cardiac mechanisms may vary between individuals. Opondo *et al*. (2015) [9] describe endurance training as a stimulus for cardiovascular adaptations that support the delivery of oxygen to working muscles. Nevertheless, the present cross-sectional design cannot demonstrate that running caused the lower RHR; differences in training duration, weekly training load, age

within the sampled range, recovery, and baseline fitness may also have contributed. Reviews of athletic cardiovascular adaptation also report that endurance training is associated with lower resting heart rate and changes in stroke volume, although individual responses vary (Fagard, 1997; Wilson *et al*., 2016) [5, 14].

The yoga group's RHR should be interpreted in light of the review by Reimers *et al*. (2018) [12], which found that yoga interventions can reduce RHR, while also noting that effects vary by intervention and study characteristics. The present source reports two different yoga means (73.37 and 70.37 beats/min), so the precise position of the yoga group relative to the other groups cannot be considered settled. More generally, a single resting measurement may be affected by posture, recent activity, sleep, hydration, stress, and measurement timing. Future studies should standardize these conditions and preferably obtain repeated measurements.

The source reports the highest mean CO among football players and the lowest among non-athletes. This observation should not be interpreted as evidence that football players necessarily have better cardiovascular function or that non-athletes have impaired cardiac function. CO is the product of heart rate and stroke volume, and resting values reflect the body's immediate circulatory requirements as well as individual physiology. Opondo *et al*. (2015) [9] discuss the importance of cardiac output for exercise performance, but resting CO alone does not measure maximal aerobic capacity. Because the source does not clearly report the unit for CO and does not provide enough methodological detail to assess the measurement conditions, clinical or physiological interpretation of these between-group differences is limited. Exercise-related changes in blood flow and cardiac output are integrated responses to metabolic demand, rather than simple indicators of resting fitness (Joyner & Casey, 2015; Hellsten & Nyberg, 2016) [6, 7].

Sport-specific cardiac adaptations are biologically plausible, but published evidence cautions against treating all athletes as one homogeneous group. Pluim *et al*. (2000) [11] reported differences in cardiac structure and function associated with endurance and strength training, while Baggish and Wood (2011) [2] emphasized the need to interpret athletic cardiac findings in the context of training exposure and clinical assessment. The sports represented in this sample involve different combinations of sustained aerobic activity, intermittent high-intensity effort, and technical or mind–body practice. However, the present dataset does not provide sufficient detail about training years, intensity, position/event specialization, or weekly training volume to test whether these factors explain the observed group differences. Contemporary sports-cardiology guidance likewise recommends interpreting athlete findings in the context of training history and clinical assessment (Martinez *et al*., 2021; Pelliccia *et al*., 2018) [8, 10].

Before submission, the authors should verify every group mean and standard deviation from the participant-level dataset, confirm CO units and the device protocol, and rerun the ANOVAs and post-hoc comparisons. Assumptions should be checked, effect sizes and confidence intervals reported, and exact p-values supplied where possible. The statistical plan should identify the post-hoc procedure and address multiple comparisons. Reporting should also include ethics approval and consent information from the actual study records, along with sampling and training-history details. The results should be framed as exploratory cross-sectional comparisons unless the design and data support stronger causal claims.

Several limitations materially affect the strength and reproducibility of the conclusions. First, RHR means conflict within the source: the non-athlete mean is reported as both 80.57 and 72.57 beats/min; football as 69.89 and 70.45; and yoga as 73.37 and 70.37. Second, CO units and some measurement details are absent. Third, some pairwise t-values, p-values, and significance labels appear inconsistent with the displayed means and standard deviations. Fourth, the document does not report ethics approval, informed consent, recruitment dates, sampling procedures, or key participant characteristics such as body size and training exposure. These are not minor editorial issues: they affect interpretation, reproducibility, and publication readiness.

Conclusion

The supplied results report statistically significant differences in resting heart rate and cardiac output across long-distance runners, team-sport athletes, yoga practitioners, and non-athletes. The transcribed means suggest the lowest RHR among long-distance runners and the highest CO among football players. However, conflicting values in the source tables and missing methodological details prevent firm conclusions about the magnitude and meaning of these differences. Verification against the original dataset and completion of the ethics, measurement, and statistical reporting details are necessary before the manuscript is suitable for journal submission.

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